

**Response to e<sup>2</sup>M Request for Clarification and References – June 2007 (Data Gaps and Scoping)**

<b><i>Biological Resources</i></b>	
61	<p>In Section 4.3.2, results from the video surveys show more than 36 percent of the bottom area to be traversed by the pipeline as hard/live bottom and identify the potential to place concrete mattresses over 58 percent of the pipeline route. Please discuss the potential impacts on EFH (which species' EFH would be affected) and benthic invertebrates (including important commercial species, benthic invertebrate species with EFH in the area, and other benthic invertebrates that occur in the areas). Also provide potential recovery times for the different habitat types. The impacts from these actions do not appear to be discussed in detail. For example, on pages 4-85 /86 the installation of the STL Buoy and Landing Pad is discussed, and mitigation measures, such as locating anchors in soft bottom areas and using mid line buoys to minimize anchor sweep are discussed. The full extent of unmitigated impacts should be discussed and then the types and potential effectiveness of mitigation measures should follow. Although the extent of sidecast cover is estimated, there is no discussion of the impacts to the biological communities observed in the areas that will be plowed or covered with concrete mattresses. Descriptions of the impacts to the biological resources should be included. Finally, on pages 4-90/91, the Application states that the areal extent of anchor sweep from pipeline construction barges has not been estimated. An evaluation of potential impacts cannot be finalized until this information is provided.</p>
<b>Response</b>	<p>The response is included below.</p>

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### **Response to Data Gap 61**

#### **EFH Species Affected by Construction Activities**

**Volume II, Appendix D** of the **Deepwater Port Application** lists and describes the species groups managed by the Gulf of Mexico Fishery Management Council (GMFMC) and NOAA Fisheries found within the project region. Those with Essential Fish Habitat (EFH) that could be affected by benthic/seafloor disturbing activities include the following:

- **Corals and coral reefs** – EFH for reef building stony corals encompasses the total distribution of coral species and life stages throughout the Gulf of Mexico including the patchy hard bottom offshore of Florida from approximately Crystal River south to the Florida Keys. Numerous stony corals, predominantly *Solenastrea hydes*, *Cladocora* sp., and *Oculina robusta* are found in this environment (Jaap and Hallock, 1990). Stony coral species identified from photographs during surveys included *Carijoa riisei*, *Cladocora arbuscula*, *Oculina diffusa*, *Oculina robusta*, *Scolymia* sp., *Siderastrea* sp., and *Solenastrea hyades*. Soft corals including *Antipatharia* (black corals) and octocorals (sea fans) may also be found in the area, but Pennatulacea (sea pens and sea pansies) are not likely to be present. EFH for *Antipatharia* includes rough, hard, exposed, stable substrate offshore in high salinity (30 to 35 ppt) waters in depths exceeding 18 m not restricted by light penetration. EFH for octocorals includes rough, hard, exposed, stable substrate in subtidal to outer shelf depths within a wide range of salinity and light penetration throughout the project area. Octocorals occur on hard bottom throughout the proposed pipeline route.
- **Penaeid shrimps** – Penaeid shrimps managed by the GMFMC and likely to occur in the project area are pink shrimp (*Penaeus duorarum*) and rock shrimp (*Sicyonia brevirostris*). Relevant EFH in the project area includes all estuaries, as well as continental shelf waters from Crystal River, Florida, to Naples, Florida, between depths of 10 and 25 fathoms (GMFMC, 2005).
- **Stone crab** (*Menippe mercenaria*) occurs in the project area. Adults reproduce in shelf waters; larvae are released in nearshore shelf waters, and after passing through several planktonic stages, young crabs settle to the bottom. Juveniles occur in shelf and inshore waters of Tampa Bay. Stone crabs prefer hard bottom and seagrass habitats ranging from inside Tampa Bay to the inner shelf. Relevant EFH for stone crab in the project area includes all estuaries and the continental shelf from estuarine waters out to depths of 10 fathoms (GMFMC, 2005).
- **Spiny lobster** (*Panulirus argus*) – occurs in the project area, but this is the periphery of its range. Abundance is generally too low to support a commercial fishery. Relevant EFH for spiny lobster extends from Tarpon Springs, Florida, to Naples, Florida, between depths of 5 and 10 fathoms (GMFMC, 2005).
- **Red drum** (*Sciaenops ocellatus*) – All life stages of red drum occur in Tampa Bay. Spawning occurs in the pass as well as nearshore coastal waters from mid-August to late November (Murphy and Taylor, 1990; Peters and McMichael, 1987). Pelagic larvae remain in the water column for an average of 17 days then settle near shore in low salinity, upper bay waters (Peters and Murphy, 1987). As they grow, red drum move back into the bay proper where they inhabit a range of habitats from soft bottom to oyster bars. Relevant EFH for red drum includes all estuaries and the continental shelf from Crystal River, Florida to Naples, Florida, between depths of 5 and 10 fathoms (GMFMC, 2005).
- **Reef Fishes** – The reef fish (snapper-grouper) management unit consists of 47 species. Although the fisheries and adult habitat of most of these species exist well offshore of the project area, the young stages of some reef fishes utilize nearshore hard bottom and seagrass meadows as nursery habitat

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(e.g., GMFMC, 2005). **Volume II, Table D.1** of the **Deepwater Port Application** gives the life stage distribution of key reef fishes for the project area. Relevant EFH for reef fishes in the project area includes all estuaries and the continental shelf from estuarine waters out to depths of 100 fathoms.

### **Other Demersal Fishery Species Affected**

The managed fishery groups discussed above encompass most of the important commercial species in the area. As discussed in **Volume II, Section 6** of the **Deepwater Port Application**, key fishery targets in the region are reef fishes, pink shrimp, coastal pelagic fishes, and stone crab. Reef fishing for red grouper, gag, and scamp generally occurs in water depths ranging from 66 to 394 ft (20 to 120 m). Tampa is one of the primary ports for shrimpers in the eastern Gulf of Mexico, but the primary pink shrimping grounds in the region are south of the project area (e.g., the Sanibel shrimp grounds west of Ft. Myers and the Tortugas grounds). Shrimp trawling can only take place on level sandy bottoms as hard bottom or other obstructions will snag and damage nets. Coastal pelagic species are caught by gillnetting or purse netting. Both of these activities are banned from state waters and can only occur in federal waters.

In the inshore waters of Tampa Bay the primary fisheries are striped mullet, bait shrimp, and blue crab. Bait shrimp are caught over shallow seagrass meadows with specialized roller frame trawl nets. Blue crabs are harvested with bottom tending traps throughout the bay. Blue crabs (*Callinectes sapidus*) inhabit estuarine, nearshore, and offshore habitats during various life stages (Guillory *et al.* 2001). Eggs are found near barrier islands or in high salinity waters near bay mouths or passes, attached to the abdomen of spawning females. Emerging larvae are pelagic and are found in offshore waters over the continental shelf. Postlarvae migrate into estuaries where they settle to the bottom in seagrass or shoreline habitats. Juveniles are found in seagrass and saltmarsh edge habitats, and also in rivers, mud, sand, benthic algae, and drift algae.

### **Other Benthic Species Affected**

Other benthic species that may be affected by seafloor-disturbing activities during installation of the pipeline and STL buoy arrays include:

- Infaunal groups such as polychaetes, bivalves, gastropods, amphipods, isopods, cumaceans, and decapods. These include both motile and sessile forms.
- Soft-bottom epifauna such as decapods, gastropods, ophiuroids, holothuroids, and sea stars.
- Hard-bottom epifauna such as sponges, bryozoans, hydroids, brachiopods, and ascidians. Examples of sponges identified during video/photographic surveys along the pipeline corridors included *Cinachyra* sp., *Cliona deletrix*, *Halichondria* sp., *Placospongia* sp.
- Demersal fishes, other than commercial and recreationally harvested species, associated with soft bottom and hard bottom habitats.

**Volume II, Section 4.2.2.3** of the **Deepwater Port Application** provides additional information about benthic communities in the region.

### **Impact Mechanisms**

Installation of the pipeline and STL buoy arrays will affect both soft bottom and hard/live bottom communities. Most of the damage would occur during pipeline installation, including plowing of the seafloor, placement of barge anchors, and anchor sweep. Benthic organisms may be affected by any of

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several impact mechanisms, including crushing, burial, sedimentation, and habitat alteration, as discussed below.

### ***Crushing and Other Direct Physical Injury***

Benthic organisms may be crushed by placement of the pipeline on the seabed, movement of the plow through the sediment, placement of laybarge anchors, sweeping of the seafloor by anchor cables, and placement of concrete mattresses. The groups most susceptible to these types of impacts would be infauna and sessile or slow-moving epifauna.

### ***Burial***

Benthic organisms will be buried along the pipeline route as sediments are pushed aside during plowing. Backfilling of the trench will bury additional organisms. Again, it is expected that infauna and sessile or slow-moving epifauna would be the groups most susceptible to these impacts. Some soft bottom organisms are able to migrate vertically to the new surface (Maurer et al., 1986; Nelson, 1988).

### ***Sedimentation***

Sediments resuspended by plowing will drift with water currents and settle to the seabed. Deposition of these sediments can suffocate, bury, or stress hard bottom and soft bottom biota.

The report by ASA International (2008) entitled, “Results of Sediment Dispersion Modeling for Proposed Pipeline Construction Activities” provides information about sediment deposition from pipeline construction activities. Sediments along much of the pipeline route are expected to consist of fine quartz sand interspersed with areas of coarse sand and gravel-size carbonates. These sediments are expected to settle rapidly to the seafloor after resuspension. The modeling predicts sediment deposits on the seabed that would typically be 2 to 3 mm thick, but can be up to 15 mm thick close to the sediment source over small, discontinuous areas. Sediment thickness tapers off to less than 2 mm within about 50 to 200 m (164 to 656 ft) from the source for most of the seafloor deposits. The total area receiving sediment deposits of 2 mm thickness could be several times greater than the area directly affected by trenching (e.g., the trench width, including sediments pushed aside by plowing, is estimated to be 20.4 m [67 ft]). However, the areas receiving the thickest accumulations would be close to the trench – essentially the same areas directly affected by the plowing or jetting *per se*.

It is expected that hard bottom biota would be more susceptible to sedimentation impacts than soft bottom biota. Many hard bottom organisms are sessile and unable to burrow up through sediment overburden (Nelson, 1989; Wesseling et al., 1999). Heavy sedimentation can result in acute stress and death, and chronic high turbidity can cause stress responses and reductions in health and growth of algae, corals, and other filter feeding organisms (Dodge et al., 1974; Dodge and Vaisnys, 1977; Bak, 1978). However, many corals can withstand some sedimentation through active removal (Rice and Hunter, 1992; Stafford-Smith, 1993; Riegl, 1995).

### ***Habitat Alteration***

Although the trench will be backfilled with the same sediment that was displaced during plowing, the sediment matrix will have been disrupted. This includes the arrangement of sediment grains, their degree of compaction, the redox chemistry of sediment pore waters, and the presence of organic coatings. The composition of benthic assemblages is controlled by a wide array of physical, chemical, and biological factors that interact in complex ways and are variable with time. Sediment grain size, chemistry, and organic content may influence recolonization of benthic organisms (Snelgrove and Butman, 1994).

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Suspension and dispersion of sediments may cause changes in sediment and water chemistry as nutrients and other substances are released from the substratum and dissolved. The results can include hypoxia or anoxia in the water column due to oxygen consumption of suspended sediments (LaSalle et al., 1991). In terms of habitat, the effects of pipeline trenching, including anchoring activities, would be similar to those resulting from dredging – e.g., include loss of erect and sessile epifauna, smoothing of sedimentary bedforms and reduction of bottom roughness, and removal of taxa that produce structure (Ocean Studies Board, 2002).

### ***Covering with Concrete Mattresses***

In areas that cannot be plowed, the pipeline will be covered with concrete mattresses (or similar armoring). The width of seafloor affected by mattresses is estimated to be 13 ft (4 m). In the **Addendum to the Deepwater Port Application**, the analysis estimated that 35.74 acres (14.46 hectares) would be affected by concrete mattresses. About 54% would be hard/live bottom habitats, and the remaining 46% would be soft bottom.

In hard/live bottom areas, the result would be replacement of the natural hard substrate by a low-relief, relatively smooth concrete covering. The mattresses are expected to eventually be colonized by epibiota and fishes. The mattresses or other armoring would not mimic the complex physical structure of the original hard substrate. However, the material would be similar to artificial reefs that have been constructed in various areas including the west Florida shelf.

Concrete mattresses will also be placed in some soft bottom areas (e.g., where plowing is not feasible due to curvature of the route). In these areas, the existing soft bottom substrate would be replaced with an artificial hard substrate. The existing soft bottom benthic community at those locations would be crushed or buried, and would not recover.

### **Impacts of STL Buoy and Landing Pad Installation**

The areal extent of benthic impacts during STL subsea system has been discussed in **Volume II, Section 4.3.2.1 of the Deepwater Port Application**. As noted in the **Addendum**, specific mooring locations around the STL buoys have been changed due to optimization of the mooring configuration, but the total area of seafloor impacts during construction is the same as in the original analysis. However, the relative impact areas for benthic habitat types has changed due to the change in configuration. The impact areas are presented in **Section 6.2.2 of the Addendum**.

Benthic community impacts during installation of the STL buoy and landing pad will be similar to those discussed above, except that there will be no plowing or jetting of the seafloor and the impacts will be limited to a relatively small area. The main impact mechanisms would be crushing, due to the placement of subsea facilities and anchors directly on the seafloor; physical abrasion and burial due to movement of sediments by anchors and anchor cables; and sedimentation due to settling of sediments resuspended by seafloor-disturbing activities.

In the **Deepwater Port Application**, it was noted that during detailed design, an anchoring plan will be developed that will provide specific procedures for anchor deployment to minimize impacts on hard/live bottom. Midline buoys will be used to the extent practicable to reduce the amount of anchor chain sweep. Also, it may be determined during detailed design that a Dynamic Positioning (DP) vessel could install the STL buoy system. In that event, the impacts from barge anchor placement would not occur. At this stage, we do not have any further specific information to estimate the reduction in impact area at the STL buoy locations. A conservative assumption would be no reduction in impact area.

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### **Potential Recovery Times**

Benthic recolonization and succession have been reviewed for a wide variety of habitats throughout the world (e.g., Thistle, 1981; Thayer, 1983; Hall, 1994; Coastline Surveys Limited, 1998; Newell et al., 1998). Recolonization is highly variable, depending on the habitat type and other physical and biological factors. Focusing on dredging, Coastline Surveys Limited (1998) and Newell et al. (1998) suggested that recovery times of 6 to 8 months are characteristic for many estuarine muds, 2 to 3 years for sand and gravel, and 5 to 10 years as the deposits become coarser. Emeis et al. (2001; as cited by Ocean Studies Board, 2002) hypothesized that recovery time is often one to five times the generation time of the organism. Therefore recovery times could range from a few months—or less—to several decades (Hutchings, 2000). Many of the larger biogenic structure-forming organisms, such as soft corals and sponges, are slow growing and long-lived.

Studies of recolonization discussed by Grober (1992) and the National Research Council (1995) indicate that recolonization of offshore dredged sites (e.g., borrow sites for beach nourishment) is highly variable. While recolonization usually begins soon after dredging ends, the process may range in duration from a few months for shallow dredging to years or decades (the latter for deep pits created by dredging borrow areas, which would not be relevant here). Although abundance and diversity of benthic infauna within borrow sites often returns to levels comparable to pre-dredging or reference conditions within less than one year, several studies have documented changes in benthic species composition that lasted much longer, particularly where sediment composition was altered (e.g., Johnson and Nelson, 1985; Bowen and Marsh, 1988; Van Dolah et al., 1992).

Recovery of soft bottom communities in and along the pipeline trench is likely to be faster than indicated by most studies of dredging impacts. Unlike typical dredging sites, the trench itself would be only a few meters wide, backfilled after being dredged, and accessible for recolonization from adjacent soft bottom areas to either side all along its length.

In general, hard bottom species take longer to recolonize their habitats than soft bottom species. Hard bottom assemblages in the area are composed of algae, sponges, scleractinian corals, octocorals, hydrozoans and other sessile organisms. Most epifaunal groups colonize disturbed or newly open hard bottom areas by settlement of planktonic larvae. Thus, the assembly of organisms on newly exposed hard bottom areas can be highly variable and depend on life history characteristics of individual species coupled with local circulation patterns. Recovery of hard bottom assemblages consisting of large sponges, octocorals, and scleractinian corals can take years or decades (Connell, 1977; Fitzhardinge and Bailey-Brock, 1989). For example, Wendt et al. (1989) studied artificial reefs ranging in age from 3.5 to 10 years off Georgia and South Carolina in water depths of 22 to 31 m. They noted the absence of large sponges and corals even at the oldest artificial reef sites and suggested that these groups are slow to colonize new substrates or reach an appreciable size.

Gulfstream Natural Gas System, LLC (2005) monitored pipeline construction areas three years after installation in Florida state waters. Transects were photographed in live bottom areas along the pipeline trench, in anchor scars, and at unimpacted reference areas. Transects in trench impact areas had lower biotic cover (~5%) than reference areas (~8%) or anchor scar areas (~13%). The most abundant organism along all transects was a macroalga, most likely a rhodophyte. An ANOVA indicated no significant difference in macroalgal cover among the trench, anchor scar, and reference sites.

### **Anchor Sweep Estimate**

Port Dolphin has developed an estimate of the areal extent of anchor sweep impacts during pipeline installation (e.g., due to movement of the pipelaying barge's anchor cables). Other pipeline installation

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impacts were originally discussed in **Volume II, Section 4.3.2** of the **Deepwater Port Application** and the areal extent of benthic impacts was recalculated in the **Addendum**. Those discussions included direct physical disturbance to the seafloor during plowing of the seafloor, placement of concrete mattresses, and anchoring of barges during construction activities.

The following assumptions were made to calculate the extent of anchor sweep impacts:

- The pipelaying barge was assumed to make four passes along the route – for pipelaying, plowing, backfilling, and mattress placement.
- During the first three passes, the barge was assumed to use 10 anchors, which will be reset every 2,000 ft (610 m). For each reset, the entire 10-anchor array was estimated to sweep an area of 1,598,882 square feet (148,526 m<sup>2</sup>) of seafloor. The derivation of this estimate is explained below.
- The fourth pass (mattress placement) will be done by smaller barges with 4-point mooring systems, which will be used as static moorings; therefore, no anchor cable sweep impact is anticipated. The use of the smaller barges will eliminate the need for a fourth pass with the pipelaying barge.
- Hard/live bottom areas were assumed to be affected in direction proportion to the percentage of these habitats along the relevant segments of the pipeline route. For the first pass, the percentages for the entire route were used (7.05% Type A, 17.96% Type B, 10.90% Type D, and 64.09% soft bottom). For the plowing and backfilling passes, the percentages for those segments identified as “plowable” were used (2.4% Type A, 2.1% Type B, 12.3% Type D, and 83.3% soft bottom).

**Figure 1** illustrates the estimated anchor sweep area for a single anchor deployment. To calculate the extent of anchor sweep impacts for a 10-anchor array, a range of anchor wire catenary analyses were performed using a standard static catenary program. This program allows a determination of catenary touchdown point on the seabed to be made for a given input of water depth, tension and cable weight. Using the catenary touchdown point, in conjunction with the anchor array model, a theoretical sweep area was then predicted. For the base case, a water depth of 75 feet (23 m) was adopted as a conservative representation of average water depth conditions along the route. Furthermore, a relatively large ratio of anchor wire length to water depth (sometimes known as the anchor “scope”) was conservatively assumed to be in the range of about 20 to 50.

Using these methods and assumptions, a total anchor wire sweep on the seabed of 1,598,882 square feet (148,526 m<sup>2</sup>) is predicted for the entire 10 anchor array for each 2,000 foot barge reset length. Based on this estimate, **Table 1** calculates the area of seafloor affected by anchor sweep along the Preferred Route for the entire pipeline installation, without mitigation.

The actual sequence of events involved in pipelaying is more complicated than indicated by these assumptions, particularly in Tampa Bay where three HDD operations will be conducted. However, the assumptions are considered a reasonable basis for estimating the number and extent of anchor sweep impacts.

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**Table 1  
Areal Extent of Anchor Sweep Impacts During Pipeline Installation  
(Entire Revised Preferred Route)  
WITHOUT MITIGATION**

Pass <sup>a</sup>	Activity	Length (feet)	No. of Anchor Resets	Anchor Sweep Area <sup>b</sup>				
				Total acres (hectares)	Soft Bottom acres (hectares)	Type A acres (hectares)	Type B acres (hectares)	Type D acres (hectares)
1 <sup>st</sup>	Pipelaying	235,549	117	4,295 (1,738)	2,752 (1,114)	303 (123)	771 (312)	468 (189)
2 <sup>nd</sup>	Plowing	115,468	58	2,129 (862)	1,860 (753)	44 (18)	24 (10)	201 (81)
3 <sup>rd</sup>	Backfilling	115,468	58	2,129 (862)	1,860 (753)	44 (18)	24 (10)	201 (81)
4 <sup>th</sup>	Mattress placement	No sweep impacts						
Total				8,552 (3,461)	6,472 (2,619)	391 (158)	819 (331)	871 (352)

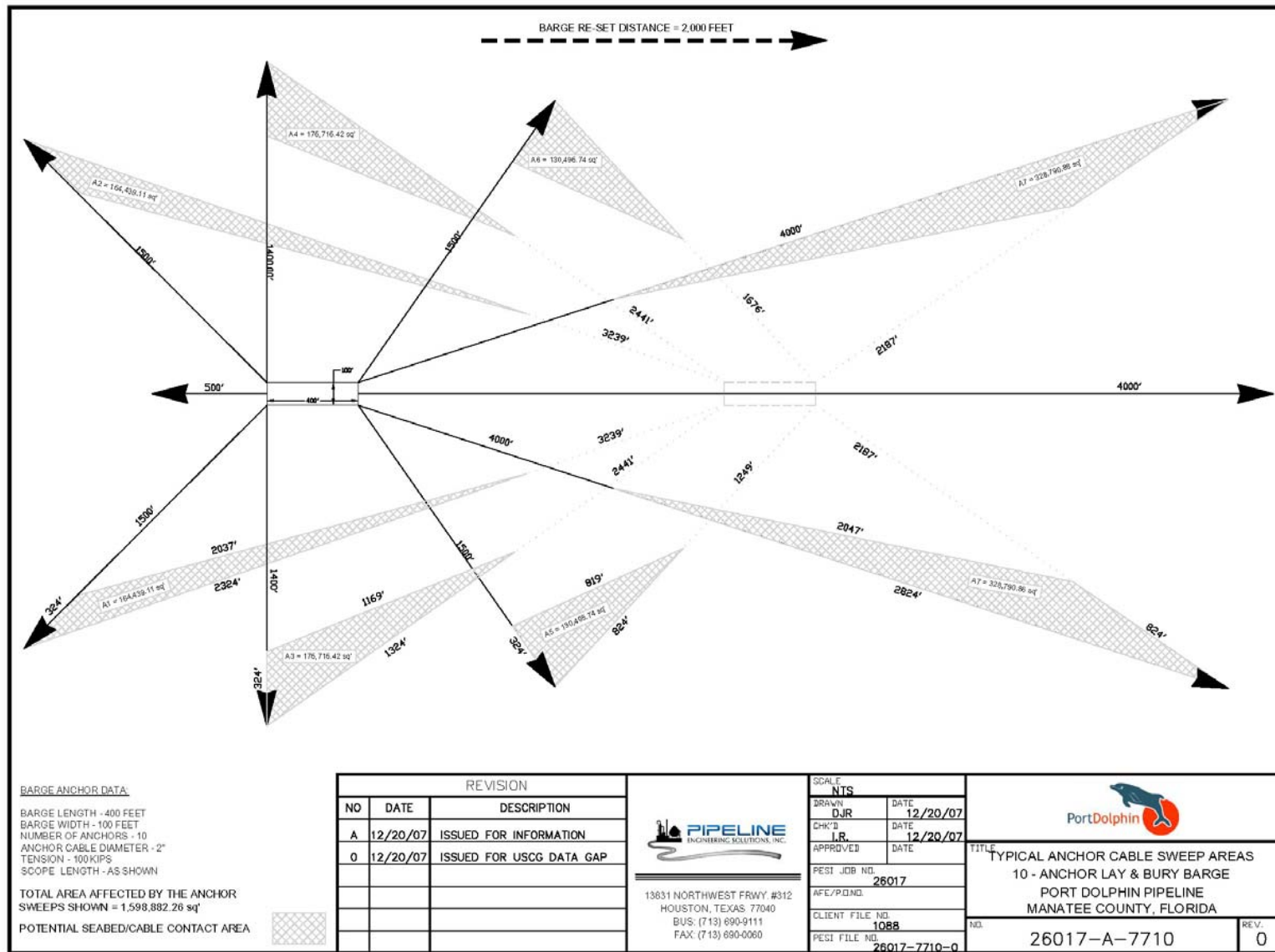
<sup>a</sup> For first three passes, assumed a barge would use 10 anchors that would be reset every 2,000 feet (610 meters) and each reset would affect an area of 1,598,882 square feet (148,526 m<sup>2</sup>). For the fourth pass, assumed smaller barges with 4-point, static mooring systems would be used (no anchor cable sweep).

<sup>b</sup> Assumed anchors would contact habitats in proportion to their occurrence along the relevant portions of the pipeline route. For the first pass, the entire route was used (7.05% Type A, 17.96% Type B, 10.90% Type D, and 64.09% soft bottom). For the second and third passes, only the plowable segments were considered (2.08% Type A, 1.11% Type B, 9.45% Type D, and 87.36% soft bottom).

The analysis predicts that 8,552 acres (3,461 hectares) would be affected by anchor cable sweep. This includes 6,472 acres (2,619 ha) of sand/soft bottom habitat and 2,081 acres (841 ha) of hard/live bottom habitats. This is in addition to the 20.26 acres (8.20 hectares) estimated to be directly contacted by anchors, as calculated in the **Addendum**.



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**Figure 1.** Diagram of seafloor areas swept by anchor cables from a typical pipelaying barge.

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### **Mitigation**

As noted in the **Deepwater Port Application**, an anchoring plan will be developed during detailed design that will provide specific procedures to minimize anchor sweep impacts on hard/live bottom habitat. For example, depending on the detailed operational methodology eventually adopted it may be possible to further alleviate anchor sweep areas on the seabed by use of low-weight anchor wires or buoyancy elements (e.g., mid-line buoys) on the wire. Such equipment would have the effect of supporting the catenary further off the seabed. A detailed analysis of anchor wire buoyancy scenarios has not been undertaken at this stage. However, an initial assessment of an anchor wire effective in-water weight reduction of about 50% suggests that corresponding reductions in seabed contact area of the order of 25% or greater could be expected to result. For this analysis, a reduction in overall footprint of 25% has been assumed, yielding a revised impact area of 1,199,162 square feet (111,395 m<sup>2</sup>) per anchor reset.

**Table 2** estimates the areal extent of anchor sweep impacts taking into account a 25% reduction due to the use of mid-line buoys.

**Table 2**  
**Areal Extent of Anchor Sweep Impacts During Pipeline Installation**  
**(Entire Revised Preferred Route)**  
**INCLUDING 25% REDUCTION DUE TO MID-LINE BUOYS**

Pass <sup>a</sup>	Activity	Length (feet)	No. of Anchor Resets	Anchor Sweep Area <sup>b</sup>				
				Total acres (hectares)	Soft Bottom acres (hectares)	Type A acres (hectares)	Type B acres (hectares)	Type D acres (hectares)
1 <sup>st</sup>	Pipelaying	235,549	117	3,221 (1,303)	2,064 (835)	227 (92)	579 (234)	351 (142)
2 <sup>nd</sup>	Plowing	115,468	58	1,597 (646)	1,395 (564)	33 (13)	18 (7)	151 (61)
3 <sup>rd</sup>	Backfilling	115,468	58	1,597 (646)	1,395 (564)	33 (13)	18 (7)	151 (61)
4 <sup>th</sup>	Mattress placement	No sweep impacts						
Total				6,414 (2,596)	4,854 (1,964)	293 (119)	614 (248)	653 (264)

<sup>a</sup> For first three passes, assumed a barge would use 10 anchors that would be reset every 2,000 feet (610 meters) and each reset would affect an area of 1,199,162 square feet (111,395 m<sup>2</sup>). For the fourth pass, assumed smaller barges with 4-point, static mooring systems (no anchor cable sweep).

<sup>b</sup> Assumed anchors would contact habitats in proportion to their occurrence along the relevant portions of the pipeline route. For the first pass, the entire route was used (7.05% Type A, 17.96% Type B, 10.90% Type D, and 64.09% soft bottom). For the second and third passes, only the plowable segments were considered (2.08% Type A, 1.11% Type B, 9.45% Type D, and 87.36% soft bottom).

The revised analysis (taking into account mid-line buoys) predicts that 6,414 acres (2,596 hectares) would be affected by anchor cable sweep. This includes 4,854 acres (1,964 ha) of sand/soft bottom habitat and 1,560 acres (631 ha) of hard/live bottom habitats.

In interpreting these impacts, it is important to consider the different types of hard/live bottom habitats mapped. According to the FDEP “Regulatory Basis of Review Mitigation Protocol Offshore Southeast Florida,” Type A is defined as “20% to 100% cover by attached epibenthic biota and/or hard bottom with greater than or equal to 0.8 feet (0.25 meters) in relief, inclusive of sand components integral to these habitats.” Type B habitat is defined as “5% to 20% cover by attached epibenthic biota and/or hard bottom with less than 0.8 feet (0.25 meters) in relief, inclusive of sand components integral to these habitats.”

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Type D habitat is defined as “sand (soft substrate/sedimentary habitat) in proximity to reef/hard bottom resources; a sandy veneer over hard substrate with less than 5% epibenthic coverage.”

The total area of Type A and B habitats affected by anchor cable sweep, taking into account a 25% reduction due to mid-line buoys, is estimated to be 907 acres (367 hectares). In these areas, the substrate itself, as well as the organisms attached to it, may be damaged by cable movement.

About 42% of the hard/live bottom area predicted to be swept by anchor cables is Type D habitat – 653 acres (264 hectares). In Type D areas, there would be no anchor cable damage to emergent hard substrate, as the cables are assumed to sweep the top few inches of the seafloor (e.g., ASA International [2008] assumed the depth swept would be one-quarter of the cable diameter). However, depending on the thickness of the sand veneer, some organisms may be attached to the underlying hard substrate and could be dislodged by the anchor cable. Overall, the damage to hard/live bottom communities due to anchor sweep in Type D areas is considered less severe than impacts to Type A and B habitats.

### ***Further Impact Reductions***

Many aspects of the anchor sweep calculations are considered to be very conservative. Consequently, impacts are likely to be less than calculated, and further reductions may be possible depending on prevailing field and operational conditions. For example:

- A relatively large ratio of anchor wire length to water depth (sometimes known as the anchor “scope”) has been conservatively assumed in the range of about 20 to 50. The “scope” could be reduced with judicious anchor placement, subject to detailed route engineering.
- There is also some degree of overlapping (redundancy) in the swept area calculations between anchor resetting positions, which has not been accounted for in the results. In other words, as the barge moves along the route, some of the swept areas will be locations that have already have been swept and thus are “double-counted.”
- There will most likely be a degree of overlapping (redundancy) of seabed impact areas between the different passes (pipelaying, plowing, and backfilling), which has not been accounted for in the final results presentation. With judicious anchor placement on each pass this may represent a significant impact area which is being “double-counted.”

Most of the hard/live bottom impact (especially to Type A and B habitats) would occur during the first pass of the pipelaying barge, because that is when the highest percentages of those habitats will be encountered (rather than during plowing and backfilling). Therefore, avoidance of Type A and B habitats by judicious anchor placement during the first pass offers the greatest potential for further reduction of live bottom impact area.

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### **LITERATURE CITED**

- ASA International. 2008. Results of Sediment Dispersion Modeling for Proposed Pipeline Construction Activities. Report for CSA International, Inc. ASA Project No. 2007-195. January 2008.
- Bak, R.P.M., 1978. Lethal and sublethal effects of dredging on reef coral. *Mar. Poll. Bull.* (1): 14-16.
- Bowen, P.R. and G.A. Marsh, 1988. Benthic faunal colonization of an offshore borrow pit in southeastern Florida. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, Miscellaneous Paper D-88-5.
- Coastline Surveys Limited. 1998. Marine Aggregate Mining Benthic and Surface Plume Study. U.S. Department of the Interior, Minerals Management Service, Office of International Activities and Marine Minerals, Plume Research Group Report 98/555/03, 168 pp.
- Connell, J.H., 1997. Disturbance and Recovery of Coral Assemblages. In: H.A. Lessios, I.G. Macintyre, and M. McGee (eds.), *Proceedings of the 8<sup>th</sup> International Coral Reef Symposium Panama*, 1: 9-22.
- Dodge, R.E. and J.R. Vaisnys. 1977. Coral populations and growth patterns: responses to sedimentation and turbidity associated with dredging. *Journal of Marine Research*, 35(4): 715-730.
- Dodge, R.E., R.C. Aller, and J. Thompson. 1974. Coral growth related to resuspension of bottom sediments. *Nature* 247: 574-577.
- Emeis, K.C., J.R. Benoit, L. Deegan, A.J. Gilbert, V. Lee, J.M. Glade, M. Meybeck, S.B. Olsen, and B. von Bodungen. 2001. Group 4: Unifying concepts for integrated coastal management. In *Science and Integrated Coastal Management*, von Bodungen, B. and R.K. Turner (eds.). Dahlem University Press, Berlin, 378 pp.
- Fitzhardinge, R.C. and J.H. Bailey-Brock. 1989. Colonization of artificial reef materials by corals and other sessile organisms. *Bulletin of Marine Science* 44(2): 567-579.
- Grober, L.E. 1992. The Ecological Effects of Beach Replenishment. M.S. Thesis, Duke University, School of the Environment, NC, 109 pp.
- Guillory, V., H. Perry, and S. VanderKooy. 2001. The blue crab fishery of the Gulf of Mexico, United States: A regional management plan. Gulf States Marine Fisheries Commission. No. 96, October 2001.
- Gulf of Mexico Fishery Management Council. 2005. Generic amendment number 3 for addressing essential fish habitat requirements, habitat areas of particular concern, and adverse effects of fishing in the following fishery management plans of the Gulf of Mexico: shrimp fishery of the Gulf of Mexico, United States waters red drum fishery of the Gulf of Mexico, reef fish fishery of the Gulf of Mexico coastal migratory pelagic resources (mackerels) in the Gulf of Mexico and South Atlantic, stone crab fishery of the Gulf of Mexico, spiny lobster in the Gulf of Mexico and South Atlantic, coral and coral reefs of the Gulf of Mexico. Gulf of Mexico Fishery Management Council, Tampa, FL.
- Gulfstream Natural Gas System, LLC. 2005. 2005 monitoring report for Florida state waters. ENSR International, July 2005. Document no. 07324-066-0010.
- Hall, S.J. 1994. Physical disturbance and marine benthic communities: life in unconsolidated sediments. *Oceanography and Marine Biology Annual Review*, 32: 179-239.
- Hutchings, J.A. 2000. Collapse and recovery of marine fishes. *Nature* 406:882-885.
- Jaap, W.C. and P. Hallock. 1990. Coral reefs in ecosystems of Florida, pp. 574-616. In: R.L. Myers and J.J. Ewel, eds. *Ecosystems of Florida*. University of Florida Press, Gainesville, FL.

## **Response to e<sup>2</sup>M Request for Clarification and References – June 2007 (Data Gaps and Scoping)**

- Johnson, R.O. and W.G. Nelson. 1985. Biological effects of dredging in an offshore borrow area. *Florida Scientist*, 48: 166-188.
- LaSalle, M.W., D.G. Clarke, J. Homziak, J.D. Lunz, and T.J. Fredette. 1991. A Framework for Assessing the Need for Seasonal Restrictions on Dredging and Disposal Operations. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, Tech. Rep. D-91-1, 74 pp.
- Maurer, D., R.T. Keck, J.C. Tinsman, W.A. Leathem, C. Wethe, C. Lord, and T.M. Church. 1986. Vertical migration and mortality of marine benthos in dredged material: a synthesis. *Internationale Revue der Gesamten Hydrobiologie*, 71: 49-63.
- Murphy, M.D. and R.G. Taylor. 1990. Reproduction, growth, and mortality of red drum *Sciaenops ocellatus* in Florida Waters. *Fish. Bull.*, U.S. 88: 531-542.
- National Research Council. 1995. Beach Nourishment and Protection. National Academy Press, Washington, DC. 334 pp.
- Nelson, W.G. 1988. An Overview of the Effects of Beach Nourishment on the Sand Beach Fauna. In: Proceedings of the 1988 National Conference on Beach Preservation Technology, Florida Shore and Beach Preservation Association, Tallahassee, FL, pp. 295-310.
- Nelson, W.G. 1989. Beach Nourishment and Hard Bottom Habitats: The Case for Caution, pp. 109-116. In: Proceedings of the 1989 National Conference on Beach Preservation Technology, Florida Shore and Beach Preservation Association, Tallahassee, FL.
- Newell, R.C., L.J. Seiderer, and D.R. Hitchcock. 1998. The impact of dredging works in coastal waters: A review of the sensitivity to disturbance and subsequent recovery of biological resources on the seabed. *Oceanography and Marine Biology Annual Review* 36: 127-178.
- Ocean Studies Board. 2002. Effects of Trawling and Dredging on Seafloor Habitat. National Academy Press, Washington, DC.
- Peters, K.M. and R.H. McMichael, Jr. 1987. Early life history of the red drum, *Sciaenops ocellatus* (Pisces: Sciaenidae), in Tampa Bay, Florida. *Estuaries* 10: 92-107.
- Rice, S.A. and C.L. Hunter. 1992. Effects of suspended sediment and burial on scleractinian corals from west central Florida patch reefs. *Bulletin of Marine Science*, 51(3): 429-442.
- Riegl, B. 1995. Effects of sand deposition on scleractinian and alcyonacean corals. *Mar. Biol.* 121:517-526.
- Snelgrove, P.V.R. and C.A. Butman. 1994. Animal-sediment relationships revisited: cause versus effect. *Oceanography and Marine Biology Annual Review* 32: 111-177.
- Stafford-Smith, M.G. and R.F.G. Ormond. 1992. Sediment-rejection mechanisms of 42 species of Australian scleractinian corals. *Australian Journal of Marine and Freshwater Research* 43: 683-705.
- Thayer, C.W., 1983. Sediment-mediated biological disturbance and the evolution of marine benthos, pp. 479-625. In: M.J.S. Tevesz and P.L. McCall (eds.), *Biotic Interactions in Recent and Fossil Benthic Communities*, Plenum Press, NY.
- Thistle, D., 1981. Natural physical disturbances and communities of marine soft bottoms. *Marine Ecology Progress Series* 6: 223-228.
- Van Dolah, R.F., P.H. Wendt, R.M. Martore, M.V. Levisen, and W.A. Roumillat. 1992. A Physical and Biological Monitoring Study of the Hilton Head Beach Nourishment Project. South Carolina Wildlife and Marine Resources Department, Marine Resource Research Institute for the Town of Hilton Head Island and South Carolina Coastal Council, 159 pp.

***Response to e<sup>2</sup>M Request for Clarification and References – June 2007 (Data Gaps and Scoping)***

Wendt, P.H., D.M. Knott, and R.F. Van Dolah. 1989. Community structure of the sessile biota on five artificial reefs of different ages. *Bulletin of Marine Science* 44: 1106–1122.

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<b><i>Cultural Resources</i></b>	
62	Please provide the geographic extent of Terra Ceia Preserve that would be affected by pipeline installation (including anchoring impacts).
<b>Response</b>	With the anticipated re-routing of the pipeline around Terra Ceia Aquatic Preserve (AP) and a modification to the type of barge planned to be used adjacent to the AP, no geographic extent of the AP would be affected by the pipeline or vessel anchors. Complete details of the nearshore pipeline re-route and associated impacts will be submitted in an Addendum document being now prepared in response to the letter issued by the USCG on August 10, 2007, for suspending Port Dolphin's application processing.

***Response to e<sup>2</sup>M Request for Clarification and References – June 2007 (Data Gaps and Scoping)***

<b><i>Cultural Resources</i></b>	
63	In Section 4.3.4, the only discussion of noise impacts is the general discussion of pile driving noise. Please provide noise modeling for all potential sources of noise including SRV transit noise, operational noise while on the buoys, and noise associated with highly direction drilling in the inshore area. Please include a more detailed discussion of the extent of noise impacts relative to National Oceanic and Atmospheric Administration (NOAA) NMFS guidelines. Specific identification of the potential for noise impacts on specific marine mammal and sea turtle species should be assessed from the noise modeling.
<b>Response</b>	Please see the attached noise modeling report.



# **PORT DOLPHIN ENERGY LLC DEEP WATER PORT: ASSESSMENT OF UNDERWATER NOISE**

Version 2.0

By



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23 Jan 2008

<b>Version</b>	<b>Date</b>	<b>Description</b>	<b>Approved by:</b>
1.0	18 Jan. 2008	First release version	Isabelle Gaboury
2.0	23 Jan. 2008	Revised results for SRV transit and approach	Isabelle Gaboury

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## **1 Project Description**

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Port Dolphin Energy LLC proposes to construct and operate a Liquefied Natural Gas (LNG) Deepwater Port (DWP) at a site approximately 45 km (28 mi) west of Tampa Bay, Florida. The project will consist of two submerged turret unloading and mooring buoys, located in approximately 30 m (98 ft) of water, connected to Port Manatee in Tampa Bay via a pipeline approximately 68 km (42 mi) in length. The buoys will serve LNG Shuttle and Regasification Vessels (SRV's), purpose-built ocean going LNG vessels capable of regasifying the LNG onboard and delivering natural gas to the sub-sea pipeline.

Underwater noise will be generated during both the construction and operational phases of the deepwater port. During construction, noise will be generated from construction vessels, pile driving, and plowing of the pipeline, and to a lesser extent from drilling and dredging operations. During operation of the port, underwater noise will be generated by the operation of the SRV's during transit and docking/undocking and by acoustic transponders on the unloading buoys. Both types of noise will be intermittent.

This report details the results of acoustical modeling carried out by JASCO Research, Ltd., in order to predict the sound fields likely to be generated by construction and operation activities associated with the Port Dolphin DWP project. The scenarios modeled, including the layout of equipment and source levels associated with various vessels and activities, are outlined in Section 2. Natural sources of ambient noise that are likely to occur within the study area are also discussed. Model methodology and environmental parameterization are discussed in Sections 3 and 4, respectively. Finally, the results of the modeling study are presented in Section 5.

## 2 Modeling Scenarios and Source Level Characterization

Levels of underwater sound were modeled using JASCO's Marine Operations Noise Model (described in Section 3) for a variety of locations and activities, representing different stages of construction and operation of the Port Dolphin facility. The sites, equipment, and levels of underwater noise associated with these scenarios are discussed in the following sub-sections. Third-octave band source levels are also tabulated in Appendix A.

### 2.1 Study Area

The region around the Port Dolphin DWP, inshore of the 50 m (164 ft) isobath, is shown in Figure 1. As discussed in the following section, modeling was carried out for activities occurring at a number of locations in the vicinity of the DWP, including along the SRV transit route, at the buoys, and along various portions of the pipeline connecting the unloading buoys to Port Manatee (Figure 1).

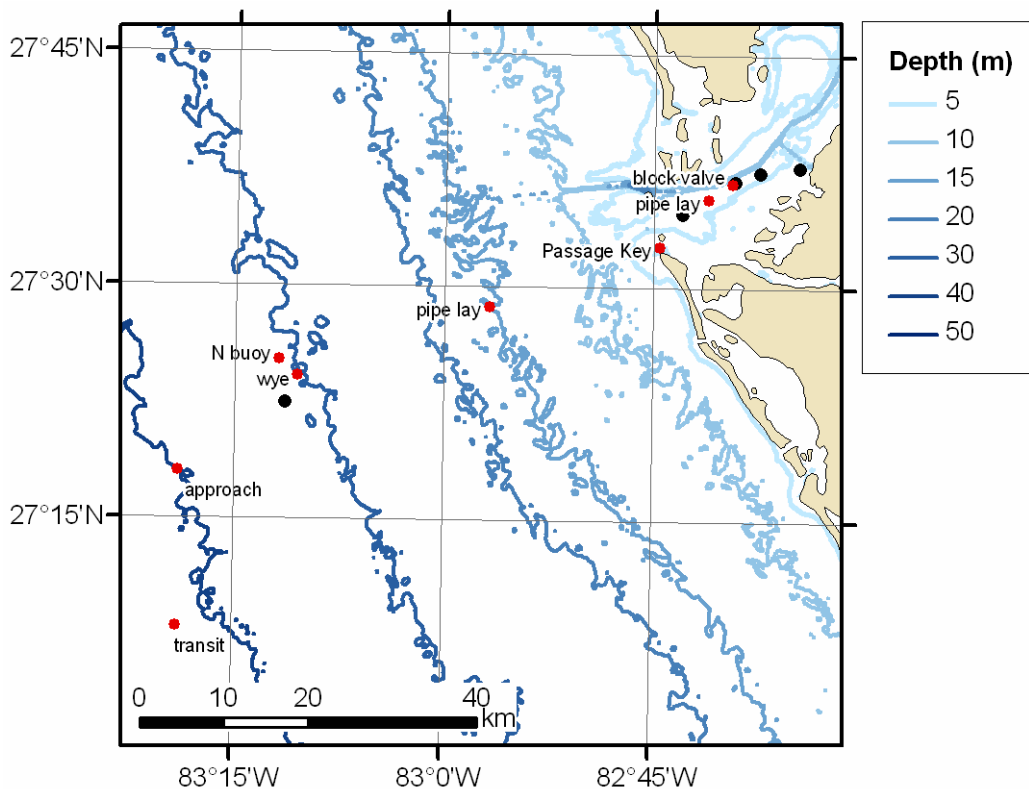


Figure 1: Overview of modeling sites. Dots mark key points along the carrier route and pipeline. The pipeline extends from the two buoys at the western-most end to the Port Manatee shore approach at the eastern-most end. Red dots represent model sites.

### 2.2 Model Scenarios and Source Levels

The scenarios that were modeled as part of this study are outlined in Table 1. Activities and locations were selected to represent key elements of the construction and operation of the DWP. The equipment list associated with each activity is based on current construction plans (Ocean Specialists, 2007). For each piece of equipment specified, proxy vessels were selected from JASCO Research's database of underwater noise measurements (right-most column of Table 1); this is discussed further in the following sub-sections.



Note that in many cases the scenarios involve multiple pieces of equipment. Although equipment spacing will vary during the course of operations, a single layout must be assumed for modeling purposes. As such, where multiple vessels were involved in the scenarios listed in Table 1 the following layout was assumed:

- The barge used for the main operation in each scenario (crane vessel, pipe laying barge, pipe burial barge) was set in the middle of the group of vessels.
- For four or fewer tugs (anchor handling and/or support), tugs were spaced at a range of 100 m (328 ft) from the center of the barge. Note that the pipe laying/burial barge itself is 122 m long by 30 m wide (400 ft x 100 ft).
- For pipe laying at Passage Key, the fifth standby tug was placed at a range of 200 m (656 ft) from the barge.

Table 1: Summary of model scenarios for the Port Dolphin LNG project. See also Figure 1. Proxy vessels and activities are discussed further in the sub-sections that follow.

Scenario		Location	Specified equipment	Proxy vessel/activity (for source levels)
<b>Construction scenarios</b>				
1	Installation of anchors, buoys, and anchor chains	North buoy	Crane vessel	Castoro II (barge), anchor operations
			Cargo barge	Assumed to be passive, hence negligible contribution
			Support vessel	Britoil 51 (tug), transiting
2	Impact pile driving (offshore)	Piggable wye site	Impact hammer	Menck MHU 3000
3	Impact pile driving (inshore)	Subsea block valve site	As for pile driving offshore	
4	Pipe laying (offshore)	15m isobath	Barge	Castoro II (barge), pipe laying
			2 anchor handling tugs	Britoil 51 (tug), anchor operations
			Support tug	Britoil 51 (tug), transiting
5	Pipe laying (inshore)	Tampa Bay	As for pipe laying offshore	

Scenario		Location	Specified equipment	Proxy vessel/activity (for source levels)
6	Pipe laying through Passage Key—live boat method	Passage Key	Barge	Castoro II (barge), pipe laying
			2 anchor handling tugs	Britoil 51 (tug), anchor operations
			2 live maneuvering tugs	Britoil 51 (tug), transiting
			Live tug on standby	Britoil 51 (tug), transiting
7	Pipeline burial—plowing (offshore)	15m isobath	Plow system	Aquarius dredge
			2 anchor handling tugs	Britoil 51 (tug), anchor operations
8	Pipeline burial—plowing (inshore)	Tampa Bay	As for pipe burial offshore	
Operational scenarios				
9	Offshore transit	34 km (18 nm) southwest of the unloading buoy	SRV, 36.1 km/h (19.5 kn) (90% propulsion)	Modeled SRV, full speed transit
10	Buoy approach	18 km (10 nm) southwest of the unloading buoy	SRV, <18.5 km/h (<10 kn) (half ahead)	Modeled SRV, half speed transit
11	Docking	Mooring buoy	SRV, dead slow, + bow and stern thrusters	Modeled SRV: main propulsion at dead slow, 2 bow thrusters and 1 stern thruster

### 2.2.1 Installation of anchors, buoys, and anchor chains

Proxies were selected for the crane and support vessels based on vessel specifications (Figure 2(a,d)). While a cargo barge may be present on-site for a portion of the operations, it was assumed that this barge would typically not be under power.

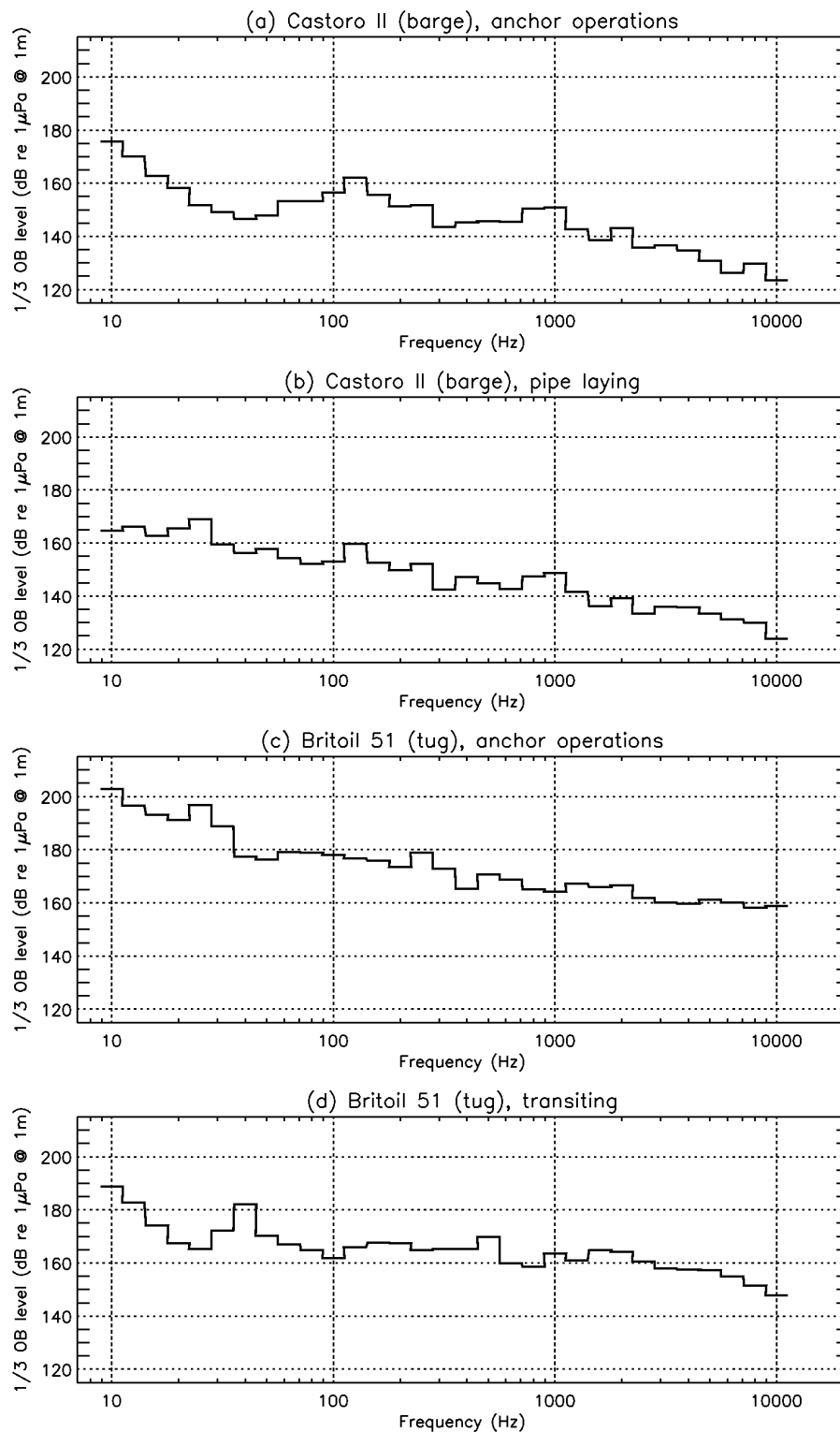


Figure 2: Third-octave band source levels for vessels involved in construction-related modeling scenarios (see Table 1). Source depths are 2.2 m and 3 m for the Castoro II and Britoil 51, respectively. Broad-band source levels are (a) 177 dB re  $\mu$ Pa, (b) 174 dB re  $\mu$ Pa, (c) 205 dB re  $\mu$ Pa, and (d) 191 dB re  $\mu$ Pa.

## 2.2.2 Impact Pile Driving

Piles may be driven as part of pipeline initiation at the piggable wye and subsea block valve sites (Figure 1, Table 1). The impact hammer involved is expected to be the same as that used for the Neptune LNG project (LGL and JASCO, 2005). As such, the same source levels were used (Figure 3(a)). For both the offshore and inshore scenarios, the source depth for pile driving was set to approximately half the local water depth (Figure 2(a)). In actuality, sound will radiate from all portions of the pilings; this mid-water column value is a precautionary estimate of the depth for an equivalent point source, as losses due to bottom and surface interactions will be less for a source at mid-depth than for one near the sea floor or surface.

Impact hammering operations will involve a pipe lay barge and tugs, similarly to pipe laying (Table 1). However, because the potential impact to marine mammals and turtles is different for impulsive and continuous sources, impact hammering noise (an impulsive source) is considered separately from vessel noise (continuous sources). Note that the source levels from impact hammering are much higher than those from the vessels that are likely to be on-site (Figure 2, Figure 3(a)).

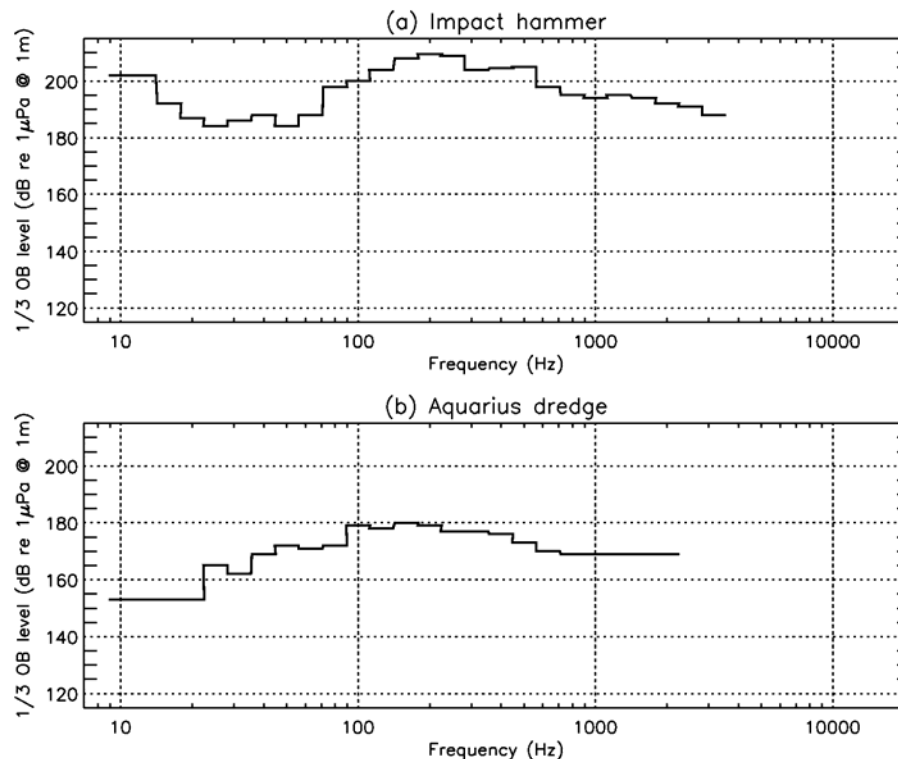


Figure 3: Third-octave band source levels for non-vessel activities involved in construction-related modeling scenarios (see Table 1). Source depth for the impact hammer is half the local water depth; source depth for the dredge is 2.2 m. Broad-band source levels are (a) 216 dB re  $\mu\text{Pa}$  (assuming a 10 dB SEL-to-RMS offset) and (b) 188 dB re  $\mu\text{Pa}$ .

## 2.2.3 Pipe Laying

A total of three sites were selected for pipe laying: one approximately mid-way along the offshore portion of the pipeline, another along the inshore portion, and a third at Passage Key (Figure 1, Table 1). Equipment lists for the offshore and inshore sites are identical: a pipe laying barge, two tugs involved in re-setting of anchors, and a third tug in transit (Table 1, Figure 2(b,c,d)). At Passage Key Inlet, shallow water and tidal currents are expected to require a modification of the pipe laying approach. The noisiest of the alternatives, referred to as the “live boat” method (Ocean Specialists, 2007), would require two

additional tugs for live handling compared with the equipment setup used for most of the pipeline route (Table 1).

## 2.2.4 Pipe Burial

Similarly to pipe laying, pipe burial using a trenching plow system will consist of an anchored barge accompanied by two anchor handling tugs. In addition, noise will be generated by the plow used to bury the pipe line (Table 1). Detailed source level data were not available for plow operations. However, Aspen Environmental Group (2005) reported a broadband source level of 185 dB re 1  $\mu$ Pa at 1 m. Based on this information, source levels from the cutter-suction dredger Aquarius (Greene, 1987) were used for modeling purposes (Figure 3(b)). Note that the dredge source levels include the sound from the barge upon which the dredge is operated; consequently, a separate barge is not specified for plowing operations in Table 1. However, based on the observation from clamshell dredging that the highest levels of underwater sound are emitted from equipment on the barge rather than from the scraping sounds of the dredge itself (Richardson *et al.*, 1995), the source depth for plowing was taken to be that of the pipe laying/burial barge.

## 2.2.5 Operational Scenarios: SRV Transit and Docking

Operational procedures for the SRV's specify maximum allowable transit speeds during transit to the unloading buoys, as well as probable use of thrusters during approach and docking (Table 2). During offshore transit (i.e., over 34 km / 18 nm from the unloading buoys), SRV's travel at full service speed, which in calm weather can be up to 36.1 km/h (19.5 kn). Speed is gradually reduced as the SRV approaches the unloading buoys, until main propulsion is at dead slow (Table 2). Bow and stern thrusters are used during docking. Once moored, ship's propulsion is not required for positioning.

Based on these operational procedures, three sample situations were selected for modeling (see Table 1):

- Offshore transit at full service speed
- Approach at half speed to 10 nm distance from the unloading buoy
- Docking at the northern buoy, using both bow thrusters and one stern thruster

Table 2: Speed limits and thruster operation during approach of SRV's to the unloading buoys and subsequent docking. Point A is located 5.6 km (3 nm) from the unloading buoys.

Zone	Speed limit	Thrusters?
>28 km (15 nm) off point A	Full service speed (36 km/h, 19.5 kn)	No
20-28 km (11-15 nm) off point A	Full maneuver speed (<26 km/h, <14 kn)	No
11-20 km (6-11 nm) off point A	Half ahead (<19 km/h, <10 kn)	No
0-11 km (0-6 nm) off point A	Slow ahead (<11 km/h, <6 kn)	No
Point A to safety zone	Dead slow ahead (<8.3 km/h, <4.5 kn)	Bow and stern thrusters in operation
Inside safety zone	Dead slow ahead (<5.6 km/h, <3 kn)	Bow and stern thrusters in operation
Docking	Dead slow	2 bow thrusters and possibly 1-2 stern thrusters in operation

Very little information is available on the underwater noise levels radiated by LNG carriers. However, some data and empirical formulas have been developed for large tankers in general. At typical cruising speeds, source levels from such vessels are dominated by propeller cavitation (Sponagle, 1988; Seol *et al.*, 2002). As described by LGL and JASCO (2005), an empirical expression for the source spectrum level (1 Hz bandwidth) in the frequency range between 100 Hz and 10 kHz is

$$SL = 163 + 10 \log BD^4 N^3 f^{-2} \text{ dB re } 1 \mu\text{Pa}$$

Here  $B$  is the number of blades,  $D$  is the propeller diameter in meters,  $N$  is the number of propeller revolutions per second, and  $f$  is the frequency in Hz. For frequencies less than 100 Hz, the source level is assumed to be constant at the 100 Hz level. In the case of ducted propellers (e.g., bow and stern thrusters), the constant is approximately 7 dB larger. The parameters used for modeling of a “typical” SRV are listed in Table 3. Specifications for the main propulsion system are based on a typical carrier, and are similar to those described by LGL and JASCO (2005). Bow and stern thrusters are expected to be single-speed, controllable-pitch devices, with power ratings of 2,000 kW each for the bow thrusters and 1,200 kW each for the stern thrusters. Based on these values, diameters and rates of revolution for the thrusters (Table 3) were based on specifications for the most common models currently available. Note that only a single set of parameters is shown for the thrusters, as rates of revolution do not change with power output for single-speed thrusters. The above model is not able to take into account the reduction in source levels that would result from a change in pitch at lower power outputs; hence, the modeled source levels are conservative (i.e., represent maximum expected levels of underwater noise).

The resulting estimated source levels for the SRV are shown in Figure 4.

Table 3: Parameters used to model cavitation noise from SRV main propulsion and thrusters.

Description	Number of blades ( $B$ )	Diameter ( $D$ )	Propeller revolutions per minute	Propeller revolutions per second ( $N$ )
Main propulsion, full speed	4	8.5	87	1.45
Main propulsion, half speed	4	8.5	45	0.75
Main propulsion, dead slow	4	8.5	10	0.17
Bow thruster	4	2.4	200	3.33
Stern thruster	4	2.0	245	4.08

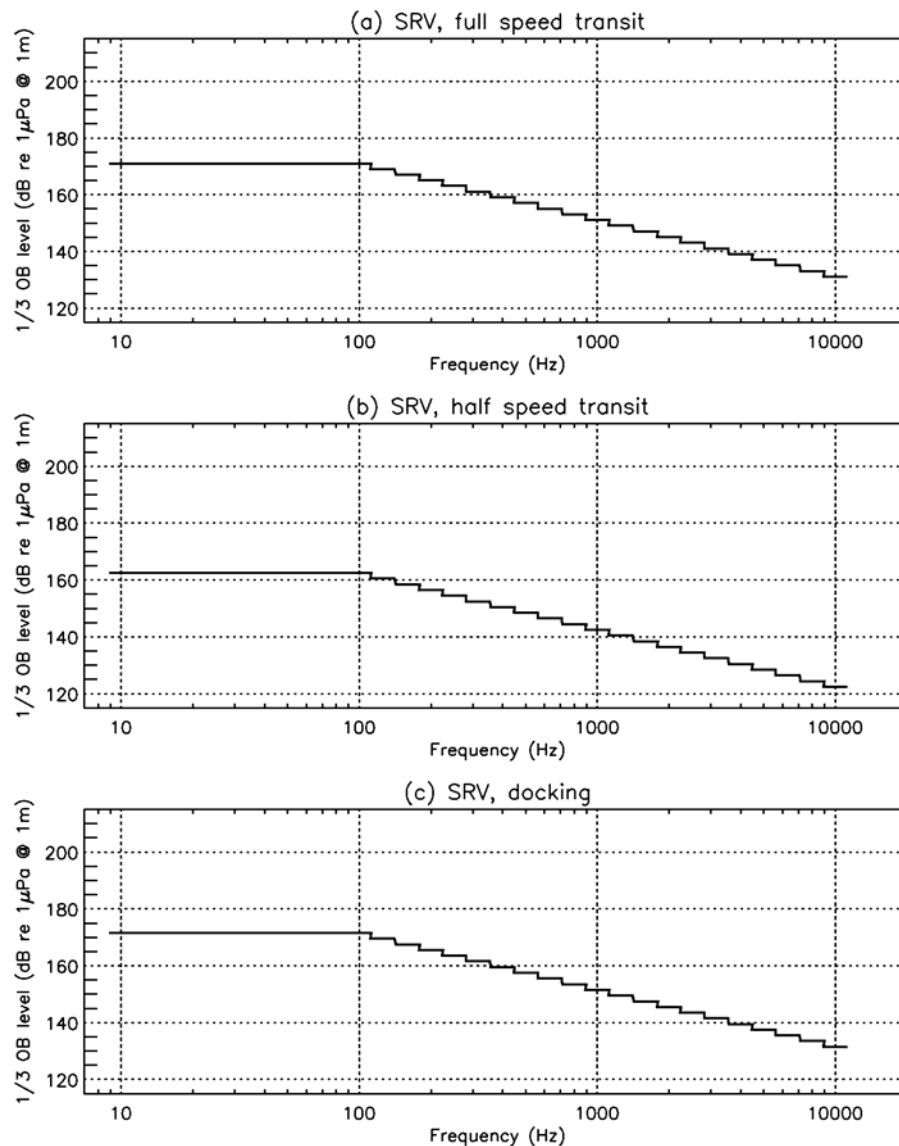


Figure 4: Third-octave band source levels for operational modeling scenarios (see Table 1). Source levels for docking (c) include main SRV propulsion at dead slow, two bow thrusters at half-power, and one stern thruster at half-power. Source depth is 6 m in all cases. Broad-band source levels are (a) 182 dB re  $\mu$ Pa, (b) 174 dB re  $\mu$ Pa, and (c) 183 dB re  $\mu$ Pa.

## 2.3 Additional Sources of Noise

The following additional sources of underwater noise are expected to be present during construction of the Port Dolphin DWP, but were not modeled:

- **Dredging:** Dredging will be involved in a few stages of construction, including horizontal directional drilling (discussed below) and pipe laying at the Sunshine Bridge crossing (Ocean Specialists, 2007). This will involve a clamshell or bucket-style dredge, operated from a barge while one or more additional barges carry out other tasks nearby. Measurements taken by JASCO during operation of a clamshell dredge indicated source levels of approximately 150-155 dB re 1  $\mu$ Pa, i.e. roughly 20 dB lower than the source levels associated with the

Castoro II during pipe laying operations (Figure 2). As such, dredging may be considered an insignificant source of noise compared with operation of the barges that will also be present.

- Horizontal Directional Drilling (HDD): HDD will be employed for installation of the pipe line at a number of locations along the inshore portion of the route, including the Port Manatee shore approach and two crossings of the Gulfstream pipeline (Ocean Specialists, 2007). This will involve using progressively larger drill strings to eventually produce a drill bore 1.22 m (48") in diameter. Simultaneously, bucket dredging will be employed to produce an exit hole at the end of the bore. Very little information exists regarding source levels from horizontal directional drilling. However, measurements taken of drillships (Greene, 1987) suggest that the contribution to the underwater noise field from drilling is likely to be far less than that from the barges from which drilling and/or dredging will be taking place.

Once the port is operational, an additional source of underwater sound in the vicinity of the unloading buoys will be the acoustic transponders installed on the buoys. Information was not available on the specific transponders intended for use at the Port Dolphin DWP at the time of writing of this report. However, specifications from commercially available buoy positioning transponders indicate operating frequencies of a few tens of kHz, and source levels of approximately 190 dB re 1  $\mu$ Pa at 1 m. Given this estimated broadband source level, we may estimate ranges to various threshold values assuming simple spherical spreading, i.e.

$$RL = SL - 20 \log_{10}(r)$$

Solving for  $r$ , we find that received levels will drop to 180 dB at a range of approximately 3 m, and to 160 dB at a range of approximately 32 m. As such, only marine mammals passing very near the unloading buoys would potentially be affected. It should also be noted that this will be a highly intermittent source of underwater noise, as the transponders will only transmit when interrogated by the SRV-based command unit.

## **2.4 Ambient Noise**

Even in the absence of man-made sounds, the sea is typically a noisy environment. A number of natural sources of noise are likely to occur within Tampa Bay and the adjoining shelf, including the following (see Chapter 5 of Richardson *et al.* 1995):

- Wind and waves: The complex interactions between wind and water surface, including processes such as breaking waves and wave-induced bubble oscillations and cavitation, are a main source of naturally occurring ambient noise for frequencies between 200 Hz and 50 kHz (Mitson, 1995; Richardson *et al.*, 1995). In general, ambient noise levels tend to increase with increasing wind speed and wave height. Surf noise becomes important near shore, with measurements collected at a distance of 8.5 km (5.3 mi) from shore showing an increase of 10 dB in the 100 to 700 Hz band during heavy surf conditions (Richardson *et al.*, 1995).
- Precipitation noise: Noise from rain and hail impacting the water surface can become an important component of total noise at frequencies above 500 Hz, and possibly down to 100 Hz during quiet times (Richardson *et al.*, 1995).
- Biological noise: Marine mammals are the main contributors within this category, and can contribute significantly to ambient noise levels. In addition, some fish and shrimp may also make significant contributions (Richardson *et al.*, 1995). The frequency band for biological contributions is from approximately 12 Hz to over 100 kHz.



- Tidally generated noise: Where strong tidal currents occur, these flows may contribute to the ambient noise field via creation of turbulence, generation of surface waves, and transport of sediments along the sea floor (Thorne, 1990; Blackwell and Greene, 2002). The latter mechanism is particularly important where rapid tidal flows occur over loose, relatively large sediments such as gravel (e.g., Blackwell and Greene, 2002), and levels on the order of 70 dB in the 10 kHz region have been reported from measurements immediately above the sea bed (Thorne, 1990).

Sources of ambient noise related to human activity include transportation (surface vessels and aircraft), dredging and construction, oil and gas drilling and production, seismic surveys, sonars, explosions, and ocean acoustic studies (Richardson *et al.*, 1995). Shipping noise typically dominates the total ambient noise for frequencies between 20 and 300 Hz.

The sum of the various natural and anthropogenic noise sources at any given location and time depends not only on the source levels (as determined by current weather conditions and levels of biological and shipping activity) but also on the ability of sound to propagate through the environment. In turn, sound propagation is dependent on the spatially and temporally varying properties of the water column and sea floor (discussed further in Section 4), and is frequency-dependent. As a result of the dependence on a large number of varying factors, the ambient noise levels at a given frequency and location can vary by 10-20 dB from day to day (Richardson *et al.*, 1995).

Very few measurements of ambient noise from Tampa Bay and the adjoining shelf are available. Shooter *et al.* (1982) analyzed approximately 12 hours of data collected in deep (3280 m bottom depth) waters in the western Gulf of Mexico, and reported median ambient noise levels of 77-80 dB re.  $\mu\text{Pa}^2/\text{Hz}$ . These levels are likely to be somewhat lower than those occurring in the vicinity of Tampa Bay, due in large part to the reduced contribution from surf in deep water. Phillips *et al.* (2006) present measurements from manatee habitats in boating channels and rivers along the Florida coast, consisting of fairly flat or slightly sloping sea floors shallower than 5 m. Ambient noise measurements in these habitats range from 69 dB in Crystal River (away from the mouth of the river) to 105 dB near the mouths of the Crystal and Indian Rivers.

### 3 Modeling Methodology

Starting from source locations and levels for a given scenario (Section 2), the acoustic field at any range from the source(s) is estimated using an acoustic propagation model. Sound propagation modeling uses acoustic parameters appropriate for the specific geographic region of interest, including the expected water column sound speed profile, the bathymetry, and the bottom geoacoustic properties (see Section 4), to produce site specific estimates of the radiated noise field as a function of range and depth.

JASCO's Marine Operations Noise Model (MONM) is used to predict the directional transmission loss footprint from one or more source locations. MONM is an advanced modeling package whose algorithmic engine is a modified version of the widely-used the Range Dependent Acoustic Model (RAM) (Collins *et al.*, 1996). RAM is based on the parabolic equation method using the split-step Padé algorithm to efficiently solve range dependent acoustic problems. RAM assumes that outgoing energy dominates over scattered energy and computes the solution for the outgoing wave equation. An uncoupled azimuthal approximation is used to provide 2-D transmission loss values in range and depth. RAM has been enhanced by JASCO to approximately model shear wave conversion at the sea floor using the equivalent fluid complex density approach of Zhang and Tindle (1995).

Because the modeling takes place over radial planes in range and depth, volume coverage is achieved by creating a fan of radials that is sufficiently dense to provide the desired tangential resolution. This  $n \times 2$ -D approach is modified in MONM to achieve greater computational efficiency by not over-sampling the region close to the source. The desired coverage is obtained through a process of tessellation, whereby the initial fan of radials has a fairly wide angular spacing (e.g., 5 degrees), but the arc length between adjacent radials is not allowed to increase beyond a preset limit (e.g., 1.5 km) before a new radial modeling segment is started, bisecting the existing ones. The new radial need not extend back to the source because its starting acoustic field at the bisection radius is "seeded" from the corresponding range step of its neighboring traverse.

The tessellation algorithm also allows the truncation of radials along the edges of a bounding quadrangle of arbitrary shape, further contributing to computational efficiency by enabling the modeling region to be more closely tailored to an area of relevance. MONM has the capability of modeling sound propagation from multiple directional sources at different locations and merging their acoustic fields into an overall received level at any given location and depth. The received sound levels at any location within the region of interest are computed from the  $\frac{1}{3}$ -octave band source levels (see Section 2.2) by subtracting the numerically modeled transmission loss at each  $\frac{1}{3}$ -octave band center frequency, and summing incoherently across all frequencies to obtain a broadband value.

#### 3.1 Estimating 90% RMS SPL from SEL

For continuous noise sources (e.g., vessel noise), MONM predicts RMS sound pressure levels (SPL) upon which U.S. safety radius requirements are based. For impulsive noise sources (impact hammering) MONM predicts sound exposure level (SEL) over a nominal time window of 1 second. For *in situ* measurements of impulsive sound sources, SPL is related to SEL via a simple relation that depends only on the RMS integration period  $T$ :

$$SPL_{RMS90} = SEL - 10\log_{10}(T) - 0.458$$

Here the last term accounts for the fact that only 90% of the acoustic pulse energy is delivered over the standard integration period (Malme *et al.*, 1986; Greene, 1997; McCauley *et al.*, 1998). The pulse duration at any given point in the sound field is highly sensitive to the specific multi-path arrival pattern from an acoustic source. In the absence of *in situ* measurements, accurate direct forecasting of the pulse duration at any significant range from the source is computationally prohibitive at present. The best alternative is to use a heuristic value of  $T$ , based on field measurements in similar environments, to estimate an RMS level from the modeled SEL. Safety radii estimated in this way are approximate since

the true time spreading of the pulse has not actually been modeled. For this study, the integration period  $T$  has been assumed equal to a pulse width of 0.1 s, resulting in the following approximate relationship between RMS SPL and SEL:

$$\text{SPL}_{\text{RMS90}} = \text{SEL} + 10$$

In various studies where the  $\text{SPL}_{\text{RMS90}}$ , SEL, and duration have been determined for individual airgun pulses, the average offset between SPL and SEL has been found to be 5 to 15 dB, with considerable variation dependent on water depth and geo-acoustic environment (Austin *et al.* 2003; MacGillivray *et al.* 2007).

### 3.2 Weighting for Hearing Capabilities of Marine Mammals and Turtles

In order to take into account the differential hearing capabilities of various groups of marine mammals, the M-weighting frequency weighting approach described by Miller *et al.* (2005) is commonly applied. The M-weighting filtering process is similar to the C-weighting method that is used for assessing impacts of loud impulsive sounds on humans. It accounts for sound frequencies extending above and below the most sensitive hearing range of marine mammals within each of five functional groups: low frequency cetaceans, mid-frequency cetaceans, high frequency cetaceans, pinnipeds in water and pinnipeds in air (Table 4). The filter weights  $Mw_i$ , for frequency band  $i$  with center frequency  $f_i$ , are defined by:

$$Mw_i = -20 \log_{10} \left( \frac{f_i^2 f_{hi}^2}{(f_i^2 + f_{lo}^2)(f_i^2 + f_{hi}^2)} \right)$$

Here  $f_{lo}$  and  $f_{hi}$  are as listed in Table 4.

Table 4: Functional hearing groups and associated auditory bandwidths, as per Miller *et al.* (2005). Note that only the in-water bandwidth is shown for pinnipeds.

Functional hearing group	Members	Estimated auditory bandwidth (Hz)	
		$f_{lo}$	$f_{hi}$
Low-frequency cetaceans	Mysticetes	7 Hz	22 kHz
Mid-frequency cetaceans	Lower-frequency odontocetes	150 Hz	160 kHz
High-frequency cetaceans	Higher-frequency odontocetes	200 Hz	180 kHz
Pinnipeds	Pinnipeds	75 Hz	75 kHz

Three types of marine mammals have been identified as being of particular interest with respect to the proposed DWP, based on their frequency of occurrence and/or endangered status (Table 5). Bottlenose and Atlantic spotted dolphins are not endangered or threatened, but are common in the vicinity of the terminal; sperm whales and manatees are both endangered. The two dolphin species and sperm whales fall into Miller *et al.*'s (2005) mid-frequency cetacean grouping. The Florida manatee is not specifically referred to by Miller *et al.* (2005). However, measurements on captive manatees (Gerstein *et al.*, 1999; Gerstein, 2002) indicate a functional hearing range of 400 Hz to 46 kHz, within the bounds listed for pinnipeds (Table 4). As such, M-weightings for pinnipeds are used as a precautionary approximation for manatees in Section 5.

Although very little information exists on the hearing capabilities of sea turtles, available literature (primarily from loggerhead turtles) indicates that sea turtles hear low frequencies, with an effective hearing range of approximately 250 Hz – 750 Hz (Ridgway *et al.*, 1969; Moein, 1994; Bartol *et al.*, 1999). Given the limited data available, it is difficult to define specific upper and lower bounds as for

marine mammal M-weightings. For the purposes of this project, low-frequency cetacean weightings were applied for turtles to provide some discounting of very high frequencies. However, this should be considered an extremely precautionary measure for sea turtles, whose effective hearing range appears to be much more limited than that of even low-frequency cetaceans.

Table 5: Key species of interest in the vicinity of the proposed Port Dolphin DWP and associated M-weightings (see Table 4). Note that the weightings applied for the Florida manatee and for sea turtles should be taken as precautionary approximations (see the text).

<b>Species of interest</b>	<b>Region</b>	<b>M-weighting</b>
Sperm whale	Offshore (shelf edge and continental slope)	Mid-frequency cetaceans
Dolphins: Bottlenose and Atlantic spotted	Coastal, shelf, and slope/deep	Mid-frequency cetaceans
Florida manatee	Coastal (Tampa Bay)	Pinnipeds
Sea turtles	Coastal, shelf, and slope	Low-frequency cetaceans

## 4 MONM Parameters

### 4.1 Source and Receiver Locations

Modeled source locations are shown in Table 6 below; see also Figure 1 in Section 2.1. These represent the center-points of the model field. Equipment was distributed around these center points as discussed in Section 2.2, with appropriate source depths based on the proxy vessels selected (see Figure 2 through Figure 4).

From each of the source location(s), the model generates a grid of acoustic levels over any desired area and for specified receiver depths. The following receiver depths were used in each case: 2 m intervals from surface to 10 m depth, then 5 m intervals to 20 m, then 10 m intervals to 100 m depth.

Table 6: Summary of modeling locations. See also Figure 1 in Section 2.1 and details of equipment layouts in Section 2.2.

Scenario		Location	Latitude (°N)	Longitude (°W)
<b>Construction scenarios</b>				
1	Installation of anchors, buoys, and anchor chains	North buoy	27° 25' 12.14"	83° 11' 50.11"
2	Impact pile driving (offshore)	Piggable wye site	27° 24' 13.06"	83° 10' 27.72"
3	Impact pile driving (inshore)	Subsea block valve site	27° 36' 45.87"	82° 39' 17.98"
4	Pipe laying (offshore)	15m isobath	27° 28' 43.32"	82° 56' 41.64"
5	Pipe laying (inshore)	Tampa Bay	27° 35' 42.70"	82° 41' 0.97"
6	Pipe laying through Passage Key—live boat method	Passage Key	27° 32' 39.18"	82° 44' 30.95"
7	Pipeline burial—plowing (offshore)	15m isobath	27° 28' 43.32"	82° 56' 41.64"
8	Pipeline burial—plowing (inshore)	Tampa Bay	27° 35' 42.70"	82° 41' 0.97"
<b>Operational scenarios</b>				
9	Offshore transit	37 km (20 nm) west of the unloading buoy	27° 08' 00"	83° 19' 00"
10	Buoy approach	18.5 km (10 nm) west of the unloading buoy	27° 18' 00"	83° 19' 00"
11	Docking	North buoy	27° 25' 12.14"	83° 11' 50.11"

### 4.2 Frequency Range

As discussed in Section 3, MONM computes transmission loss, and hence received sound levels, for individual third-octave bands. As there is a trade-off between the number of frequencies computed

and computation time, it is desirable to use the minimum frequency range that will capture most of the energy from the sources present and provide good overlap with the hearing capabilities of the species of interest in the region.

For this study, a frequency range of 10 Hz to 2 kHz was used. While this upper limit is less than the upper limit of cetacean hearing (Section 3.2), the frequency characteristics of the sound sources involved in construction and terminal operations (Section 2.2) are such that this frequency range captures almost all of the sound energy emitted by the vessels and equipment, even when applying the relatively high-frequency cutoffs associated with M-weighting for mid-frequency cetaceans.

### 4.3 Bathymetry

The relief of the sea floor is one of the most crucial parameters affecting the propagation of underwater sound, and detailed bathymetric data are therefore essential to accurate modeling. For each of the sites, bathymetric data were extracted from the NGDC US Coastal Relief model (Divins and Metzger 2007) with a horizontal resolution of 3 arc-seconds (approximately 92 m in the N-S direction and 82 m in the E-S direction for the study area). Bathymetric contours are shown in Figure 1 of Section 2.1.

### 4.4 Geoacoustic Properties

Tampa Bay is located on the southwestern flank of the Ocala Platform (Brooks and Doyle, 1998). This section of consolidated sediments, which is represented by limestones of different formations, is covered by a thin layer of unconsolidated sediments. The top of the bedrock section consists of soft Miocene-Oligocene limestones with a thickness of 80-190 m, which is underlain by hard dolomite and limestone (Crandall, 2007).

Surface sediments in the region are dominated by the Tampa Bay ebb-tidal delta, which is responsible for continuous late-Holocene sediment cover extending to approximately 15 km offshore (Locker *et al.*, 1999; Hine *et al.*, 2001). These sediments consist of fine quartz sand, as well as some coarse sand and gravel size carbonates. While the sediment layer is variable, sediment thicknesses of 4-5 m are common near shore. Beyond the near-shore region, the sediment cover thins to expose occasional hard-bottom (Locker *et al.*, 1999). Similarly, sediments between the mouth of Tampa Bay and Port Manatee are primarily sandy (USGS, 2007). Sediment thicknesses here are typically less than 6 m, although this increases to a depth of 16-17 m within the deepest depressions (Brooks and Doyle, 1998; Edgar, 2002).

Taking into account the information presented above, the geoacoustic profile was constructed based on values suggested by Hamilton (1980), assuming an average profile consisting of 5 m of fine sand overlying two limestone layers (Table 7).

Table 7: Tampa Bay geoacoustic profile

Depth (m)	Description	Density (g/cm <sup>3</sup> )	P-wave		S-wave	
			Velocity (m/s)	Attenuation	Velocity (m/s)	Attenuation
0–5	unconsolidated sandy sediment	1.8-1.85	1700–1750	0.8	200	0.1
5–125	soft limestone	2.5	2500	0.25		
>125	hard limestone	2.7	3500	0.13		

#### 4.4.1 Alternative Profiles for Sensitivity Testing

Particularly in shallow water, where opportunities exist for multiple bottom interactions, model predictions are very sensitive to the bottom parameters used. As a result, uncertainty in the geoacoustic profile translates to uncertainty in the model results. For example, in the case of Tampa Bay and the adjoining continental shelf, there is considerable spatial variability in the thickness of the near-surface sand layer. In addition, there is some uncertainty in the thicknesses and geoacoustic properties of the underlying limestone layers.

In order to quantify these sources of variability, additional model runs were carried out with a series of modified geoacoustic profiles, based on the main profile in Table 7. The following variations were considered:

- The thickness of the sand layer was varied, from no sand at all to a maximum thickness of 10 m.
- The properties of the soft limestone layer were modified to simulate a slightly harder, higher-velocity rock: density was increased by 0.1 g/cm<sup>3</sup>, and p-wave velocity was increased by 500 m/s.
- The depth of the interface between the soft and hard limestones was varied from 80 m to 190 m, bracketing the range of interface depths reported by Crandall (2007).

#### 4.5 Sound Speed Profiles

Sound speed profiles in the ocean for each modeling location were derived from the US Naval Oceanographic Office's Generalized Digital Environmental Model (GDEM) database (Teague *et al.*, 1990). The latest release of the GDEM database (version 3.0) provides average monthly profiles of temperature and salinity for the world's oceans on a latitude/longitude grid with 0.25 degree resolution. Profiles in GDEM are provided at 78 fixed depth points up to a maximum depth of 6,800 m. The profiles in GDEM are based on historical observations of global temperature and salinity from the US Navy's Master Oceanographic Observational Data Set (MOODS).

For each acoustic model scenario, a single temperature/salinity profile was extracted from the GDEM database for the appropriate season and source location and converted to speed of sound in seawater using the equations of Coppens (1981):

$$\begin{aligned}c(z, T, S) &= 1449.05 + 45.7T - 5.21t^2 - 0.23t^3 \\ &\quad + (1.333 - 0.126t + 0.009t^2)(S - 35) + \Delta \\ \Delta &= 16.3Z + 0.18Z^2 \\ Z &= (z/1000)(1 - 0.0026\cos(2\phi)) \\ t &= T/10\end{aligned}$$

Here  $z$  is depth in meters,  $T$  is temperature in degrees Celsius,  $S$  is salinity in psu and  $\phi$  is latitude (in radians).

The resulting sound speed profiles for the study area are shown in Figure 5, for the month of January. Note that the sound speed profile will vary seasonally. As terminal operations will occur year-round, and construction activities will cover several months, this has the potential to produce seasonal variations in the impacts from underwater noise associated with the DWP. January was selected as a "worst-case" month for offshore operations, as the cooler temperatures and decreased stratification will produce a sound speed profile which will tend to reduce refraction of sound into the bottom and thus reduce transmission loss. In contrast, the July profile for the offshore region is more downward-refracting

(Figure 6). In order to test the effect of these seasonal variations on received sound levels, selected model scenarios were run for both January and July sound speed profiles.

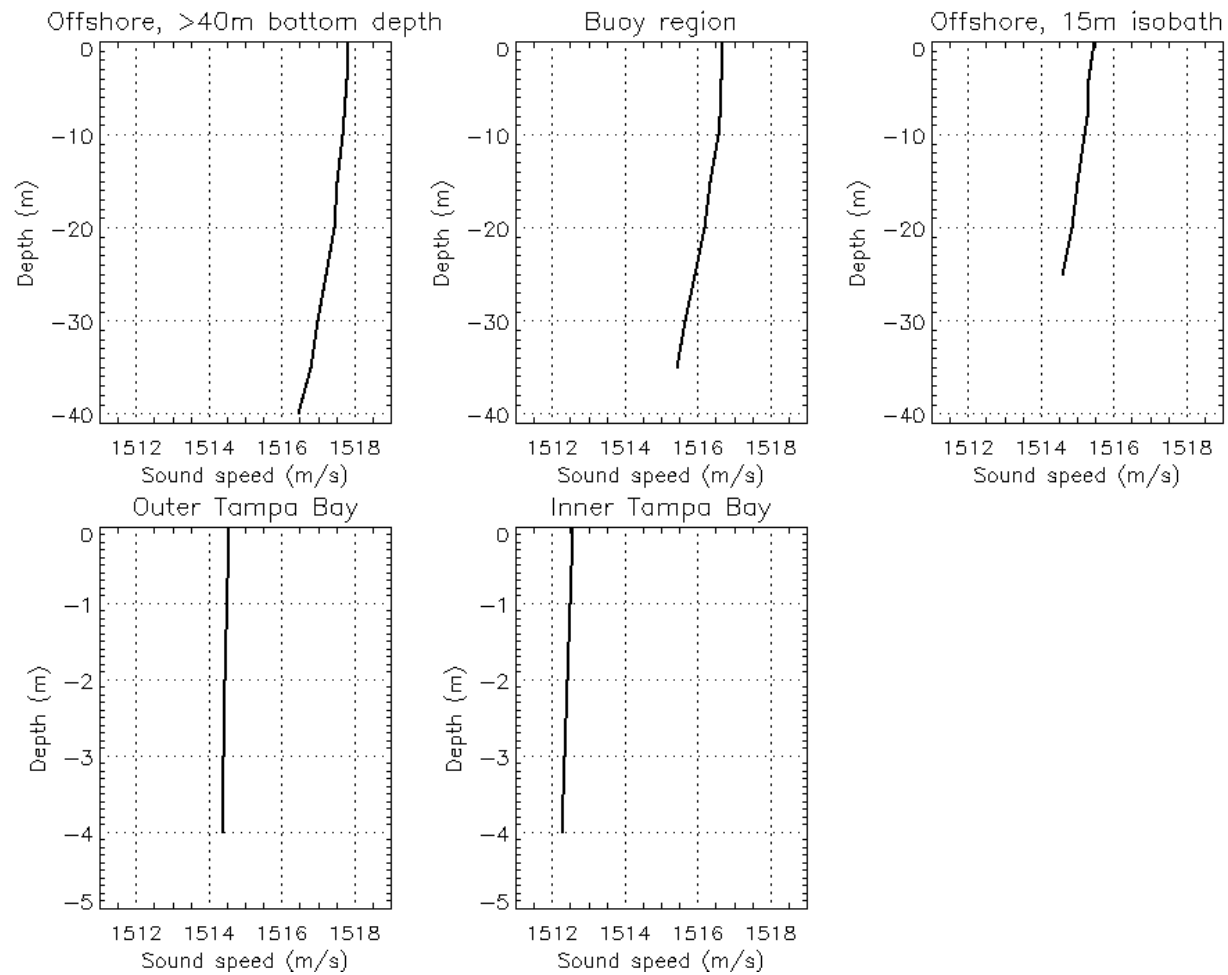


Figure 5: Predicted sound speed profiles for the month of January, from GDEM version 3.0 (Teague et al., 1990).



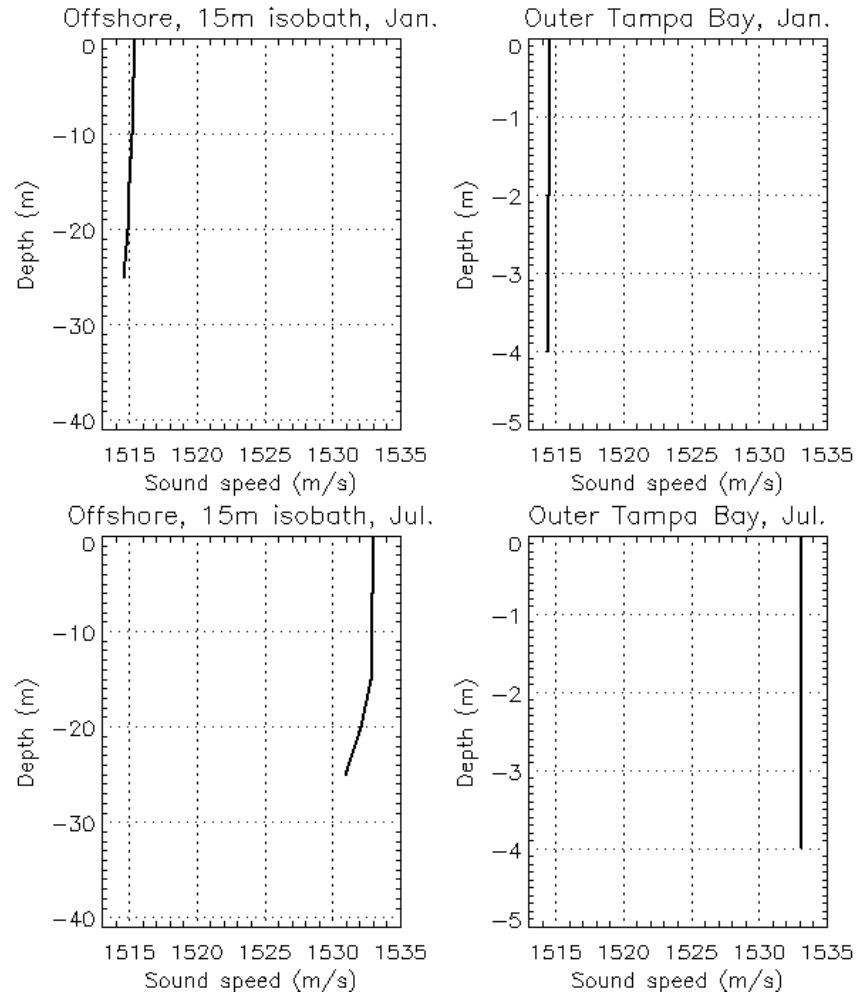


Figure 6: Predicted sound speed profiles for the months of January and July, from GDEM version 3.0 (Teague *et al.*, 1990).

## 5 Model Results

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The MONM propagation model was run in the full  $n \times 2$ -D sense as described in Section 3. Geographically rendered maps of the estimated received sound levels are shown in Appendix B for each of the scenarios described in Section 2. The tables in the following sub-sections summarize the results of the acoustic modeling in terms of radii to threshold values of 120 dB to 190 dB RMS. In addition, the threshold levels relevant to NMFS criteria for Level A and Level B harassment are highlighted. Note that the radial resolution of the model runs was 10 m.

For an impulsive source such as impact hammering, the acoustic level values in the model output represent the SEL metric, a suitable measure of the impact of an impulsive sound because it reflects the total acoustic energy delivered over the duration of the event at a receiver location. In order to determine the RMS SPL, a pulse duration of 0.1 s was assumed, resulting in a conversion factor of +10 dB (Section 3.1). Thus, RMS levels (in dB re  $1\mu\text{Pa}$ ) were taken to be 10 dB higher than SEL values (in dB re  $1\mu\text{Pa}^2 \cdot \text{s}$ ). This conversion is not required for continuous noise sources (vessel noise, plowing), for which the model outputs RMS values.

For each sound level threshold, the tables below list the 95% radius. Given a regularly gridded spatial distribution of modeled received levels, the 95% radius is defined as the radius of a circle that encompasses 95% of the grid points whose value is equal to or greater than the threshold value. This definition is meaningful in terms of potential impact to an animal because, regardless of the geometrical shape of the noise footprint for a given threshold level, it always provides a range beyond which no more than 5% of a uniformly distributed population would be exposed to sound at or above that level. Modeled sound levels were sampled at several depths at each site, up to the seafloor depth. The tables list radii based on maximum received levels over these ranges of depths.

Note that for some scenarios, higher threshold values only occur in the vicinity of individual pieces of equipment, with relatively little overlap of the sound fields from neighboring vessels. In these cases the overall radius depends primarily on the spacing between the vessels, and a single scenario-specific radius cannot sensibly be defined. For example, in the case of pipe laying in Passage Key (Figure 7 below), contour levels greater than 160 dB only occur in the immediate vicinity of the barge and tugs. In the tables that follow, such a situation is indicated by an entry such as “<0.2 km”.

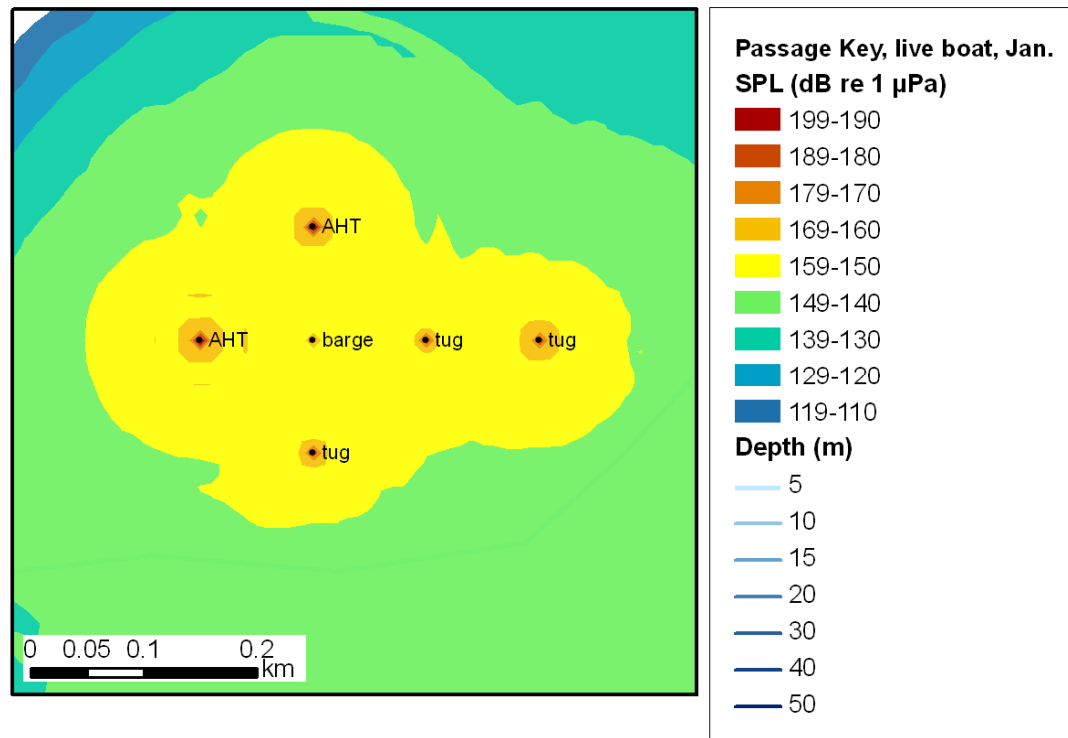


Figure 7: Estimated received sound levels near the sources, for pipe laying in Passage Key (see also Figure 12 in Appendix B). Note that “AHT” refers to an anchor-handling tug, while “tug” refers to a tug whose propulsion system is active but which is not actively pushing or pulling.

## 5.1 Un-Weighted Model Results

Raw model results, i.e. without application of M-weightings (see Section 3.2), are presented in the following two sub-sections.

### 5.1.1 Construction Scenarios

Radii to various threshold values are shown below for construction activities occurring in the offshore (Table 8) and inshore (Table 9) regions. See also Figure 8 through Figure 15 in Appendix B. Impact hammering is by far the loudest of the activities. However, it will likely occur only during relatively brief periods of time. Radii for pipe laying and burial are similar to one another, on the order of 6-8 km for the 120 dB contour and less than the equipment spacing for the 180 dB contour (Table 8, Table 9). Note that radii for a given activity vary with water depth; for example, the radius to the 120 dB contour during pipe laying varies from 7.5 km offshore (water depth of 15 m) to a mere 1.6 km in Passage Key (water depth less than 5 m). This is primarily due to the dramatically reduced transmission of lower-frequency sounds in shallower waters. For example, in the region of the Passage Key site the water depths are less than a single wavelength for frequencies up to at least a few hundred Hz ( $f=c/\lambda$ ). Considering Figure 2 in Section 2.2, we see that most of the energy from the vessels associated with pipe laying occurs at these low frequencies, and so will propagate poorly.

Table 8: 95<sup>th</sup> percentile radii for offshore construction scenarios. See Figure 1 for site locations. Radii corresponding to Level A and Level B harassment criteria are shown in bold italics. Note that radii for threshold values up to 140 dB exceeded the model bounds for impact hammering.

SPL (dB re 1 $\mu$ Pa)	95 <sup>th</sup> percentile radius (km)			
	Buoy installation	Impact hammering	Pipe laying	Pipe burial
120	<b>3.9</b>	>20	<b>7.5</b>	<b>8.4</b>
130	1.4	>20	3.8	3.9
140	0.35	>20	2.0	2.0
150	<0.20	14.4	0.52	0.59
160	<0.20	<b>4.5</b>	<0.20	<0.20
170	<0.20	1.1	<0.20	<0.20
180	<b>&lt;0.20</b>	<b>0.18</b>	<b>&lt;0.20</b>	<b>&lt;0.20</b>
190	<b>&lt;0.20</b>	<b>0.03</b>	<b>&lt;0.20</b>	<b>&lt;0.20</b>

Table 9: 95<sup>th</sup> percentile radii for inshore construction scenarios. See Figure 1 for site locations. Radii corresponding to Level A and Level B harassment criteria are shown in bold italics.

SPL (dB re 1 $\mu$ Pa)	95 <sup>th</sup> percentile radius (km)			
	Impact hammering	Pipe laying: Passage Key	Pipe laying: Tampa Bay	Pipe burial: Tampa Bay
120	18.3	<b>1.6</b>	<b>6.0</b>	<b>6.7</b>
130	12.3	0.95	2.1	2.4
140	8.0	0.49	0.89	0.98
150	3.7	0.24	0.39	0.44
160	<b>1.9</b>	<0.21	<0.20	<0.20
170	0.85	<0.20	<0.20	<0.20
180	<b>0.30</b>	<b>&lt;0.20</b>	<b>&lt;0.20</b>	<b>&lt;0.20</b>
190	<b>0.07</b>	<b>&lt;0.20</b>	<b>&lt;0.20</b>	<b>&lt;0.20</b>

### 5.1.2 Operational Scenarios

Radii to various threshold values are shown in Table 10 below for transit, buoy approach, and docking of an SRV. See also Figure 16 through Figure 18 in Appendix B. Radii are similar for the transit and docking scenarios, i.e. 3.6-3.8 km for the 120 dB contour. As might be expected given the relative source levels (Figure 4 in Section 2.2.5), radii are considerably less for the approach scenario, during which main propulsion is at half speed and thrusters are not yet in operation.

Table 10: 95<sup>th</sup> percentile radii for operational scenarios. See Figure 1 for site locations. Radii corresponding to Level A and Level B harassment criteria are shown in bold italics. Note that values are not shown for threshold values higher than the source level.

SPL (dB re 1 $\mu$ Pa)	95 <sup>th</sup> percentile radius (km)		
	SRV transit	SRV buoy approach	SRV docking
120	<b>3.8</b>	<b>1.7</b>	<b>3.6</b>
130	1.5	0.43	1.5
140	0.32	0.09	0.37
150	0.05	0.01	0.09
160	0.01	<0.01	0.01
170	<0.01	<0.01	<0.01
180	<b>&lt;0.01</b>	-----	<b>&lt;0.01</b>
190	-----	-----	-----

## 5.2 Weighting for Hearing Capabilities of Marine Mammals and Turtles

As discussed in Section 3.2, model results may be weighted to reflect the hearing capabilities of various marine species. Ninety-fifth percentile radii are shown in Table 8 through Table 13 below for various combinations of model scenarios and functional hearing groups, based on the study sites listed in Table 1 of Section 2.2 and the species distributions listed in Table 5 of Section 3.2.

Comparing the radii in the following tables with the un-weighted radii in the previous section, we see relatively little reduction after weighting for low-frequency cetaceans and pinnipeds, as might be expected given their relatively low values for  $f_{lo}$  (see Table 4 of Section 3.2). Note, however, that the actual hearing capabilities of sea turtles and manatees, for which these M-weightings are applied as precautionary approximations, are likely to be less. As a result, these radii likely represent over-estimates for these species. A greater reduction in 95<sup>th</sup> percentile radii is seen when weighting for mid-frequency cetaceans (which includes sperm whales and dolphins).

Table 11: 95<sup>th</sup> percentile radii for offshore construction scenarios, M-weighted for low- and mid-frequency cetaceans. See Table 8 for un-weighted radii. Radii corresponding to Level A and Level B harassment criteria are shown in bold italics.

SPL (dB re 1 $\mu$ Pa)	95 <sup>th</sup> percentile radius (km)			
	Buoy installation	Impact hammering	Pipe laying	Pipe burial
<b>Low-frequency cetaceans</b>				
120	<b>3.8</b>	>20	<b>7.4</b>	<b>8.3</b>
130	1.4	>20	3.6	3.8
140	0.35	>20	1.8	1.9
150	<0.20	14.3	0.51	0.55
160	<0.20	<b>4.5</b>	<0.20	<0.20
170	<0.20	1.1	<0.20	<0.20
180	<b>&lt;0.20</b>	<b>0.18</b>	<b>&lt;0.20</b>	<b>&lt;0.20</b>
190	<0.01	0.03	<0.20	<0.20
<b>Mid-frequency cetaceans</b>				
120	<b>2.9</b>	>20	<b>6.8</b>	<b>7.9</b>
130	0.90	>20	2.2	2.7
140	0.22	>20	0.76	0.91
150	<0.20	11.1	0.24	0.28
160	<0.20	<b>3.1</b>	<0.20	<0.20
170	<0.20	0.72	<0.20	<0.20
180	<b>&lt;0.01</b>	<b>0.10</b>	<b>&lt;0.20</b>	<b>&lt;0.20</b>
190	<0.01	0.01	<0.01	<0.01

Table 12: 95<sup>th</sup> percentile radii for inshore construction scenarios, M-weighted for low- and mid-frequency cetaceans and for pinnipeds. See Table 9 for un-weighted radii. Radii corresponding to Level A and Level B harassment criteria are shown in bold italics. Note that both cetacean and pinniped criteria are shown for the pinniped M-weighting, as manatees do not clearly belong to either group for the purposes of harassment criteria.

SPL (dB re 1 $\mu$ Pa)	95 <sup>th</sup> percentile radius (km)			
	Impact hammering	Pipe laying: Passage Key	Pipe laying: Tampa Bay	Pipe burial: Tampa Bay
<b>Low-frequency cetaceans</b>				
120	18.3	<b>1.6</b>	<b>6.0</b>	<b>6.7</b>
130	12.2	0.95	2.1	2.4
140	7.9	0.49	0.88	0.98
150	3.7	0.24	0.39	0.44
160	<b>1.9</b>	<0.21	<0.20	<0.20
170	0.85	<0.20	<0.20	<0.20
180	<b>0.30</b>	<b>&lt;0.20</b>	<b>&lt;0.20</b>	<b>&lt;0.20</b>
190	0.07	<0.20	<0.20	<0.20
<b>Mid-frequency cetaceans</b>				
120	18.3	<b>1.5</b>	<b>5.9</b>	<b>6.6</b>
130	12.2	0.92	2.0	2.3
140	7.8	0.40	0.77	0.88
150	3.6	0.22	0.28	0.32
160	<b>1.7</b>	<0.21	<0.20	<0.20
170	0.70	<0.20	<0.20	<0.20
180	<b>0.20</b>	<b>&lt;0.20</b>	<b>&lt;0.20</b>	<b>&lt;0.20</b>
190	0.04	<0.01	<0.01	<0.01
<b>Pinnipeds (in water)</b>				
120	18.3	<b>1.5</b>	<b>6.0</b>	<b>6.7</b>
130	12.3	0.94	2.1	2.4
140	7.9	0.45	0.84	0.94
150	3.7	0.23	0.34	0.39
160	<b>1.8</b>	<0.21	<0.20	<0.20
170	0.80	<0.20	<0.20	<0.20
180	<b>0.26</b>	<b>&lt;0.20</b>	<b>&lt;0.20</b>	<b>&lt;0.20</b>
190	<b>0.06</b>	<b>&lt;0.01</b>	<b>&lt;0.01</b>	<b>&lt;0.01</b>

Table 13: 95<sup>th</sup> percentile radii for operational scenarios, M-weighted for low- and mid-frequency cetaceans. See Table 10 for un-weighted radii. Radii corresponding to Level A and Level B harassment criteria are shown in bold italics. Note that values are not shown for threshold values higher than the un-weighted source level.

SPL (dB re 1 $\mu$ Pa)	95 <sup>th</sup> percentile radius (km)		
	SRV transit	SRV buoy approach	SRV docking
<b>Low-frequency cetaceans</b>			
120	<b><i>3.8</i></b>	<b><i>1.6</i></b>	<b><i>3.5</i></b>
130	1.5	0.40	1.5
140	0.31	0.09	0.34
150	0.04	0.01	0.08
160	0.01	<0.01	0.01
170	<0.01	<0.01	<0.01
180	<b><i>&lt;0.01</i></b>	-----	<b><i>&lt;0.01</i></b>
190	-----	-----	-----
<b>Mid-frequency cetaceans</b>			
120	<b><i>1.7</i></b>	<b><i>0.5</i></b>	<b><i>1.7</i></b>
130	0.37	0.11	0.41
140	0.05	0.01	0.10
150	0.01	<0.01	0.01
160	<0.01	<0.01	<0.01
170	<0.01	<0.01	<0.01
180	<b><i>&lt;0.01</i></b>	-----	<b><i>&lt;0.01</i></b>
190	-----	-----	-----

### 5.3 Sensitivity of Model Results to Environmental Parameters

As discussed in Sections 4.4 and 4.5, model results are sensitive to uncertainties and variations in the environmental parameters that are input to the model, including water column sound speed profiles and geoacoustic properties of the sea floor. In order to quantify the effects of these sources of uncertainty, MONM was run for a number of variations on the main setup described in the previous sections, using pipe laying as an example scenario (effects will be similar for other scenarios).

As expected given the seasonal variation in the water column sound speed profile (see Figure 6 in Section 4.5), radii to various thresholds are less in July than they are in January (Table 14). As a result, the assumption presented in Section 4.5 that January values would represent a seasonal “worst-case” appears to be valid.



Table 14: 95<sup>th</sup> percentile radii for inshore and offshore pipe laying, modeled using water column sound speed profiles from two different times of year (see Figure 6 in Section 4.5). Radii corresponding to Level A and Level B harassment criteria are shown in bold italics.

SPL (dB re 1 $\mu$ Pa)	95 <sup>th</sup> percentile radius (km): Pipe laying			
	Offshore, January	Offshore, July	Inshore, January	Inshore, July
120	<b>7.5</b>	<b>6.9</b>	<b>6.0</b>	<b>5.5</b>
130	3.8	3.3	2.1	2.0
140	2.0	1.8	0.89	0.83
150	0.52	0.50	0.39	0.37
160	<0.20	<0.20	<0.20	<0.20
170	<0.20	<0.20	<0.20	<0.20
180	<b>&lt;0.20</b>	<b>&lt;0.20</b>	<b>&lt;0.20</b>	<b>&lt;0.20</b>
190	<b>&lt;0.20</b>	<b>&lt;0.20</b>	<b>&lt;0.20</b>	<b>&lt;0.20</b>

The model results were found to be sensitive to the presence or absence of an unconsolidated sand layer overlying the limestone basement (Table 15; see also Section 4.4.1). The effect is slightly more pronounced at the inshore site, where shallower water favors greater interaction with the bottom, hence magnifying the effect of changing the bottom characteristics. While adding even a thin sand layer significantly reduces the radii, particularly at the inshore site, the change produced by increasing the depth of the sand layer from 2.5 m to 5 m is relatively small (Table 15). Similarly, increasing the thickness of the sand layer even further to 10 m has no significant effect on the estimated radii. Varying the geoacoustic properties of the soft limestone layer and the depth of the interface between the two limestone layers (as discussed in Section 4.4.1) also fails to produce any significant changes in the modeled radii.

Table 15: 95<sup>th</sup> percentile radii for inshore and offshore pipe laying, modeled using a sand layer of varying thickness (see Section 4.4.1). Radii corresponding to Level A and Level B harassment criteria are shown in bold italics.

SPL (dB re 1 $\mu$ Pa)	95 <sup>th</sup> percentile radius (km): Pipe laying					
	Offshore, no sand	Offshore, 2.5 m sand layer	Offshore, 5 m sand layer	Inshore, no sand	Inshore, 2.5m sand layer	Inshore, 5 m sand layer
120	<b>11.8</b>	<b>7.8</b>	<b>7.5</b>	<b>9.1</b>	<b>6.0</b>	<b>6.0</b>
130	4.8	4.0	3.8	3.6	2.2	2.1
140	2.0	2.0	2.0	1.5	0.96	0.89
150	0.72	0.62	0.52	0.67	0.45	0.39
160	<0.20	<0.20	<0.20	0.22	<0.20	<0.20
170	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
180	<b>&lt;0.20</b>	<b>&lt;0.20</b>	<b>&lt;0.20</b>	<b>&lt;0.20</b>	<b>&lt;0.20</b>	<b>&lt;0.20</b>
190	<b>&lt;0.20</b>	<b>&lt;0.20</b>	<b>&lt;0.20</b>	<b>&lt;0.20</b>	<b>&lt;0.20</b>	<b>&lt;0.20</b>

## 6 Literature Cited

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- Aspen Environmental Group. 2005. Monterey Accelerated Research System Cabled Observatory EIR/EIS, March 2005. Chapter 4. p4.8-6.
- Austin, M.E., A.O. MacGillivray, D.E. Hannay, and S.A. Carr. 2003. Acoustic Monitoring of Marathon Canada Petroleum ULC 2003 Courland/Empire Seismic Program. Marathon Canada Petroleum ULC, by JASCO Research Ltd.
- Bartol, S.M., J.A. Musick, and M.L. Lenhardt. 1999. Auditory evoked potentials of the loggerhead sea turtle (*Caretta caretta*). *Copeia* 1999(3): 836-840.
- Blackwell, S.B., and C.R. Greene, Jr. 2002. Acoustic measurements in Cook Inlet, Alaska, during August 2001. Report prepared by Greeneridge Sciences, Inc., Aptos and Santa Barbara, CA for the National Marine Fisheries Service, Anchorage, AK. 42pp.
- Brooks, G.R. and L.J. Doyle, 1998. Recent sedimentary development of Tampa Bay, Florida: A microtidal estuary incised into Tertiary platform carbonates. *Estuaries*, Vol. 21, No. 3, pp. 391-406.
- Collins, M.D., R.J. Cederberg, D.B. King, and S.A. Chin-Bing. 1996. Comparison of algorithms for solving parabolic wave equations. *J. Acoust. Soc. Am.* 100(1): 178-182.
- Coppens, A.B. 1981. Simple equations for the speed of sound in Neptunian waters. *Journal of the Acoustical Society of America* 69:862-863.
- Crandall, C. 2007. Hydrogeologic settings and ground-water flow simulation of the Northern Tampa Bay Regional Study Area, Florida, section 5 of Paschke, S.S., ed., Hydrogeologic settings and ground-water flow simulations for regional studies of the transport of anthropogenic and natural contaminants to public-supply wells—studies begun in 2001: Reston, Va., U.S. Geological Survey Professional Paper 1737-A, pp. 5-1 – 5-30.
- Divins, D.L., and D. Metzger. NGDC Coastal Relief Model. Retrieved October, 2007. <http://www.ngdc.noaa.gov/mgg/coastal/costal.html>
- Edgar, T. 2002. Research Vessel Marion Dufresne Cores Tampa Bay, Florida. Sound Waves Monthly Newsletter, September 2002.
- Gerstein, E.R., L. Gerstein, S.E. Forsythe, and J.E. Blue. 1999. The underwater audiogram of the West Indian manatee (*Trichechus manatus*). *J. Acoust. Soc. Am.* 105(6): 3575-3583.
- Gerstein, E.R., 2002. Manatees, bioacoustics and boats. *American Scientist* 90(2): 154.
- Greene, C.R., Jr. 1987. Characteristics of oil industry dredge and drilling sounds in the Beaufort Sea. *J. Acoust. Soc. Am.* 82(4): 1315-1324.
- Greene, C.R., Jr. 1997. Physical acoustics measurements. p. 3-1 to 3-63 *In*: W.J. Richardson (ed.), Northstar marine mammal monitoring program, 1996: marine mammal and acoustical monitoring of a seismic program in the Alaskan Beaufort Sea. LGL Rep. 2121-2. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for BP Explor. (Alaska) Inc., Anchorage, AK, and Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 245 p.
- Hamilton, E.L. 1980. Geoacoustic modeling of the sea floor. *J. Acoust. Soc. Am.* 68(5). 1313-1340.
- Hine, A.C., G.R. Brooks, R.A. Davis, Jr., L.J. Doyle, G. Gelfenbaum, S.D. Locker, D.C. Twichell, and R.H. Weisberg. 2001. A Summary of Findings of the West-Central Florida Coastal Studies Project. USGS Open File Report 01-303, <http://pubs.usgs.gov/of/2001/of01-303/index.html>.

- LGL Limited and JASCO Research Limited. 2005. Assessment of the Effects of Underwater Noise from the Proposed Neptune LNG Project. October 12, 2005.
- Locker, S.D., G.R. Brooks, R.A. Davis, A.C. Hine, and G. Gelfenbaum. 1999. West-Central Florida Coastal Transect # 6: Anna Maria Island. U.S. Geological Survey Open-File Report 99-510.
- MacGillivray, A.O., M.M. Zykov, and D.E. Hannay. 2007. Chapter 3: Summary of Noise Assessment; in Marine Mammal Monitoring and Mitigation During Open Water Seismic Exploration by ConocoPhillips Alaska, Inc. in the Chukchi Sea July-October 2006. Report by LGL Alaska Research Associates and JASCO Research Ltd. January.
- Malme, C.I., P.W. Smith, and P.R. Miles. 1986. Characterisation of geophysical acoustic survey sounds. Prepared by BBN Laboratories Inc., Cambridge, for Battelle Memorial Institute to the Minerals Management Service, Pacific Outer Continental Shelf Region, Los Angeles, CA.
- McCauley, R.D., M.-N. Jenner, C. Jenner, K.A. McCabe, and J. Murdoch. 1998. The response of humpback whales (*Megaptera novaeangliae*) to offshore seismic survey noise: preliminary results of observations about a working seismic vessel and experimental exposures. APPEA J.—Austral. Petrol. Prod. & Explor. Assoc. J. 38: 692-707.
- Miller, J.H., A.E. Bowles, B.L. Southall, R.L. Gentry, W.T. Ellison, J.J. Finneran, C.R. Greene Jr., D. Kastak, D.R. Ketten, P.L. Tyack, P.E. Nachtigall, W.J. Richardson and J.A. Thomas. 2005. Strategies for weighting exposure in the development of acoustic criteria for marine mammals. Journal of the Acoustical Society of America 118:2019 (Abstract). Presentation available at: [http://www.oce.uri.edu/faculty\\_pages/miller/Noise\\_Weighting\\_10\\_18\\_2005.ppt](http://www.oce.uri.edu/faculty_pages/miller/Noise_Weighting_10_18_2005.ppt).
- Mitson, R.B., Ed. (1995). Underwater Noise of Research Vessels: Review and Recommendations. ICES Cooperative Research Report No. 209, 61.
- Moein, S.E. 1994. Auditory evoked potentials of the loggerhead sea turtle (*Caretta caretta*) M.Sc. Thesis, School of Marine Science, College of William and Mary, Virginia.
- Ocean Specialists, Inc. 2007. Hoegh LNG Port Dolphin Offshore Pipeline Construction Method Statement. Report, Revision #8. November 23, 2007.
- Phillips, R., C. Niezrecki, and D.O. Beusse. 2006. Theoretical detection ranges for acoustic based manatee avoidance technology. J. Acoust. Soc. Am. 120(1): 153-163.
- Richardson, W.J., C.R. Greene, Jr., C.I. Malme, and Denis H. Thomson. 1995. Marine Mammals and Noise. Academic Press, San Diego, CA, 576pp.
- Ridgway, S.H., E.G. Wever, J.G. McCormick, J. Palin, and J.H. Anderson. 1969. Hearing in the giant sea turtle, *Chelonia mydas*. Proceedings of the National Academy of Sciences 64(3): 884-890.
- Seol, H., B. Jung, J.C. Suh, and S. Lee. 2002. Prediction of non-cavitating underwater propeller noise. Journal of Sound and Vibration 257(1): 131-156.
- Shooter, J.A., T.E. DeMary, and R.A. Koch. 1982. Ambient Noise in the Western Gulf of Mexico. ADA-114126, Applied Research Laboratories, Texas University at Austin, 35 pp.
- Sponagle, N. 1988. Variability of ship noise measurements. DREA Technical Memorandum 88/210, 38pp.
- Teague, W. J., M. J. Carron, and P. J. Hogan. 1990. A comparison between the generalized digital environmental model and Levitus climatologies. J. Geophys. Res., 95(C5), 7167–7183.
- Thorne, P.D. 1990. Seabed generation of ambient noise. Journal of the Acoustical Society of America 87(1): 149-153.

USGS. 2007. Tampa Bay Study: Data: Sediment Cores.

[http://gulfsci.usgs.gov/tampabay/data/3\\_sedcore/index.html](http://gulfsci.usgs.gov/tampabay/data/3_sedcore/index.html), accessed November 2007.

Zhang, Z. and C. Tindle. 1995. Improved equivalent fluid approximations for a low shear speed ocean bottom. J. Acoust. Soc. Am. 98, 3391-3396.

## **Appendix A: Source Levels**

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## SOURCE LEVELS

The third-octave band source levels input to the acoustic propagation model for various pieces of equipment are listed in Table 16 through Table 18 below. Their use is discussed further in Section 2.

Table 16: Third-octave band source levels for vessels involved in construction-related modeling scenarios (see Section 2.2). Source depths are 2.2 m and 3 m for the Castoro II and Britoil 51, respectively.

Frequency (Hz)	Castoro II (barge), anchor operations	Castoro II (barge), pipe laying	Britoil 51 (tug), anchor operations	Britoil 51 (tug), transiting
10	175.6	164.7	202.8	188.7
12.5	170.0	166.2	196.5	182.7
16	162.7	162.7	193.1	174.1
20	158.3	165.5	191.1	167.5
25	151.8	169.0	196.7	165.2
31.5	149.1	159.6	188.8	172.2
40	146.6	156.2	177.3	182.2
50	147.9	157.7	176.4	170.2
63	153.3	154.3	179.2	167.1
80	153.2	152.2	178.8	164.9
100	156.4	153.0	178.1	161.8
125	162.2	159.8	176.7	166.0
160	155.6	152.5	175.9	167.6
200	151.4	149.8	173.5	167.5
250	151.7	152.2	178.8	164.8
315	143.6	142.4	172.8	165.2
400	145.2	147.2	165.4	165.2
500	145.8	144.8	170.7	169.8
630	145.5	142.7	168.8	159.9
800	150.5	147.5	165.1	158.6
1000	150.8	148.7	164.2	163.6
1250	142.7	141.7	167.3	161.0
1600	138.6	136.1	165.9	164.9
2000	143.2	139.3	166.5	164.2
<b>Broadband</b>	<b>177.2</b>	<b>173.9</b>	<b>205.2</b>	<b>190.8</b>

Table 17: Third-octave band source levels for non-vessel activities involved in construction-related modeling scenarios (see Section 2.2). Source depth for the impact hammer is half the local water depth; source depth for the dredge is 2.2 m.

<b>Frequency (Hz)</b>	<b>Impact hammer</b>	<b>Aquarius dredge</b>
10	202.0	153.0
12.5	202.0	153.0
16	192.0	153.0
20	187.0	153.0
25	184.0	165.0
31.5	186.0	162.0
40	188.0	169.0
50	184.0	172.0
63	188.0	171.0
80	198.0	172.0
100	200.0	179.0
125	204.0	178.0
160	208.0	180.0
200	209.5	179.0
250	209.0	177.0
315	204.0	177.0
400	204.5	176.0
500	205.0	173.0
630	198.0	170.0
800	195.0	169.0
1000	194.0	169.0
1250	195.0	169.0
1600	194.0	169.0
2000	192.0	169.0
<b>Broadband</b>	<b>216.2</b>	<b>187.7</b>

Table 18: Third-octave band source levels for operational modeling scenarios (see Section 2.2). Source levels for docking include main SRV propulsion at dead slow, two bow thrusters, and one stern thruster. Source depth is 6 m in all cases.

<b>Frequency (Hz)</b>	<b>SRV, full speed transit</b>	<b>SRV, half speed transit</b>	<b>SRV, docking</b>
10	171.0	162.4	171.5
12.5	171.0	162.4	171.5
16	171.0	162.4	171.5
20	171.0	162.4	171.5
25	171.0	162.4	171.5
31.5	171.0	162.4	171.5
40	171.0	162.4	171.5
50	171.0	162.4	171.5
63	171.0	162.4	171.5
80	171.0	162.4	171.5
100	171.0	162.4	171.5
125	169.1	160.5	169.6
160	167.0	158.4	167.4
200	165.0	156.4	165.5
250	163.1	154.5	163.6
315	161.1	152.5	161.6
400	159.0	150.4	159.5
500	157.1	148.5	157.5
630	155.1	146.5	155.5
800	153.0	144.4	153.5
1000	151.0	142.4	151.5
1250	149.1	140.5	149.6
1600	147.0	138.4	147.4
2000	145.0	136.4	145.5
<b>Broadband</b>	<b>182.1</b>	<b>173.5</b>	<b>182.6</b>



## **Appendix B: Sound Maps**

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## SOUND MAPS

Sound field maps are shown below for each of the scenarios described in Section 2 (see summaries in Table 1 and Figure 1). At each point within the sound field, maximum sound levels are selected over all modeled depths, down to the local bottom depth. In the case of the impact hammer, which is an impulsive source,  $SPL_{RMS}$  values were estimated from the SEL values output by the model by the addition of 10 dB (see Section 3.1). Model results are discussed further in Section 5.

### Buoy Installation

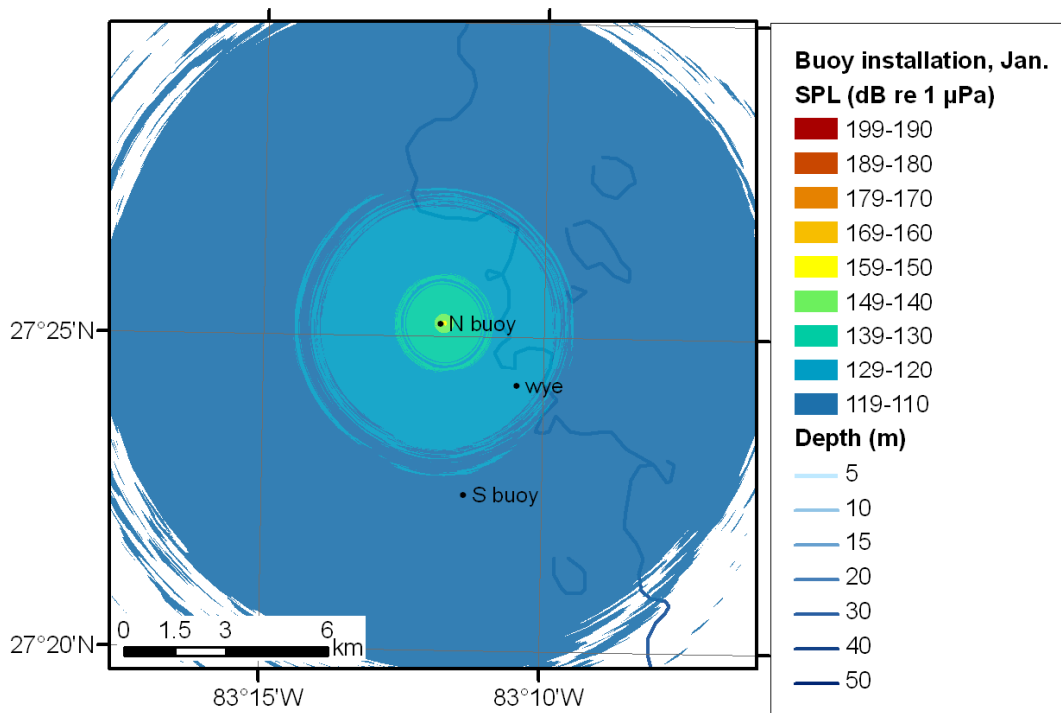


Figure 8: Estimated received sound levels for activities related to installation of the north anchor buoy (see Table 1, Section 2.2.1).

## Impact Hammering

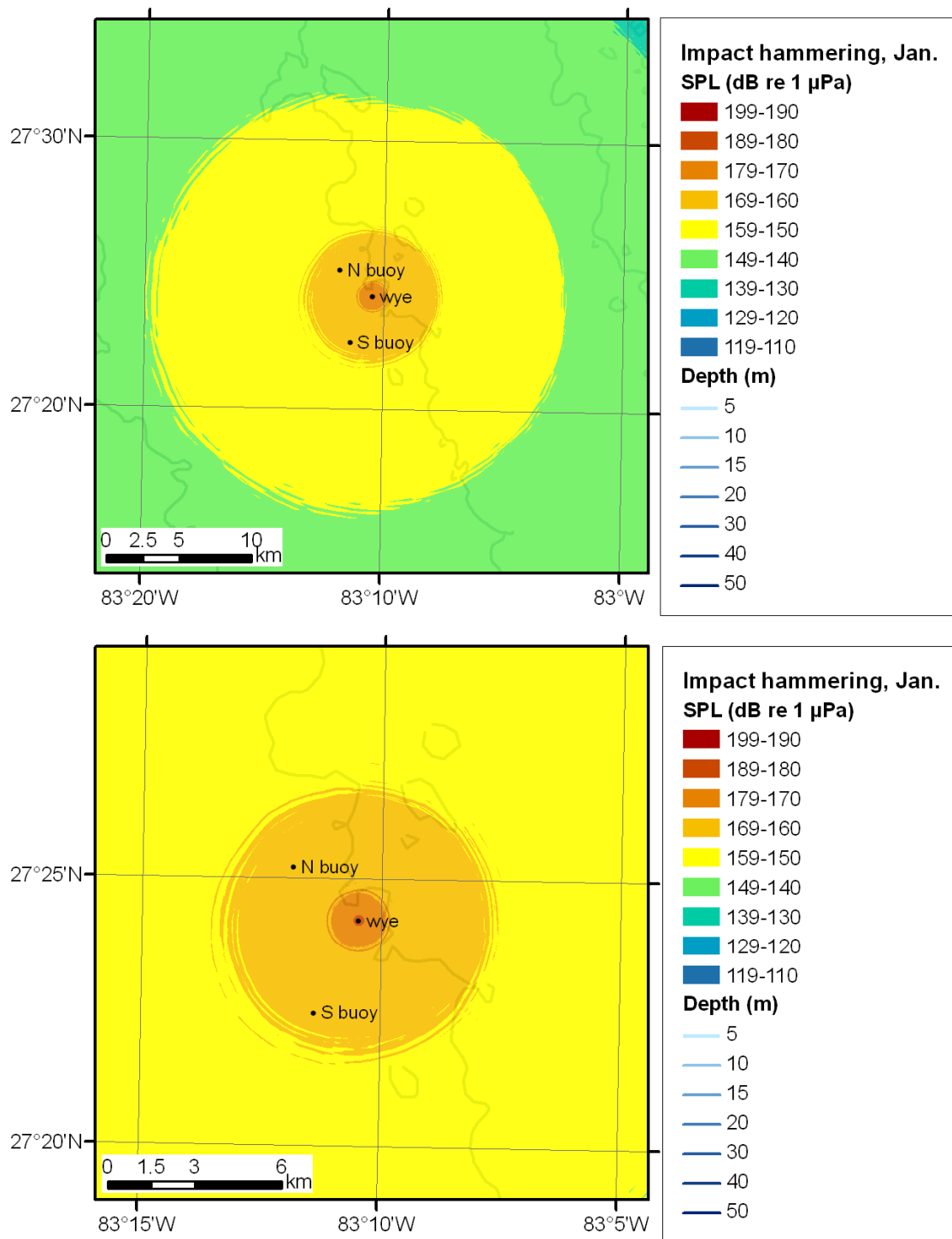


Figure 9: Estimated received sound levels for impact hammering at the piggable wye (see Table 1, Section 2.2.2). The lower panel is a zoomed-in (2x) version of the upper panel.

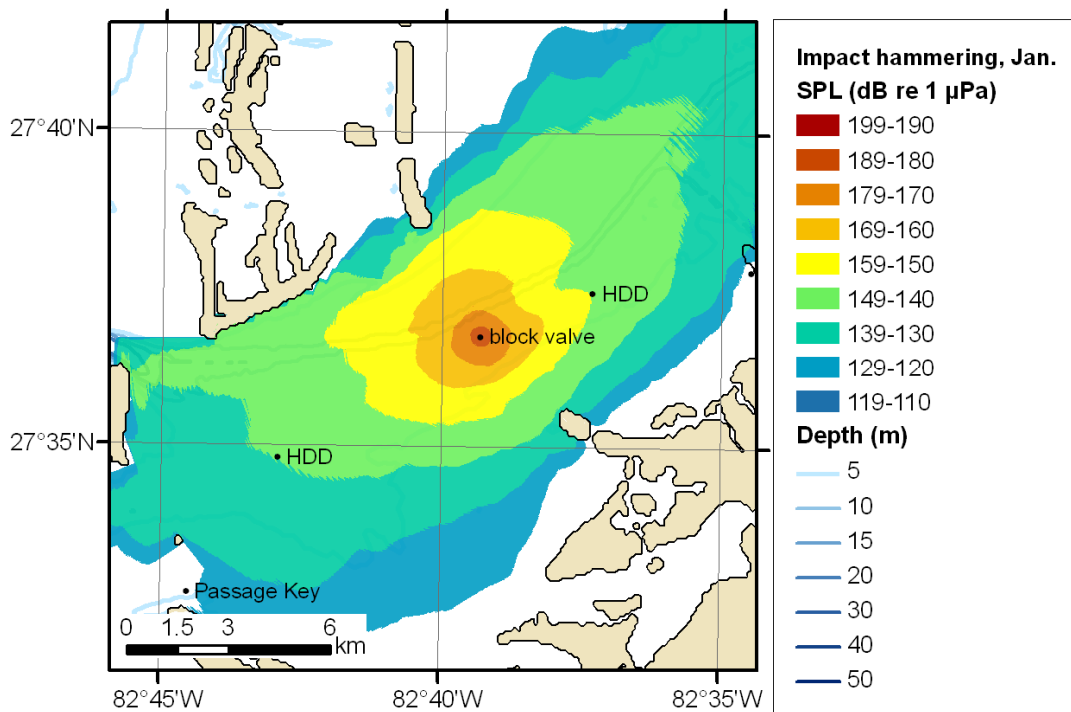


Figure 10: Estimated received sound levels for impact hammering at the subsea block valve (see Table 1, Section 2.2.2).

## Pipe Laying

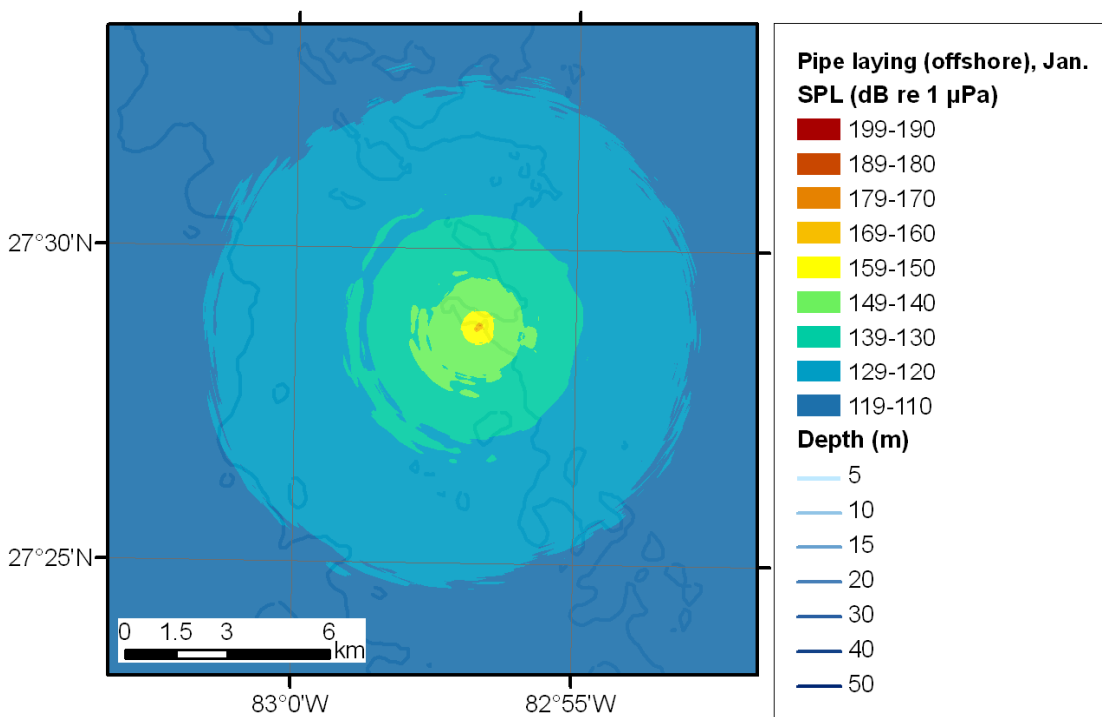


Figure 11: Estimated received sound levels for offshore pipe laying (see Table 1, Section 2.2.3).

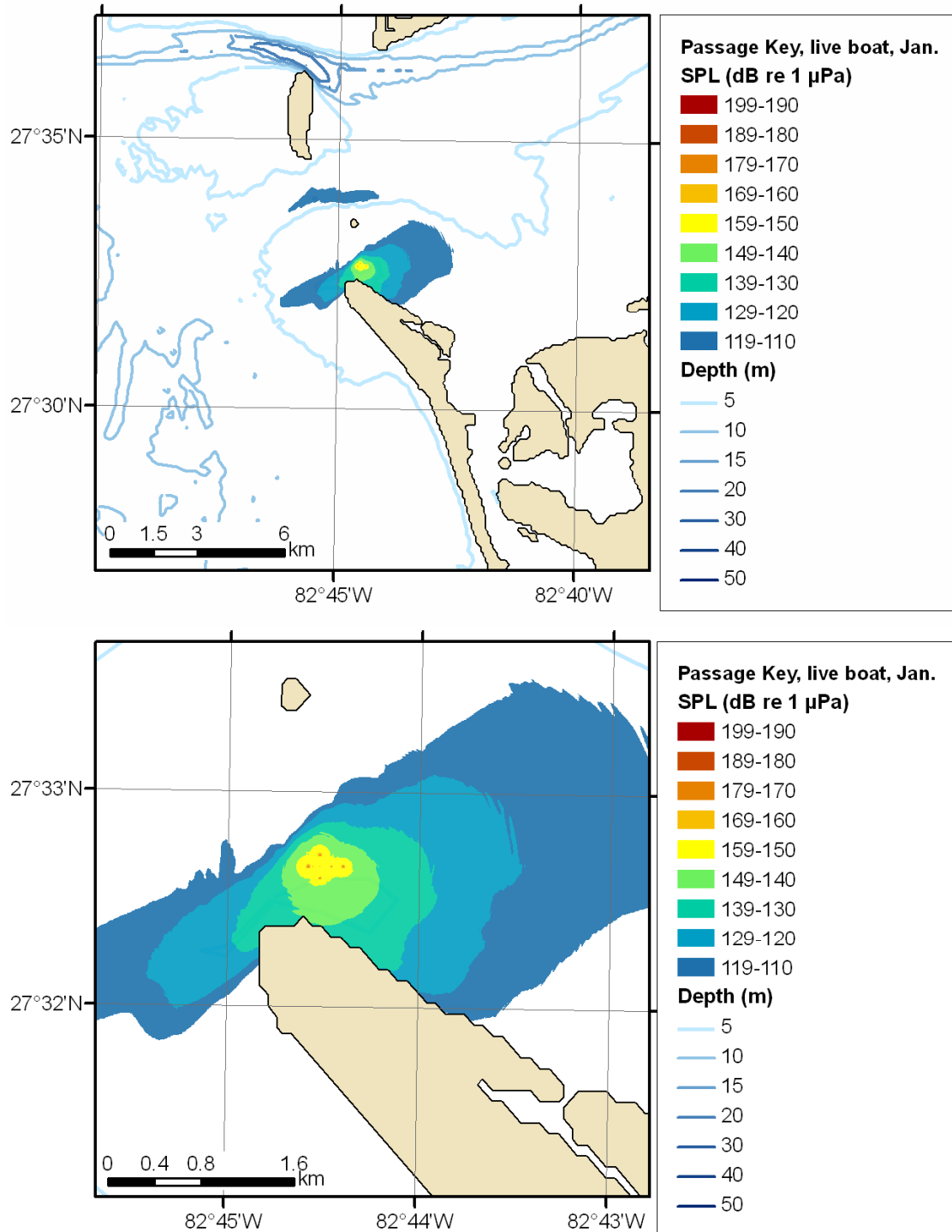


Figure 12: Estimated received sound levels for pipe laying in Passage Key (see Table 1, Section 2.2.3). The lower panel is a zoomed-in version of the upper panel.

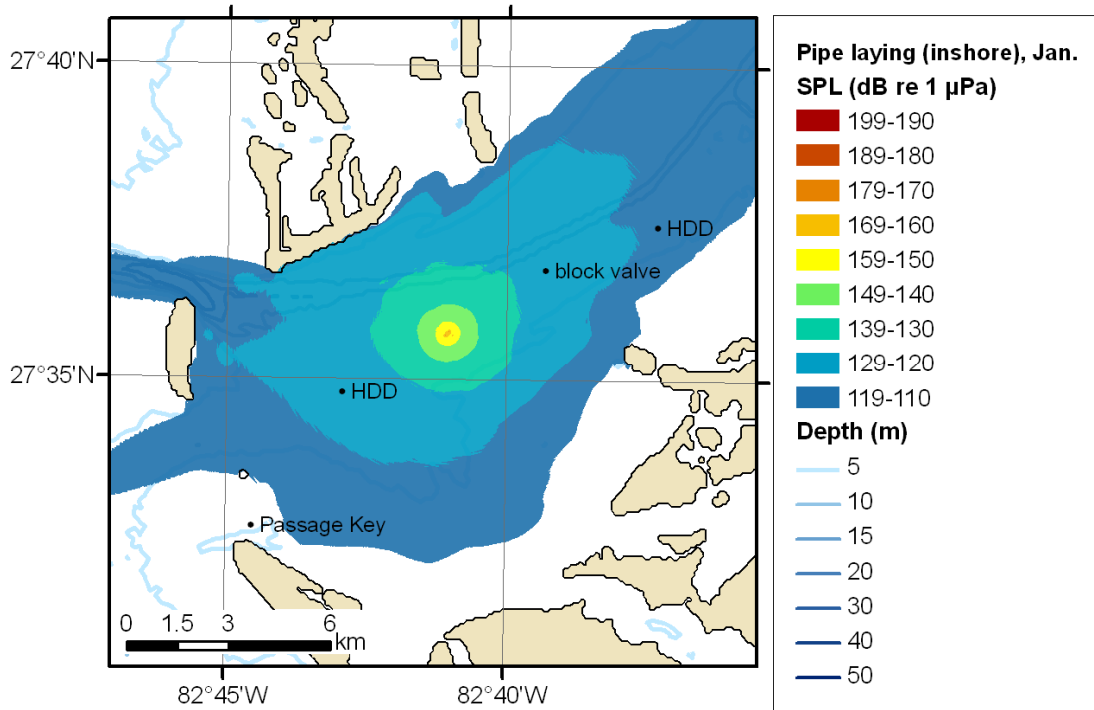


Figure 13: Estimated received sound levels for inshore pipe laying (see Table 1, Section 2.2.3).

## Pipe Burial

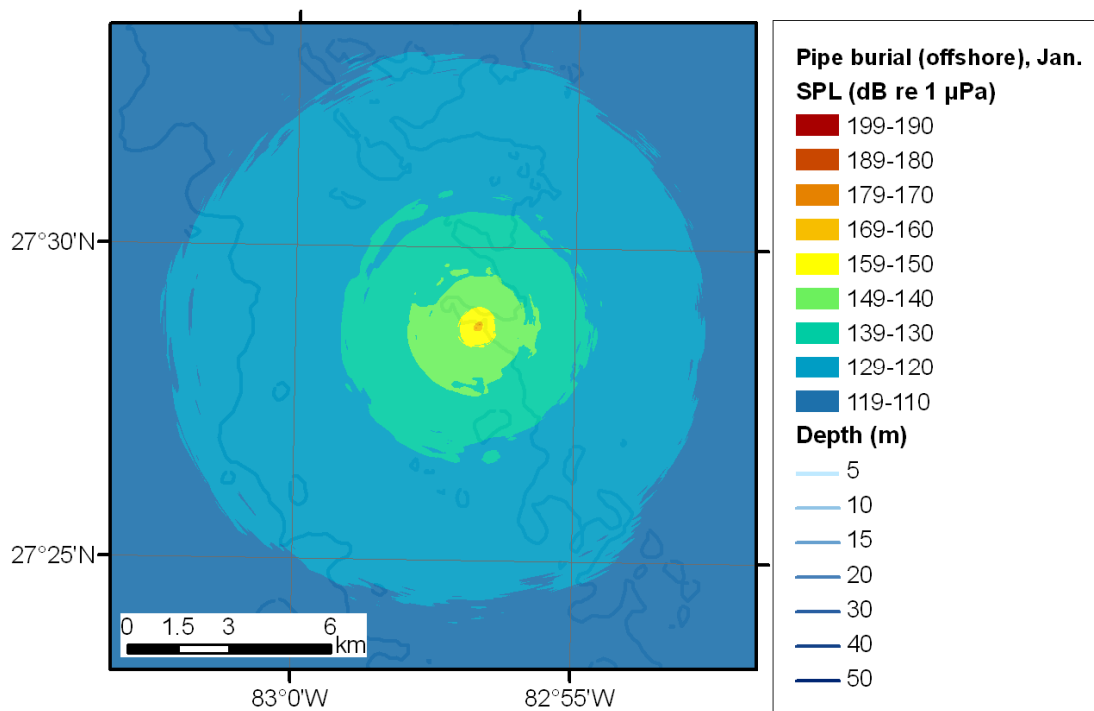


Figure 14: Estimated received sound levels for offshore pipe burial (see Table 1, Section 2.2.4).

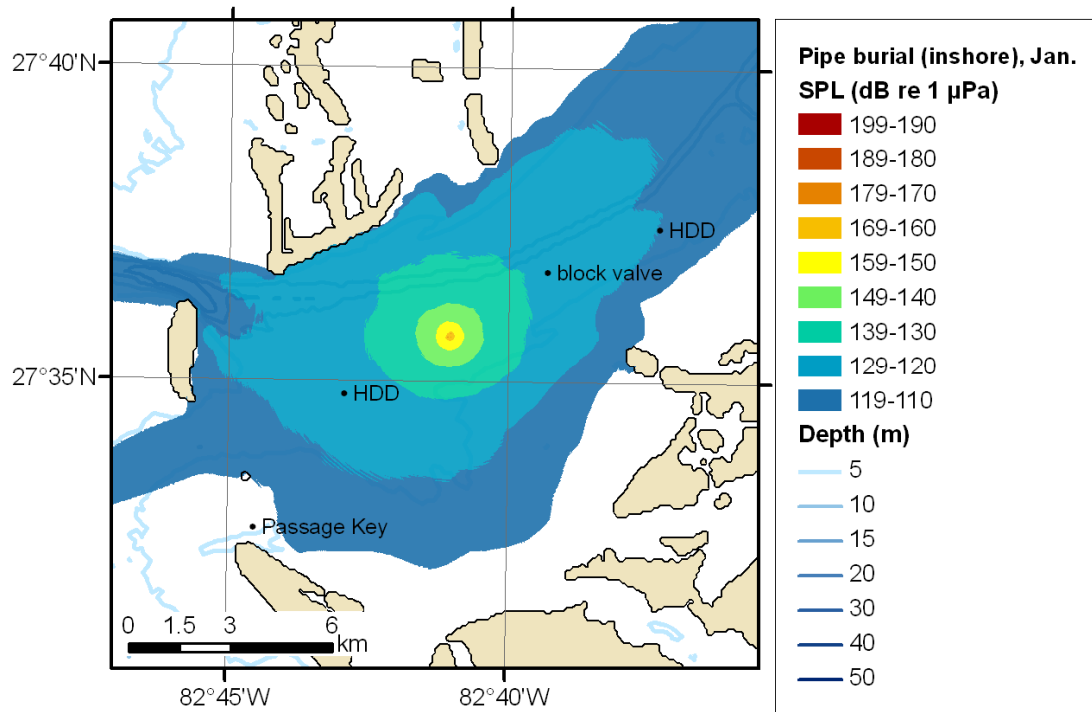


Figure 15: Estimated received sound levels for inshore pipe burial (see Table 1, Section 2.2.4).

## Operational Scenarios

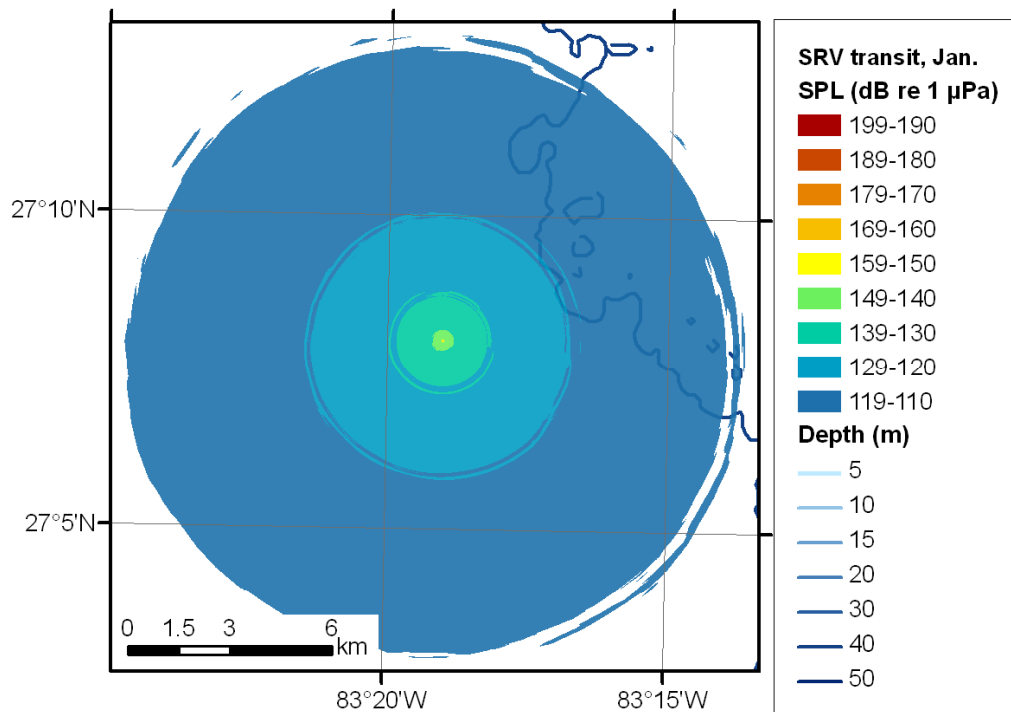


Figure 16: Estimated received sound levels for SRV transit (see Table 1, Section 2.2.5).

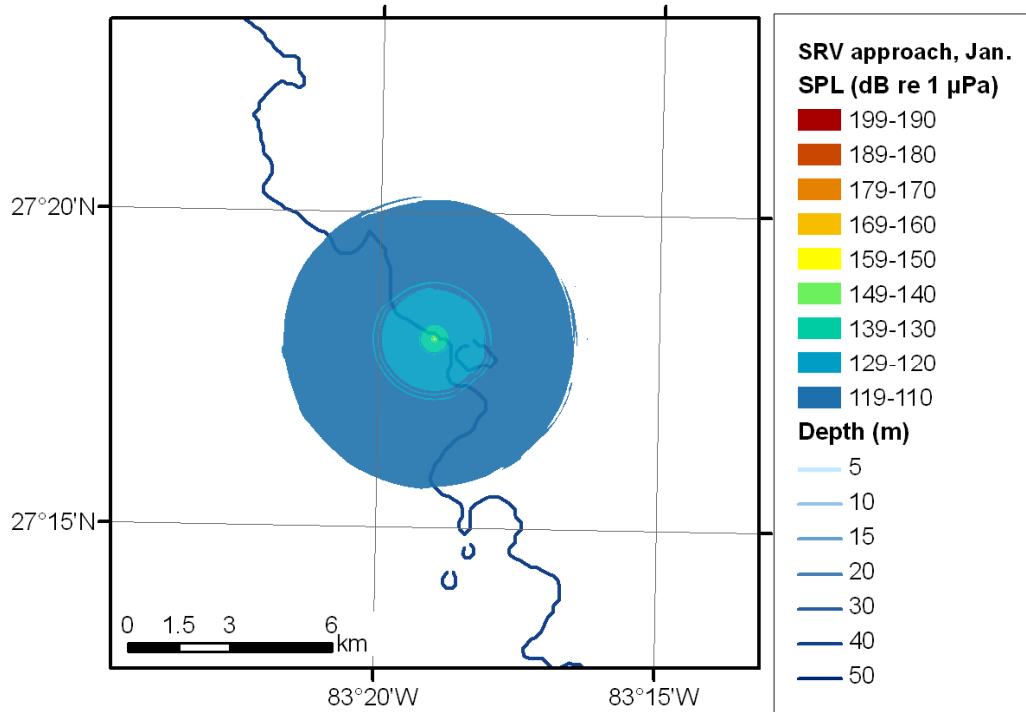


Figure 17: Estimated received sound levels for SRV approach (see Table 1, Section 2.2.5).

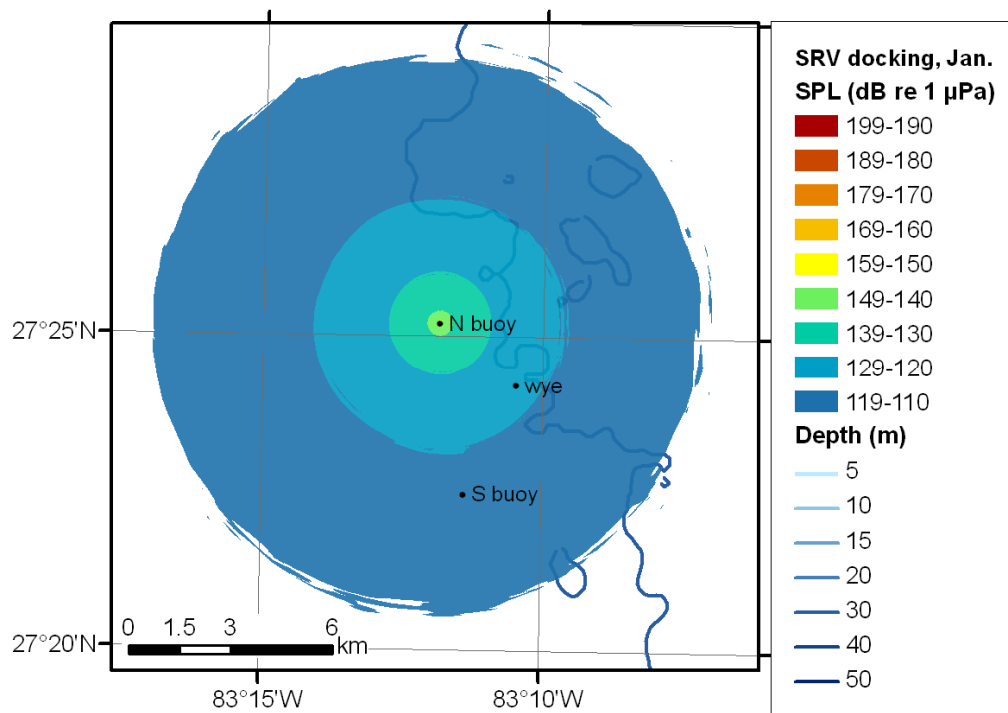


Figure 18: Estimated received sound levels for SRV docking (see Table 1, Section 2.2.5).



## **Appendix C: LGL Marine Mammal Impact Report**

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# **ASSESSMENT OF THE EFFECTS OF UNDERWATER NOISE FROM THE PROPOSED PORT DOLPHIN ENERGY LNG DEEP WATER PORT PROJECT**

By



for

**CSA International, Inc.**

8502 SW Kansas Ave

Stuart, FL 34997

772-219-3000

LGL Report No. TA4606

23 January 2008

# **ASSESSMENT OF THE EFFECTS OF UNDERWATER NOISE FROM THE PROPOSED PORT DOLPHIN ENERGY LNG DEEP WATER PORT PROJECT**

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## **ASSESSMENT OF THE EFFECTS OF UNDERWATER NOISE FROM THE PROPOSED PORT DOLPHIN LNG PROJECT**

The details of the proposed Port Dolphin LNG project are discussed elsewhere in this application. The relevant aspects are summarized later in this assessment. The proposed project activities during construction and operation will introduce noise into the water column, which may affect marine animals. The potential for those effects to occur and their significance are addressed in this assessment.

Two groups of marine animals are considered: marine mammals (toothed whales and Florida manatees) and sea turtles. The assessment consists of four parts. (1) The first part of the assessment summarizes other parts of the Application that discuss species and numbers in each group that are present in the area likely to be influenced by the project. This is followed by (2) a review of the known effects of the types of noise emanating from the Port Dolphin project based on information from other studies. Part (3) refers to an acoustic analysis of the source levels of the various project noises followed by modelling of the propagation of the noises out from the source. Finally, (4) the propagation results are combined with the animal density data to determine the numbers of animals that might be exposed to the noise. This is followed by an assessment of potential effects based on the known responses of these animals as determined in other studies.

### **(1) Numbers and Species of Animals Present**

A detailed analysis of the marine mammals and sea turtles that occur in the northeastern Gulf of Mexico is presented in Chapter 4 of Volume II of this Deepwater Port License Application. The data in that section are used as the basis for the assessment of the effects of underwater noise in the following sections.

From Chapter 4. Three marine mammals are most likely to occur in the project area. Bottlenose dolphins and Atlantic spotted dolphins are likely to be present in continental shelf and coastal waters, including the STL buoy locations and along the pipeline route. The Florida manatee occurs primarily in coastal waters within Tampa Bay and would not be expected to occur at the STL buoy locations or along open water, offshore portions of the pipeline route. The Florida manatee is an endangered species, whereas the bottlenose dolphin and Atlantic spotted dolphin are not endangered or threatened. The cetacean fauna of the northern Gulf of Mexico's continental shelf, including the project area, typically consists of the bottlenose dolphin and the Atlantic spotted dolphin (Davis et al. 1998; Davis et al. 2000). Along the shelf edge and within the deeper waters of the continental slope, the cetacean community typically includes 19 species.

In addition to marine mammals, there are five species of marine or sea turtles that occur in the eastern Gulf of Mexico: loggerhead, green, hawksbill, Kemp's ridley, and leatherback.

Relevant aspects of the hearing capabilities and the known responses to underwater noise for the key species are discussed in the next section.

## **(2) Known Effects of Underwater Noise from Project Activities**

### **Marine Mammals**

Marine mammals rely heavily on the use of underwater sounds to communicate and gain information about their environment. The reactions of marine mammals to noise can be variable and depend on the species involved, time of year, and the activity of the animal at the time of exposure to noise. Because underwater noise sometimes propagates for long distances, the radius of audibility can be large for a strong noise. However, marine mammals usually do not respond overtly to audible, but weak, man-made sounds (Richardson et al. 1995). Thus, the zone of "responsiveness" is usually much smaller than the zone of audibility. Potential effects of noise on marine mammals include masking, disturbance (behavioral), hearing impairment (temporary threshold shift [TTS] and permanent threshold shift [PTS]), and non-auditory physiological effects.

### **Masking**

Masking is the obscuring of sounds of interest by other sounds, often at similar frequencies. Marine mammals are highly dependent on sound, and their ability to recognize sound signals amid noise is important in communication, predator and prey detection, and, in the case of toothed whales, echolocation.

Even in the absence of man-made sounds, the sea is usually noisy. Background ambient noise often interferes with or masks the ability of an animal to detect a sound signal even when that signal is above its absolute hearing threshold. Natural ambient noise includes contributions from wind, waves, precipitation, other animals, and (at frequencies above 30 kHz) thermal noise resulting from molecular agitation (see Chapter 5 of Richardson et al. 1995). Background noise can also include sounds from distant human activities such as shipping. This is particularly true in the Tampa Bay area where there is heavy ship and boat traffic. Masking of natural sounds can result when human activities produce high levels of background noise. Conversely, if the background level of underwater noise is high (e.g., on a day with strong wind and high waves), an anthropogenic noise source will not be detectable as far away as would be possible under quieter conditions, and will itself be masked. Ambient noise is highly variable on continental shelves (e.g., Thompson 1965; Myrberg 1978; Chapman et al. 1998; Desharnais et al. 1999). This inevitably results in a high degree of variability in the range at which marine mammals can detect anthropogenic sounds.

Although masking is a natural phenomenon to which marine mammals must be adapted, introduction of strong sounds into the sea at frequencies important to marine mammals will inevitably increase the severity and the frequency of occurrence of masking. For example, if a baleen whale is exposed to continuous low-frequency noise from an industrial source, this will reduce the size of the area around that whale within which it will be able to hear the calls of

another whale. In general, little is known about the importance to marine mammals of detecting sounds from conspecifics, predators, prey, or other natural sources. In the absence of much information about the importance of detecting these natural sounds, it is not possible to predict the impacts if mammals are unable to hear these sounds as often, or from as far away, because of masking by industrial noise (Richardson et al. 1995). In general, masking effects are expected to be less severe when sounds are transient than when they are continuous. Also, human-induced masking is likely to be less severe for species that hear best at higher frequencies (e.g. dolphins) than for baleen whales that hear best at the low frequencies dominated by industrial sounds.

Although some degree of masking is inevitable when high levels of man-made broadband sounds are introduced into the sea, marine mammals have evolved systems and behavior that function to reduce the impacts of masking. Structured signals such as the echolocation click sequences of small toothed whales may be readily detected even in the presence of strong background noise because their frequency content and temporal features usually differ strongly from those of the background noise (Au and Moore 1988; 1990). It is primarily the components of background noise that are similar in frequency to the sound signal in question that determine the degree of masking of that signal. Low-frequency industrial noise, such as shipping, has little or no masking effect on high-frequency echolocation sounds. Redundancy and context can also facilitate detection of weak signals. These phenomena may help marine mammals detect weak sounds in the presence of natural or man-made noise.

Most masking studies in marine mammals present the test signal and the masking noise from the same direction. The sound localization abilities of marine mammals suggest that, if signal and noise come from different directions masking would not be as severe as the usual types of masking studies might suggest (Richardson et al. 1995). The dominant background noise may be highly directional if it comes from a particular anthropogenic source such as a ship or industrial site. Directional hearing may significantly reduce the masking effects of these noises by improving the effective signal-to-noise ratio. In the cases of high-frequency hearing by the bottlenose dolphin (*Tursiops truncatus*), beluga whale (*Delphinapterus leucas*), and killer whale (*Orcinus orca*), empirical evidence confirms that masking depends strongly on the relative directions of arrival of sound signals and the masking noise (Penner et al. 1986; Dubrovskiy 1990; Bain et al. 1993; Bain and Dahlheim 1994).

Toothed whales, and probably other marine mammals as well, have additional capabilities besides directional hearing that can facilitate detection of sounds in the presence of background noise. There is evidence that some toothed whales can shift the dominant frequencies of their echolocation signals from a frequency range with much ambient noise toward frequencies with less noise (Au et al. 1974, 1985; Moore and Pawloski 1990; Thomas and Turl 1990; Romanenko and Kitain 1992; Lesage et al. 1999). A few marine mammal species are known to increase the source levels of their calls in the presence of elevated sound levels (Dahlheim 1987; Au 1993; Lesage et al. 1999; Terhune 1999).

These data demonstrating adaptations for reduced masking pertain mainly to the very high-frequency echolocation signals of toothed whales. There is less information about the existence of corresponding mechanisms at moderate or low frequencies, or in other types of marine



mammals. For example, Zaitseva et al. (1980) found that, for the bottlenose dolphin, the angular separation between a sound source and a masking noise source had little effect on the degree of masking when the sound frequency was 18 kHz, in contrast to the pronounced effect at higher frequencies. Directional hearing has been demonstrated at frequencies as low as 0.5-2 kHz in several marine mammals, including killer whales (see Section 8.4 in Richardson et al. 1995). This ability may be useful in reducing masking at these frequencies.

In summary, high levels of noise generated by anthropogenic activities may act to mask the detection of weaker biologically important sounds by some marine mammals. This masking would be more prominent for lower frequencies. For higher frequencies, such as used in echolocation by toothed whales, several mechanisms are available that may allow them to reduce the effects of such masking.

### **Disturbance**

Disturbance can induce a variety of effects, such as subtle changes in behavior, more conspicuous dramatic changes in activities, and displacement. Disturbance is one of the main concerns of the potential impacts of man-made noise on marine mammals. Behavioral reactions of marine mammals to sound are difficult to predict because they are dependent on numerous factors including species, state of maturity, experience, current activity, reproductive state, time of day, and weather state. If a marine mammal does react to an underwater sound by changing its behavior or moving a small distance, the impacts of that change may not be important to the individual, the stock, or the species as a whole. However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on the animals could be important.

Based on the literature reviewed in Richardson et al. (1995), it is apparent that most small and medium-sized toothed whales exposed to prolonged or repeated, underwater sounds are unlikely to be displaced unless the overall received level is at least 140 dB re 1  $\mu$ Pa. The limited available data indicate that the sperm whale (*Physeter macrocephalus*) is sometimes, though not always, more responsive than other toothed whales. Baleen whales probably have better hearing sensitivities at lower sound frequencies, and in several studies have been shown to react at received sound levels of approximately 120 dB re 1  $\mu$ Pa.

Toothed whales appear to exhibit a greater variety of reactions to man-made underwater noise than do baleen whales. Toothed whale reactions can vary from approaching vessels (e.g., to bow ride) to strong avoidance.

### **Hearing Impairment**

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds. The minimum sound level necessary to cause permanent hearing impairment is higher, by a variable and generally unknown amount, than the level that induces barely detectable temporary hearing loss or temporary threshold shift (TTS). The level associated with the onset of TTS is often considered to be a level below which there is no danger of permanent damage. Current NMFS policy regarding exposure of marine mammals to high-

level sounds is that cetaceans should not be exposed to impulsive sounds exceeding 180 and 190 dB re 1  $\mu$ Pa (rms), respectively (NMFS 2000).

### **Temporary Threshold Shift**

TTS is the mildest form of hearing impairment. It is the process whereby exposure to strong sound results in a non-permanent elevation in hearing threshold making it more difficult to hear sounds (Kryter 1985). TTS can last from minutes or hours to days. The magnitude of the TTS depends on the level and duration of the noise exposure, among other considerations (Richardson et al. 1995). For sound exposures at or somewhat above the TTS level, hearing sensitivity recovers rapidly after exposure to the noise ends. TTS commonly occurs in mammals, including humans.

Only a few data on sound levels and durations necessary to elicit mild TTSs have been obtained for marine mammals, and all of these data are quite recent. TTS studies in humans and terrestrial mammals provide information helpful in understanding general principles of TTS, but it is unclear to what extent these data can be extrapolated to marine mammals.

### **Permanent Threshold Shift**

There are no data on noise levels that might induce permanent hearing impairment in marine mammals. In theory, physical damage to a marine mammal's hearing apparatus could occur immediately if it is exposed to sound impulses that have very high peak pressures, especially if they have very short rise times. Also, very prolonged exposure to a noise strong enough to elicit a TTS, or shorter-term exposure to noise levels well above the TTS level, could cause hearing injury. Such damage can result in a permanent decrease in functional sensitivity of the hearing system at some or all frequencies. Richardson et al. (1995) hypothesized that permanent hearing impairment caused by prolonged exposure to continuous man-made noise is not likely to occur in marine mammals for sounds with source levels up to ~200 dB re 1  $\mu$ Pa-m.

Single or occasional occurrences of mild TTS do not cause permanent auditory damage in humans or other terrestrial mammals, and presumably do not do so in marine mammals. Sound impulse duration, peak amplitude, and rise time are the main factors thought to determine the onset and extent of PTS. Based on existing data, Ketten (1995) noted that the criteria for differentiating the sound pressure levels that result in a PTS (or TTS) are location and species specific. PTS effects may also be influenced strongly by the health of the receiver's ear.

For sound exposures at or somewhat above the TTS level, hearing sensitivity recovers rapidly after exposure to the noise ends. At least in terrestrial mammals, the received sound level from a single noise exposure must be far above the TTS level for there to be any risk of PTS (Kryter 1985, 1994; Richardson et al. 1995). Relationships between TTS and PTS levels have not been studied in marine mammals but are assumed to be similar to those in humans and other terrestrial mammals.

### **Non-Auditory Physiological Effects**

Non-auditory physiological effects may also occur in marine mammals exposed to very strong underwater sound. Possible types of non-auditory physiological effects or injuries that, in theory, might occur, include stress, neurological effects, bubble formation, resonance effects, and other types of organ or tissue damage. It is possible that some marine mammal species (i.e., beaked whales) may be especially susceptible to injury and/or stranding when exposed to strongly pulsed sounds, particularly at higher frequencies. None of the activities associated with the Port Dolphin project will generate sounds loud enough to cause physiological effects.

### **Marine Mammal Hearing**

Direct hearing measurements are available for only a few marine mammal species because of the difficulty of obtaining such measurements from free-living animals. The results of hearing studies in marine mammals that could occur in the Port Dolphin project area are presented below. It is generally thought that an animal's hearing range is likely to be related to the range of sounds that it produces. Evidence in support of this in marine mammals comes from the fact that the peak spectral frequencies of echolocation signals recorded in odontocetes are near the best frequencies of hearing for individuals of the same species for which behavioral audiograms have been recorded (Ketten 2000).

Odontocetes or toothed whales are considered to be high-frequency specialists, with peak spectra of their vocalizations ranging between 10 and 200 kHz (Ketten 2000). Most noise from the Port Dolphin project will be at low frequencies, well below the best hearing frequencies of the toothed whales. Hearing measurements have been made in several species of odontocete, including the bottlenose dolphin, which are rather well studied because of the availability of well-trained, captive individuals.

#### **Bottlenose Dolphin (*Tursiops truncatus*)**

The bottlenose dolphin was the first species of odontocete for which an audiogram was produced. Johnson (1967) measured the hearing sensitivity of a single 8- or 9-year old male bottlenose dolphin to frequencies ranging from 75 Hz to 150 kHz. That animal's greatest hearing sensitivity (45 dB re 1  $\mu$ Pa) was at about 50 kHz. Its hearing threshold at 75 Hz was 137 dB re 1  $\mu$ Pa and its hearing threshold at 150 kHz was 135 dB re 1  $\mu$ Pa, which was thought to be its effective upper frequency limit of hearing.

Au et al. (2002) measured the hearing sensitivity of a single 18-year-old female bottlenose dolphin using behavioral techniques and produced an audiogram remarkably similar to that of Johnson (1967). They also measured its hearing sensitivity to 2-second broadband signals with peak frequencies around 100 kHz, designed to simulate echoes from bottlenose dolphin echolocation signals. The measured hearing thresholds for these broadband signals were  $33.9 \pm 3.1$  dB re 1  $\mu$ Pa<sup>2</sup> for a unimodal stimulus and  $32.3 \pm 2.8$  dB re 1  $\mu$ Pa<sup>2</sup> for a bimodal stimulus, which were lower than those found using pure tone signals.

Turl (1993) measured the low-frequency hearing sensitivity of a bottlenose dolphin in the

frequency range of 50–300 Hz. That dolphin's hearing thresholds at 300 and 200 Hz were similar to those reported by others, with signal detection at sound pressure levels approximately 10–15 dB above the ambient noise level. However, for frequencies from 50–150 Hz, after a few trials, the dolphin's sensitivity suddenly improved and she was able to detect signals near the ambient noise level. Turl suggested that the dolphin was detecting particle velocity or some combination of pressure and velocity rather than the acoustic stimulus itself at lower frequencies.

An eastern Pacific bottlenose dolphin (*Tursiops* spp.) captured near Baja California, Mexico, was found to have maximum hearing sensitivities at 25 kHz (47 dB) and 50 kHz (46 dB) (Ljungblad et al. 1982). That dolphin responded reliably to signals in the range of 2–135 kHz but did not respond to 136- to 160-kHz signals at sound pressure levels up to 120 dB re 1  $\mu$ Pa.

Ridgway and Carder (1997) presented evidence of individual variation in the hearing sensitivities of eight (four male and four female) bottlenose dolphins. Three of the male dolphins (aged 23, 26, and 34 years) had lost sensitivity to 70-, 80-, 100-, and 120-kHz tones, and one female dolphin was insensitive to 100- and 120-Hz tones. They also reported on one 9-year-old female bottlenose dolphin who did not respond to any sound when measured behaviorally and electrophysiologically. She also was unable to vocalize. Brill et al. (2001) reported age-related hearing loss in a 33-year-old male bottlenose dolphin. That dolphin had lost sensitivity to frequencies >55 kHz and his right ear was 16–33 dB less sensitive than his left ear in the 10–40-kHz range.

#### **Atlantic Spotted Dolphin (*Stenella frontalis*)**

This species produces underwater sounds that range from 0.1 Hz to 8 kHz. They are also able to produce ultrasounds when using echolocation (Richardson et al. 1995). Echolocation clicks have two dominant frequency ranges at 40 to 50 kHz and 110 to 130 kHz, depending on source level (i.e., lower source levels typically correspond to lower frequencies and higher frequencies to higher source levels (Au and Herzing 2003). Echolocation click source levels as high as 210 dB re 1  $\mu$ Pa-m peak-to-peak have been recorded (Au and Herzing 2003). There are no hearing data for Atlantic spotted dolphins. However, similar to other toothed whales, they probably have good hearing sensitivity at moderate and high frequencies (8–90 kHz), with diminishing sensitivity at progressively lower frequencies, and relatively poor sensitivity to low frequency sounds.

#### **Florida Manatee (*Trichechus manatus*)**

Manatees swim slowly just below or at the surface of the water, and thus they are vulnerable to boat collisions. The West Indian manatee is capable of hearing sounds from 15 Hz to 46 kHz, with the best sensitivity at 6 to 20 kHz (Gerstein et al. 1999). The ability to detect high frequencies may be an adaptation to shallow water, where the propagation of low frequency sound is limited (Gerstein et al. 1999).

Manatees produce vocalizations from 0.6 to 12 kHz (dominant frequency range from 2 to 5 kHz), and last 0.18 to 0.9 sec (Richardson et al. 1995; Niezrecki et al. 2003; O'Shea and Pøche

2006). Recently, vocalizations below 100 Hz have also been recorded (Frisch and Frisch 2003). Average source levels for vocalizations range from 90 to 138 dB re 1  $\mu$ Pa (average: 100 to 112 dB) (Nowacek et al. 2003; Phillips et al. 2004).

### **Sea Turtle Hearing**

Little is known about sea turtle sound production and hearing or the dependency of turtles on sound for survival (Croll et al. 1999; Bartol and Ketten 2006). The majority of studies have looked at green (Ridgway et al. 1969) and loggerhead sea turtles (Bartol et al. 1999). More recently, auditory brainstem response hearing studies have been conducted on captive juvenile and subadult green and juvenile Kemp's ridley sea turtles (Bartol and Ketten 2006). These studies generally indicate that at least some species are capable of hearing low-frequency sounds (Ridgway et al. 1969; Lenhardt et al. 1983; Bartol et al. 1999), and that sensitivity appears to vary with age (Bartol and Ketten 2006). The range of maximal sensitivity for sea turtles is 100–800 Hz with an upper limit of about 1,000 Hz. Hearing below 80 Hz is apparently less sensitive but still potentially of use (Lenhardt 1994). Green turtles are most sensitive between 200 and 700 Hz, with peak sensitivity at 300–400 Hz with slight variation for juveniles and subadults, the latter based on a few individuals (Ridgway et al. 1969; Bartol and Ketten 2006). The overall range of green sea turtle hearing is reported at 60–1,000 Hz (Ridgway et al. 1969). Juvenile loggerheads were reported to have a hearing range of 250–1,000 Hz (Bartol et al. 1999). Loggerheads avoid sources of low-frequency sound in the 25–1,000 Hz range (O'Hara and Wilcox 1990). Two juvenile Kemp's ridley turtles generally had a lower upper range and lower range of sensitivity compared to what is known for green and loggerhead sea turtles. Sounds emitted by female leatherback turtles when nesting were in the 300–500 Hz range (Mrosovsky 1972).

Bartol et al. (1999) tested the hearing of juvenile loggerhead sea turtles. Those authors used a standard electrophysiological method (auditory brainstem response, ABR) to determine the response of the sea turtle ear to two types of vibrational stimuli: (1) brief, low-frequency broadband clicks, and (2) brief tone bursts at four frequencies from 250 to 1000 Hz. They demonstrated that loggerhead sea turtles hear well between 250 and 1000 Hz; within this frequency range, the turtles were most sensitive at 250 Hz. These authors did not measure hearing sensitivity below 250 Hz or above 1000 Hz. There was an extreme decrease in response to stimuli above 1000 Hz and the vibrational intensities required to elicit a response may have damaged the turtle's ear. The signals used in this study were very brief — 0.6 ms for the clicks, and 0.8 to 5.5 ms for the tone bursts. In other animals, auditory thresholds decrease with increasing signal duration up to about 100 – 200 ms. Thus, sea turtles probably could hear weaker signals than demonstrated in this study if the signal duration were longer.

Moein et al. (1994) used a related evoked potential method to test the hearing of loggerhead sea turtles exposed to a few hundred pulses from a single airgun. Turtle hearing was tested before, within 24 h after, and two weeks after exposure to pulses of airgun sound. Levels of airgun sound to which the turtles were exposed were not specifically reported. The authors concluded that five turtles (of ~11 tested?) exhibited some change in their hearing when tested

within 24 h after exposure relative to pre-exposure hearing, and that hearing had reverted to normal when tested two weeks after exposure. These results are consistent with the occurrence of Temporary Threshold Shift (TTS), i.e. temporary hearing impairment, upon exposure of the turtles to airgun pulses. Unfortunately, the report does not state the size of the airgun used, or the received sound levels at various distances. The distances of the turtles from the airgun were also variable during the tests; the turtle was about 30 m from the airgun at the start of each trial, but it could then either approach the airgun or move away to a maximum of about 65 m during subsequent airgun pulses. Thus, the levels of airgun sounds that apparently elicited TTS are not known. Nonetheless, it is noteworthy that there was evidence of TTS from exposure to pulses from a single airgun. However, it may be relevant that these turtles were confined and unable to move more than about 65 m away. Turtles in the open sea might move away, resulting in less exposure than occurred during this experiment.

In summary, the limited available data indicate that the frequency range of best hearing sensitivity by sea turtles extends from roughly 250-300 Hz to 500-700 Hz. Sensitivity deteriorates at lower and higher frequencies. However, there is some sensitivity to frequencies as low as 60 Hz, and probably as low as 30 Hz. Thus, there is substantial overlap in the frequencies that sea turtles detect vs. the frequencies of many industrial noises. We are not aware of measurements of the absolute hearing thresholds of any sea turtle to waterborne sounds. In the absence of relevant absolute threshold data, it is not possible to estimate how far away an anthropogenic noise source might be audible.

### **Types of Noise Associated with the Port Dolphin Project**

Underwater sounds produced during the construction and operation of the Port Dolphin LNG deepwater port can be classified into three broad categories. Sounds of short duration that are produced intermittently or at regular intervals, such as sounds from pile driving, are classified as "pulsed." Sounds produced for extended periods, such as sounds from generators, are classified as "continuous." Sounds from moving sources, such as ships, can be continuous, but for an animal at a given location, these sounds are "transient" (i.e., increasing in level as the ship approaches and then diminishing as it moves away). Studies indicate that marine animals respond somewhat differently to the three categories of noise. In general, baleen whales tend to react to lower received levels of continuous sound than of pulsed sound. Masking effects are expected to be less severe when sounds are pulsed or transient than when they are continuous. Because little information is available on the effects on marine mammals and sea turtles of the specific noise sources likely to be produced at the Port Dolphin site, marine animal reactions to the three broad categories of noise produced by other industrial activities are reviewed below.

#### **Continuous Sounds**

Dolphins and other toothed whales may show considerable tolerance of floating and bottom-founded drillrigs and their support vessels. Kapel (1979) reported many pilot whales (*Globicephala melas*) within visual range of drillships and their support vessels off West Greenland. Beluga whales (*Delphinapterus leucas*) have been observed swimming within 100-

150 m of an artificial island while drilling was underway (Fraker and Fraker 1979, 1981), and within 1,600 m of the drillship *Explorer I* while the vessel was drilling (Fraker and Fraker 1981). Some belugas in Bristol Bay and the Beaufort Sea, Alaska, when exposed to playbacks of drilling sounds, altered course to swim around the source, increased swimming speed, or reversed direction of travel (Stewart et al. 1982; Richardson et al. 1995). Reactions of beluga whales to semi-submersible drillship noise were less pronounced than were reactions to motorboats with outboard engines. Captive belugas exposed to playbacks of recorded semi-submersible noise seemed quite tolerant of that sound (Thomas et al. 1990).

Harbor porpoises (*Phocoena phocoena*) off Vancouver Island, British Columbia, were found to be sensitive to the simulated sound of a 2-MW offshore wind turbine (Koschinski et al. 2003). The porpoises remained significantly further away from the sound source when it was active, and this effect was seen out to a distance of 60 m. The device used in that study produced sounds in the frequency range of 30–800 Hz, with peak source levels of 128 dB re 1  $\mu$ Pa at 1 m at the 80 and 160 Hz frequencies.

TTSs were measured in a single captive bottlenose dolphin (*Tursiops truncatus*) after exposure to a continuous tone with maximum sound pressure levels at frequencies ranging from 4–11 kHz that was gradually increased in intensity to 179 dB re 1  $\mu$ Pa and in duration to 55 minutes (Nachtigall et al. 2003). No threshold shifts were measured at sound pressure levels of 165 or 171 dB re 1  $\mu$ Pa. However, at 179 dB re 1  $\mu$ Pa, TTSs >10 dB were measured during different trials with exposures ranging from 47–54 minutes. Hearing sensitivity was apparently recovered within 45 minutes after noise exposure.

## **Transient Sounds**

### **Vessels**

Broadband source levels (at 1 m) for most small ships where marine mammal reactions have been measured are in the 170–180 dB re 1  $\mu$ Pa range, excluding infrasonic components (Richardson et al. 1995). Broadband underwater sounds from the offshore supply ship *Robert Lemeur* in the Beaufort Sea were 130 dB at a distance of 0.56 km (Greene 1987), and were 11 dB higher when bow thrusters were operating than when they were not (Greene 1985, 1987). The *Robert Lemeur* had nozzles around the thruster propellers. Broadband noise levels from ships lacking nozzles or cowlings around the propellers can be about 10 dB higher than those from ships with the nozzles (Greene 1987).

Some species of small toothed cetaceans avoid boats when they are approached to within 0.5–1.5 km, with occasional reports of avoidance at greater distances (Richardson et al. 1995). Some toothed whale species appear to be more responsive than others. Beaked whales and beluga whales seem especially responsive to boats.

Dolphins may tolerate boats of all sizes, often approaching and riding the bow and stern waves (Shane et al. 1986). At other times, dolphin species that are known to be attracted to boats will avoid them. Such avoidance is often linked to previous boat-based harassment of the animals (Richardson et al. 1995). Coastal bottlenose dolphins that are the object of whale-

watching activities have been observed to swim erratically (Acevedo 1991), remain submerged for longer periods of time (Janik and Thompson 1996; Nowacek et al. 2001), display less cohesiveness among group members (Cope et al. 1999), whistle more frequently (Scarpaci et al. 2000), and rest less often (Constantine et al. 2004) when boats were nearby. Pantropical spotted dolphins (*Stenella attenuata*) and spinner dolphins (*S. longirostris*) in the eastern Tropical Pacific, where they have been targeted by the tuna fishing industry because of their association with these fish, show avoidance of survey vessels up to six nautical miles away (Au and Perryman 1982; Hewitt 1985), whereas spinner dolphins in the Gulf of Mexico were observed bowriding the survey vessel in all 14 sightings of this species during one survey (Würsig et al. 1998).

Harbor porpoises tend to avoid boats. In the Bay of Fundy, Polacheck and Thorpe (1990) found harbor porpoises to be more likely to be swimming away from the transect line of their survey vessel than swimming toward it and more likely to be heading away from the vessel when they were within 400 m of it. Similarly, off the west coast of North America, Barlow (1988) observed harbor porpoises avoiding a survey vessel by moving rapidly out of its path within 1 km of that vessel.

Bottlenose dolphins along the inshore waters of the Florida coast are exposed to very high levels of underwater noise and disturbance. For example, the 120 resident bottlenose dolphins in Sarasota Bay share the inshore waters with over 34,000 registered boats (Nowacek et al. 2001). This population is exposed to a close approach (within 100 m) by a boat approximately every 6 minutes on average. Presumably, the situation is similar in the Tampa Bay area.

Beluga whales are generally quite responsive to vessels. Belugas in Lancaster Sound in the Canadian Arctic showed dramatic reactions in response to icebreaking ships, with received levels of sound ranging from 101 dB to 136 dB re 1  $\mu$ Pa in the 20–1,000-Hz band at a depth of 20 m (Finley et al. 1990). Responses included emitting distinctive pulsive calls that were suggestive of excitement or alarm and rapid movement in what seemed to be a flight response. Reactions occurred out to 80 km from the ship. Although belugas in the St. Lawrence River occasionally show positive reactions to ecotourism boats by approaching and investigating those boats, one study found the belugas to surface less frequently, swim faster, and group together in the presence of boats (Blane and Jaakson 1994). Another study found belugas to use higher-frequency calls, a greater redundancy in their calls (more calls emitted in a series), and a lower calling rate in the presence of vessels (Lesage et al. 1999). The level of response of belugas to vessels is partly a function of habituation. The distant fleeing responses in the High Arctic do not occur in the Beaufort Sea and the Gulf of St. Lawrence where ship traffic is much more frequent and regular.

Most beaked whales tend to avoid approaching vessels (e.g., Würsig et al. 1998). They may also dive for an extended period when approached by a vessel (e.g., Kasuya 1986). Northern bottlenose whales (*Hyperoodon ampullatus*), on the other hand, are sometimes quite tolerant of slow-moving vessels (Reeves et al. 1993; Hooker et al. 2001).



Sperm whales generally show no overt reactions to vessels unless they are approached to within several hundred meters (Watkins and Schevill 1975; Würsig et al. 1998; Magalhães et al. 2002). Observed reactions include spending more (Richter et al. 2003) or less (Watkins and Schevill 1975) time at the surface, increasing swimming speed or changing heading (Papastavrou et al. 1989; Richter et al. 2003), and diving abruptly (Würsig et al. 1998).

### **Pulsed Sounds**

The noise generated by the Port Dolphin project will mostly be continuous sources. However, there may be pile-driving used to set the anchors for the two DWPs and for other tasks. Pile-driving produces pulsive noise and therefore, a discussion of the known effects of pulsive noise is included here. Most research has been on the effects of the airgun pulses used of offshore oil and gas exploration.

### **Masking Effects**

Masking effects of pulsed noise on marine mammal calls and other natural sounds are believed to be negligible given the discontinuous nature of these sounds. Some whales are known to continue calling in the presence of seismic pulses—their calls can be heard between the pulses (e.g., Richardson et al. 1986; McDonald et al. 1995; Greene and McLennan 2000). Although there was one report that sperm whales ceased calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994), more recent studies have reported that sperm whales continued calling in the presence of seismic pulses (Madsen et al. 2002; Jochens and Biggs 2003).

### **Disturbance Effects**

Observed behavioral reactions of baleen whales to pulsed sounds vary depending on the sound source level, type of whale exposed to the sounds, and the whales' activity when the sounds were heard. Most baleen whales exhibit some displacement from strong pulsed sounds. In most cases, the displacement is temporary and/or of limited extent. Experimental results (e.g., Würsig et al. 2000; Akamatsu et al. 1993) show that responses to impulsive noise sources are also highly variable among toothed whales. Under some circumstances, some species will avoid such noises when received levels exceed 180 dB. The variability is presumably related to the fact that the observations and experiments on toothed whales involved a variety of species in a variety of situations, and involved sources that emitted sounds at widely varying source levels and at differing frequencies, pulse lengths, and inter-pulse intervals.

Data on short-term reactions (or lack of reactions) of cetaceans to impulsive noises do not necessarily provide information about long-term effects. It is not known whether impulsive noises affect reproductive rate or distribution and habitat use in subsequent days or years. Gray whales continue to migrate annually along the west coast of North America despite intermittent seismic exploration (and much ship traffic and an existing developed oil field) in that area for decades (Malme et al. 1984). Bowhead whales continue to travel to the eastern Beaufort Sea each summer despite previous long-term seismic exploration in their summer and autumn range.

Bowheads are often seen in summering areas where seismic exploration occurred in preceding summers (Richardson et al. 1987). They also have been observed over periods of days or weeks in areas repeatedly ensonified by seismic pulses. However, it is not known whether the same individual bowheads were involved in these repeated observations (within and between years) in strongly ensonified areas. It is also not known whether whales that tolerate exposure to seismic pulses are stressed.

### **Hearing Impairment**

Temporary hearing loss in toothed whales exposed to pulsed sounds has been reported. Ridgway et al. (1997) and Schlundt et al. (2000) exposed bottlenose dolphins and beluga whales to single 1-s pulses of underwater sound. TTSs generally became evident at received levels of 192-201 dB re 1  $\mu$ Pa rms at 3, 10, 20, and 75 kHz. At 75 kHz, one dolphin exhibited a TTS at 182 dB, and at 0.4 kHz, no dolphin or beluga exhibited a TTS after exposure to levels up to 193 dB (Schlundt et al. 2000). There was no evidence of permanent hearing loss, as all hearing thresholds returned to baseline values at the end of the study.

Finneran et al. (2002) exposed a beluga whale and a bottlenose dolphin to single pulses using an 80-in<sup>3</sup> water gun. Masked TTS (MTTS), defined as a TTS that occurred with considerable background noise, was observed in a beluga after exposure to a single impulse with a peak-to-peak pressure of 226 dB re 1  $\mu$ Pa, peak pressure of 160 kPa, and total energy flux of 186 dB re 1  $\mu$ Pa<sup>2</sup>·s. Thresholds returned to within 2 dB of the pre-exposure value approximately four minutes after exposure. No MTTS was observed in a bottlenose dolphin exposed to one pulse with a peak-to-peak pressure of 228 dB re 1  $\mu$ Pa, equivalent to a peak pressure of 207 kPa and total energy flux of 188 dB re 1  $\mu$ Pa<sup>2</sup>·s (Finneran et al. 2000, 2002). In that study, TTS was defined as occurring when the post-exposure threshold was  $\geq 6$  dB higher than the pre-exposure threshold. Pulse duration at the highest exposure levels, where MTTS became evident in the beluga, was typically 10-13 ms.

### **Non-Auditory Physiological Effects**

Very little is known about the potential for impulsive sounds to cause non-auditory physiological effects in marine mammals. Available data suggest that such effects, if they occur at all, would be limited to short distances from the very loud noise sources. However, the available data do not allow for meaningful quantitative predictions of the numbers (if any) of marine mammals that might be affected in these ways. Marine mammals that show behavioral avoidance of pulsed sounds, including most baleen whales, some odontocetes, and some pinnipeds, are unlikely to incur auditory impairment or other physical effects.

Romano et al. (2004) exposed a beluga whale and a bottlenose dolphin to single underwater impulsive sounds (up to 200 kPa) from a seismic water gun and measured nervous system and immune system indicators before and after these exposures. In the beluga whale, levels of norepinephrine, epinephrine, and dopamine increased significantly with increasing sound levels and were significantly greater after sound exposures  $>100$  kPa than after sound exposures  $<100$  kPa and after control exposures. In the bottlenose dolphin, there was a

significant increase in aldosterone level and a significant decrease in monocyte count after exposure to impulsive sounds. How short-term stress responses might affect the long-term health of cetaceans is unknown.

### **Seismic Surveys**

Little systematic information is available on the reactions of toothed whales to seismic pulses. Their reactions to seismic surveying are variable and not well characterized. Dolphins and porpoises are often seen by observers on active seismic vessels, occasionally at close distances (e.g., bow riding). However, some studies, especially near the UK, showed localized (~1 km) avoidance. Recent studies show little evidence of reactions by sperm whales to airgun pulses, contrary to earlier indications. There are no specific data on responses of beaked whales to seismic surveys. There is increasing evidence that some beaked whales may strand after exposure to strong noise from mid-frequency sonars. Whether they ever do so in response to low frequency seismic survey noise is unknown.

Seismic operators sometimes see species of toothed whales near operating airgun arrays (e.g., Duncan 1985; Arnold 1996; Stone 2003). When a 3,959-in<sup>3</sup>, 18-gun array was firing off California, toothed whales behaved in a manner similar to that observed when the airguns were silent (Arnold 1996). Most, but not all, dolphins often seemed to be attracted to the seismic vessel and floats, and some rode the bow wave of the seismic vessel, seemingly unperturbed by firing guns. However, in Puget Sound, Dall's porpoises observed when a 6,000-in<sup>3</sup>, 12-16 gun array was firing, tended to be heading away from the boat (Calambokidis and Osmeck 1998). White-beaked (*Lagenorhynchus albirostris*) and white-sided dolphins (*L. acutus*) in the U.K. showed fewer positive interactions (approaching, bow riding, swimming alongside) with a seismic vessel while its airgun array was operating. These species, along with killer whales, harbor porpoises, and bottlenose dolphins all were seen further away from the seismic vessel when its airguns were firing than when they were not (Stone 2003).

Goold (1996a,b,c) studied the effects of 2D seismic surveys in the Irish Sea on common dolphins (*Delphinus delphis*). Passive acoustic surveys were conducted from the "guard ship" that towed a hydrophone 180 m aft. The results indicated that there was a local displacement of dolphins around the seismic operation. However, observations indicated that the animals were tolerant of the sounds at distances outside a 1-km radius from the guns (Goold 1996a). Initial reports of larger-scale displacement were later shown to represent a normal autumn migration of dolphins through the area, and were not attributable to seismic surveys (Goold 1996a,b,c).

There are some limited observations suggesting that sperm whales in the Southern Ocean ceased calling during some (but not all) times when exposed to weak noise pulses from extremely distant (>300 km) seismic exploration (Bowles et al. 1994). This "quieting" was suspected to represent a disturbance effect. Sperm whales exposed to pulsed man-made sounds at higher frequencies often cease calling (Watkins and Schevill 1975; Watkins et al. 1985).

On the other hand, recent (and more extensive) data from vessel-based monitoring programs in UK waters suggest that sperm whales in that area show little evidence of avoidance or behavioral disruption in the presence of operating seismic vessels (Stone 2003). These types

of observations are difficult to interpret because the observers are stationed on or near the seismic vessel, and may underestimate reactions by some of the more responsive species or individuals, which may be beyond visual range. A recent study off northern Norway indicated that sperm whales continued to call when exposed to pulses from a distant seismic vessel, with received levels of up to 146 dB re 1  $\mu$ Pa peak-peak, and remained in the area throughout the survey (Madsen et al., 2002). Similarly, sperm whales in the Gulf of Mexico did not alter their calling behavior in the presence of seismic pulses, and there was no indication that they moved away from the sound source at received levels of up to 148 dB (Jochens and Biggs 2003). A study conducted off Nova Scotia detected no difference in the acoustic abundance of male sperm whales between years without any seismic survey activity and years with an active seismic program, with received levels of 130 to 150 dB re 1  $\mu$ Pa (McCall Howard 1999). In addition, in the Gulf of Mexico, Davis et al. (2000) found no differences in sighting frequencies of sperm whales among areas with and without seismic surveys, with received levels of up to >12 dB above ambient noise levels.

### **(3) NOISE SOURCES OF THE PORT DOLPHIN PROJECT AND PROPAGATION MODELING OF UNDERWATER NOISE**

Acousticians from JASCO Research have modeled the various noise sources associated with the Port Dolphin project (Gaboury et al. 2008). That report evaluates sound propagation to determine the amounts of noise that marine animals will be exposed to. The data in Gaboury et al. (2008) underlie the predictions of project effects that are made in the Section 4.

### **(4) PREDICTED EFFECTS OF UNDERWATER NOISE FROM THE PORT DOLPHIN PROJECT ON MARINE MAMMALS AND SEA TURTLES**

In this section, we integrate the information from previous sections to predict the biological effects of the underwater noise associated with the proposed Port Dolphin Project. Data on the species and numbers of marine animals in the project area are summarized in Chapter 4 of Volume II. Information on the known effects of the types of noise associated with the Port Dolphin Project is summarized in Section 2 based on the results of other studies. The source levels and modeled propagation characteristics of underwater noise from the Port Dolphin Project are presented in Section 3. Here, in Section 4, we determine the number of animals that might be affected by the proposed project based on the modeled sound fields from the project activities.

#### **Potentially-affected Marine Animals**

The principal groups of marine animals addressed in this assessment are marine mammals (toothed whales and manatees) and sea turtles. The two groups are discussed separately below.

#### **Marine Mammals**

Seven species of baleen whales occur in the Gulf of Mexico but they occupy waters that are off the shelf and beyond the range of any significant noise from the Port Dolphin project.

The only noise that they will be exposed to will be from the ocean passage of the SRVs. At sea, the SRVs will be like any other large ship and will have similar effects. Since offshore shipping is routine, baleen whales are not discussed further.

Twenty-one species of odontocete were identified in the Gulf of Mexico were identified in Chapter 4, Volume II. Of these, only the bottlenose dolphin and Atlantic spotted dolphin are regular in the Port Dolphin project area. The following analyses are restricted to these two species and to the Florida manatee, which is the only manatee in the area.

### **Pulsive Sounds**

National Marine Fisheries Service (NMFS 2000) has developed criteria for allowable levels of noise to which whales can be exposed without potentially affecting them. For pulsed sounds, NMFS requires that individual whales not be exposed to received levels of over 180 dB re 1  $\mu$ Pa (rms) to protect the animals from potentially damaging noise levels. Received levels of over 160 dB may cause disturbance or “Level B” harassment. Level B harassment is defined by the Marine Mammal Protection Act as “... *disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering.*” Corresponding criteria for Florida manatees have not been determined. To be conservative, the cetacean criteria are used for the manatee in the present document.

Pulsive sounds from the Port Dolphin Project will occur from pile-driving used to fix the anchors of each of the two DWPs and at points along the pipeline route. Based on the acoustic modeling in Gaboury et al. (2008), it is predicted that the M-weighted 180 dB contour for bottlenose and Atlantic spotted dolphins will occur at about 100 m from the source of the pile-driving noise in offshore waters and at 200 m in inshore waters. Given the general vessel activity that will occur in conjunction with the pile-driving, it is safe to conclude that the dolphins will approach close enough to be exposed to 180 dB levels. The M-weighted 160 dB “disturbance criterion” for the pile-driving pulses would extend to 3.1 km in offshore waters and 1.7 km in inshore waters for bottlenose dolphin, Atlantic spotted dolphin, and manatee. Assuming circular sound fields, the areas ensonified to over 160 dB would be about 30.2 km<sup>2</sup> in offshore waters and 9.1 km<sup>2</sup> in inshore waters. Using the density estimates in Table 4-13 in Volume II, it is estimated that, depending upon the season, 0.7 to 2.2 groups of bottlenose dolphins could be expected per 100 km<sup>2</sup> of habitat or 0.2 to 0.7 groups per 30.2 km<sup>2</sup>. The average size of bottlenose dolphin groups in the Eastern Gulf of Mexico was 12.3. Therefore, it is predicted that 2 to 9 bottlenose dolphins could be temporarily disturbed in offshore waters. By similar logic, the number of groups per 9.1 km<sup>2</sup> that might be disturbed in inshore waters ranges from 0.06 to 0.2. At 12.3 animals per group, it is predicted that 1 to 3 bottlenose dolphins could be temporarily disturbed.

Using a similar approach for Atlantic spotted dolphins provides estimates of 1 to 4 animals that might be disturbed by exposure to received levels of 160 dB or more in offshore waters and 0.2 to 1 in inshore waters (based on density data in Table 4-13, Volume II). Clearly, the project pile-driving will have very little effect on dolphin populations in the Tampa Bay area.

Gaboury et al. (2008) considered manatees to be closest to pinnipeds for consideration of the M-weighting. However, the zone of best hearing in manatees is in the 6-20 kHz range (Gerstein et al. 1999), which would indicate that the manatee might best be considered a ‘mid-frequency’ species. The manatee is a shallow-water coastal species that would not be exposed to the mostly low frequency noise generated by project activities offshore. In inshore waters, the manatees will not occur within the 200 m radius of the 180 dB contour from the pile-driving. The 160 dB radius in inshore waters is 1.7 km but it is unlikely that much of that noise (mostly low frequency with long wave lengths) would propagate into the shallow waters occupied by manatees. Therefore, it is concluded that this phase of the project would no effect on manatees in the Tampa Bay area.

### **Transient Continuous Sounds**

Two types of transient sounds will occur: the slow-moving pipe-laying dredging operation and faster regular passages by the LNG carriers (SRVs) as they arrive at and leave the DWPs. The pipe-laying operation will occur once during a 4-5 month period. The passages by the SRVs will occur every 4-8 days during the life of the project.

The responses of marine animals to continuous underwater sounds are poorly known and highly variable within and among species depending upon many circumstances. NMFS has used a criterion of 120 dB as the level at which whales may be disturbed by continuous underwater noise. This criterion has been adopted in the present analysis.

**Buoy Installation**--Gaboury et al. (2008) modelled the sound levels associated with installation of the DWP buoys in the offshore waters. The arbitrary criterion for disturbance of 120 dB for the three mid-frequency species considered here has a radius of 2.9 km. Assuming a circular sound field offshore, the area ensonified with sounds of 120 dB or more would be about 26.4 km<sup>2</sup>. Based on the Department of the Navy study cited in Table 4-13 in Volume II, there were 0.1 to 0.4 groups of Atlantic spotted dolphins per 100 km<sup>2</sup> of nearshore habitat in the Eastern Gulf of Mexico. With an average group size of 26.5, there could be between 1 and 3 spotted dolphins that could be disturbed by the installation of the offshore buoys. Similar analyses for bottlenose dolphins suggests that, depending on season, between 2 and 7 bottlenose dolphins could be disturbed by the installation of the buoys.

The DWP buoys are far enough offshore that there will be no disturbing noise reaching manatees in shallow coastal waters.

**Pipe-laying Operations**—Pipe-laying operations are expected to occur over 4-5 month period. Propagation of the underwater noise generated by the operation will be variable depending on the water depth at the source. Gaboury et al. (2008) modeled three scenarios: offshore, Passage Key, and Tampa Bay.

For the mid-frequency species in the **offshore**, the 120 dB re 1 µPa disturbance criterion will have a radius of 6.8 km and encompass an area of about 145 km<sup>2</sup>, assuming a circular affected area. The densities of Atlantic spotted dolphins and bottlenose dolphins in the nearshore Eastern Gulf of Mexico were 0.1 to 0.4 groups (2.2 to 10.7 individuals) per 100 km<sup>2</sup>

and 0.7 to 2.2 groups (8.2 to 26.7 individuals) per 100 km<sup>2</sup>, respectively (Table 4-13, Volume II). Therefore, the numbers of Atlantic spotted dolphins subjected to the 120 dB criterion area of 145 km<sup>2</sup> could range from 3 to 16. The corresponding numbers of bottlenose dolphins that could be affected are 12 to 39.

Pods of odontocetes are often fast-moving and may not stay in the small areas discussed here for very long. Therefore, different pods may be exposed to the noise during the 4-5 month construction period but each pod is likely to be exposed for only a short period. There are no data on turnover rates but the overall number of whale days of exposure might be well represented by the numbers calculated here.

The potentially disturbing noise (120 dB and over) from the offshore buoy installation will have no effect on the coastal manatees because the received sounds will be well below the 120 dB level.

The very shallow water (~5 m) in **Passage Key** prevents propagation of most of the low frequency sounds. The M-weighted 120 dB zone is expected to extend only 1.5 km from the source in Passage Key. Animals in Passage Key are likely to be disturbed by the presence of the vessels as much as by the noise itself. The small size of the affected area means that very few dolphins and manatees would be disturbed,

In **Tampa Bay**, sounds from the pipe-laying operation would propagate better than in Passage Key. The M-weighted 120 dB zone is expected to extend 5.9 km for the mid-frequency species of interest here (Gaboury et al. 2008). This would equate to an ensonified area of ~109 km<sup>2</sup>, if the area was circular. However, given the confines of Tampa Bay and the presence of coasts and shallow water, the ensonified area would be less than the nominal 109 km<sup>2</sup>. The Atlantic spotted dolphin is found primarily on the continental shelf and is not likely to occur in Tampa Bay whereas the bottlenose dolphin occurs in Tampa Bay more regularly. If the continental shelf density applies in Tampa Bay, then about 9-27 individuals could be disturbed, depending upon the season during which the activity will occur.

**Pipeline Burial/Covering**—The process of burying the pipeline is expected to take 4-5 months. Gaboury et al. (2008) modelled the underwater noise associated with this operation in offshore and inshore (Tampa Bay) locations. At the offshore location, the M-weighted 120 dB zone is expected to extend 7.9 km for the mid-frequency dolphins of interest here. This equates to an ensonified area of ~196 km<sup>2</sup>, assuming the area was circular. Depending on the season, the predicted numbers of bottlenose dolphins that would be present, and potentially disturbed, in the ensonified area would range from 16 to 52. Similarly, the numbers of Atlantic spotted dolphins that are disturbed would range from 4 to 21. Along most of the offshore pipeline route, noise from the pipeline burial operation would not reach into the shallow waters occupied by manatees. There may be a small number of occasions when there is some very minor disturbance to manatees but these would be rare.

In the inshore waters of Tampa Bay, the M-weighted underwater noise level of 120 dB is expected to extend to 6.6 km covering an area of ~137 km<sup>2</sup>, assuming a circular area. However, given the confines of Tampa Bay and the presence of coasts and shallow water, the ensonified

area would be less than 137 km<sup>2</sup>. The Atlantic spotted dolphin is found primarily on the continental shelf and is not likely to occur in Tampa Bay whereas the bottlenose dolphin occurs in Tampa Bay more regularly. If the continental shelf density applies in Tampa Bay, then about 11-37 bottlenose dolphins could be disturbed, depending upon the season during which the activity occurs. There is some potential for a small amount of underwater noise to propagate into coastal waters occupied by manatees. However, this cannot be quantified without very site-specific data on the locations of manatees and the bottom topography of these occupied areas.

**LNG Carrier Transits**— Gaboury et al. (2008) modelled three scenarios involving the SRVs. They included cruise speed of 36 km/h (19.5 knots); approach speed of <18 km/h (10 knots); and docking at the DWP (dead slow with 2 bow thrusters and 1-2 stern thrusters operating). The cruise and docking scenarios were quite similar but the approach scenario produced less underwater noise. The unweighted 120 dB radius were 3.9 km for cruise speed, 1.7 km for approach speed, and 3.6 km for docking. When M-weighting for mid-frequency species was applied, the respective distances were 1.7 km, 0.5 km and 1.7 km. Taking the highest levels of 3.9 km and 1.7 km, the effective ensonified area would be 47.8 km<sup>2</sup> or 9.1 km<sup>2</sup>. In either case the number of dolphins potentially disturbed would be small. Using the unweighted case, the total number of dolphins (both species) in the 47.8 km<sup>2</sup> disturbed area would range from 5 to 18 individuals (calculated from Table 4-13, Volume II). When the M-weighting is considered, the number of dolphins in the disturbed area would range from 1 to 3 animals.

A SRV would arrive at one DWP and another carrier would depart from the other DWP every 4-8 days. Thus, the amount of time that any individual dolphin is likely to be exposed to disturbing noise is very small and probably inconsequential, particularly since most marine mammals habituate to regularly occurring, non-threatening ship passages. However, given that voyages occur year-round it might be appropriate to sum the average number of animals in each quarter to arrive at a more realistic total of animals that might be disturbed. Summing the average number of dolphins for the four quarters yields a total of 94.2 dolphins or 45 per 47.8 km<sup>2</sup> that might be disturbed over the course of a year.

Again, it is clear that offshore underwater noise associated with the SRVs will not propagate into the coastal waters occupied by manatees and there will be no effects on that species.

### **Fixed-Location Continuous Sounds**

Two types of underwater noise will occur regularly at the fixed locations of the two DWPs. The first is the sounds from the thrusters on each carrier that will be used to position the carrier over the DWP buoy. This operation was discussed earlier. The second type is the noise that will emanate from the SRV while it is fixed to the DWP. These noises are associated with the re-gasification process and with maintaining ship functions while moored with the main engines turned-off. The noise levels of the re-gasification process are quite low and barely reach 110 dB in the water near the vessel. There are no situations where the noise level exceeds 120 dB even a



few meters from the vessel. Therefore, there will be no effects on marine animals (LGL and JASCO Research 2005).

### **Sea Turtles**

Five species of sea turtle occur in the Eastern Gulf of Mexico. The effects of underwater noise on sea turtles are not well studied. There are no safety criteria for sea turtles similar to those used by NMFS for marine mammals.

### **Pulsive Sounds**

There is very little information available on the responses of sea turtles to pulsed sounds. The available information comes from experiments using seismic airguns. Avoidance out to 30 m was demonstrated in loggerhead turtles in a 10-m deep canal exposed to seismic airgun sounds (O'Hara and Wilcox 1990). The airguns used in that study produced a sound with its strongest components at a frequency of 25 Hz, with some frequencies up to 1 kHz. Although those authors did not report received sound pressure levels, McCauley et al. (2000), using a similar sound source, estimated that the received sound pressure levels in the O'Hara and Wilcox (1990) study would have been on the order of 175–176 dB re 1  $\mu$ Pa rms.

McCauley et al. (2000) observed the responses of a caged green turtle and a loggerhead turtle to the approach and retreat of an operating seismic airgun. Those animals noticeably increased their swimming activity above a source level of approximately 166 dB re 1  $\mu$ Pa rms. Above 175 dB re 1  $\mu$ Pa rms their behavior became more erratic, possibly indicating an agitated state. The turtles spent increasingly more time swimming as the airgun level increased. The point at which the turtles showed the more erratic behavior likely indicates the point at which avoidance would occur for unrestrained turtles. To be conservative, it is assumed here that 170 dB represents the threshold at which pulsed sounds elicit a disturbance response in sea turtles.

Received noise levels of 170 dB will occur up to 0.85 to 1.1 km from the inshore and offshore pile-driving operations, respectively ensonifying areas of about 2.3 to 3.8 km<sup>2</sup> (see Section 3). Turtle densities in the nearshore zone of the eastern Gulf of Mexico ranged from 6 to 19 per 100 km<sup>2</sup> depending upon the season (Table 4-15 in Volume II). It should be remembered that these are minimal density estimates that are not fully corrected for unseen animals. Nonetheless, combining the small areas ensonified with the observed densities indicates that small numbers (1 or 2) of sea turtles would be temporarily disturbed by the pulsed noise from the pile-driving.

### **Continuous Sounds**

The only information available on sea turtle reactions to continuous sound sources comes from one study of captive loggerhead turtles. In that study, resting turtles reacted to low-frequency (20–80 Hz) continuous tones projected into their tank by swimming to the surface and remaining there (Lenhardt 1994). These "startle responses" were elicited using sound vibrations in the tank. There are no data on the disturbance responses of free-swimming, wild sea turtles. Sea turtles are low-frequency hearing specialists similar to baleen whales, which have

disturbance criteria for pulsive sounds of 160 dB and continuous sounds of 120 dB or a difference of 40 dB. Based on very limited data, it appears that pulsive sounds of 175 dB are necessary to disturb sea turtles. A 40 dB difference in pulsive to continuous response ratio for sea turtles would establish a received level for continuous sounds of about 135 dB to elicit disturbance responses by sea turtles. A conservative disturbance response threshold of 130 dB is used in the following analyses. There is no need to use the M-weighted values here since weighted and unweighted values are essentially the same for low-frequency hearing species such as the sea turtles.

### **Transient Continuous Sounds**

Two types of transient sounds will occur: the slow-moving pipe-laying and burying operation and faster regular passages by the LNG carriers (SRVs) as they arrive at and leave the DWPs. The pipe-laying operation will occur once during a 4-5 month period. The passages by the SRVs will occur every 4-8 days during the life of the project.

**Buoy Installation**--Gaboury et al. (2008) modelled the sound levels associated with installation of the DWP buoys in the offshore waters. The criterion for disturbance of 130 dB for sea turtles has a radius of 1.4 km. Assuming a circular sound field offshore, the area ensonified with sounds of 130 dB or more would be about 6.1 km<sup>2</sup>. Based on the Department of the Navy study cited in Table 4-15 in Volume II, there were 6.0 to 19.2 sea turtles per 100 km<sup>2</sup> of nearshore habitat in the Eastern Gulf of Mexico. Based on these data, there could be between 0 and 2 sea turtles that could be disturbed by the installation of the offshore buoys. Therefore, the effects will be negligible.

**Pipe-laying Operations**—Pipe-laying operations are expected to occur over 4-5 month period. Propagation of the underwater noise generated by the operation will be variable depending on the water depth at the source. Gaboury et al. (2008) modelled three scenarios: offshore, Passage Key, and Tampa Bay.

For sea turtles in the **offshore**, the 130 dB re 1 µPa disturbance criterion will have a radius of 3.6 km and encompass an area of about 41 km<sup>2</sup>, assuming a circular ensonified area. The densities of sea turtles (all species combined) in the nearshore Eastern Gulf of Mexico ranged from 6.0 to 19.2 per 100 km<sup>2</sup> (Table 3-15, Volume II). Therefore, the numbers of sea turtles subjected to the 130 dB criterion area of 41 km<sup>2</sup> could range from 2 to 8, depending upon season. Given the length of the construction season, it is likely that there will be some movement of turtles into and out of the ensonified area so that a larger number of individuals might be temporarily disturbed. There are no data bearing on this question.

The very shallow water (~5 m) in **Passage Key** prevents propagation of most of the low frequency sounds. The 130 dB zone is expected to extend only 1 km from the source in Passage Key. Animals in Passage Key are likely to be disturbed by the presence of the vessels as much as by the noise itself. The small size of the affected area means that very few sea turtles would be disturbed,

In **Tampa Bay**, sounds from the pipe-laying operation would propagate better than in Passage Key. The 130 dB zone is expected to extend 2.1 km from the source (Gaboury et al. 2008). This would equate to an ensonified area of  $\sim 13.9 \text{ km}^2$ , if the area was circular. However, given the confines of Tampa Bay and the presence of coasts and shallow water, the ensonified area would not always be as much as  $13.9 \text{ km}^2$ . If the continental shelf density of sea turtles applies in Tampa Bay, then about 1-3 individuals could be disturbed, depending upon the season during which the activity occurs.

**Pipeline Burial/Covering**—The process of burying the pipeline is expected to take 4-5 months. Gaboury et al. (2008) modelled the underwater noise associated with this operation in offshore and inshore (Tampa Bay) locations. At the offshore location, the 130 dB zone is expected to extend 3.8 km from the source. This equates to an ensonified area of  $\sim 45 \text{ km}^2$ , assuming the area was circular. Depending on the season, the predicted numbers of sea turtles that would be present, and potentially disturbed, in the ensonified area would range from 3 to 9.

In the inshore waters of Tampa Bay, the underwater noise level of 130 dB is expected to extend to 2.1 km covering an area of  $\sim 14 \text{ km}^2$ , assuming a circular area. However, given the confines of Tampa Bay and the presence of coasts and shallow water, the ensonified area would be less than  $14 \text{ km}^2$  at some locations. Again, if the continental shelf density applies in Tampa Bay, then about 1-3 sea turtles could be disturbed, depending upon the season during which the activity occurs.

For all of the pipe-laying and related activities and all three areas considered above, it is concluded, based on the small areas ensonified, the small number of turtles that might be disturbed, and the single period of activities, that the effects of noise from the pipe-laying, dredging and burying would be negligible on turtle populations and on individual turtles.

**LNG Carrier Transits**— Gaboury et al. (2008) modelled three scenarios involving the SRVs. They included cruise speed of 36 km/h (19.5 knots); approach speed of 19 km/h (10 knots); and docking at the DWP (dead slow with 2 bow thrusters and 1-2 stern thrusters operating). The cruise and docking scenarios actually produced similar results, whereas the approach scenario was much lower with respect to underwater noise. The unweighted 130 dB radius was 1.5 km for cruise speed, 0.4 km for approach speed, and 1.5 km for docking. Taking the highest level of 1.5 km, the effective ensonified area would be about  $7 \text{ km}^2$ . Therefore, depending upon the season and using the densities calculated by the Department of the Navy in Table 4-15, Volume II, the numbers of sea turtles that could be disturbed in the ensonified area would not exceed 1.

A SRV would arrive at one DWP and another carrier would depart from the other DWP every 4-8 days. Thus, the amount of time that any individual dolphin is likely to be exposed to disturbing noise is very small and probably inconsequential, particularly since most marine animals habituate to regularly occurring, non-threatening ship passages. However, given that voyages occur year-round it might be appropriate to sum the average number of animals in each quarter to arrive at a more realistic total of animals that might be disturbed. Summing the average number of turtles for the four quarters yields a total density of 45.8 per  $100 \text{ km}^2$  (Table

4-15, Volume II) or about about 3 turtles that might be disturbed over the course of a year. This would be a negligible effect.

### **Fixed-Location Continuous Sounds**

Underwater noise associated with the docking of the SRVs at the DWPs was discussed above. Underwater noise that will emanate from the SRV while it is fixed to the DWP are associated with the re-gasification process and with maintaining ship functions while moored with the main engines turned-off. The noise levels of the re-gasification process are quite low and barely reach 110 dB in the water near the vessel. There are no situations where the noise level exceeds 130 dB even a few meters from the vessel (LGL and JASCO Research 2005). Therefore, there will be no effects on sea turtles.

### **Summary**

The previous analyses indicate that underwater noise from the Port Dolphin project will not damage any marine animals and will temporarily disturb only very small numbers of them. The dolphins, manatees and sea turtles occupying the Port Dolphin area are already exposed to much higher levels of disturbance from the large amounts of ship traffic using the Tampa Bay area and the thousands of fishing boats and recreational boats in the area. Marine animals in the region have apparently adapted to the existing levels of disturbance and the addition of the small amount of additional disturbance from the Port Dolphin project will be barely perceptible above the existing levels.

## **5. BIBLIOGRAPHY/REFERENCES**

- Acevedo, A. 1991. Interactions between boats and bottlenose dolphins, *Tursiops truncatus*, in the entrance to Ensenada De La Paz, Mexico. *Aquat. Mamm.* 17(3):120-124.
- Akamatsu, T., Y. Hatakeyama and N. Takatsu. 1993. Effects of pulsed sounds on escape behavior of false killer whales. *Nippon Suisan Gakkaishi* 59: 1297-1303.
- Arnold, B.W. 1996. Visual monitoring of marine mammal activity during the Exxon 3-D seismic survey/Santa Ynez Unit, offshore California/9 November to 12 December 1995. Rep. from Impact Sciences Inc., San Diego, CA, for Exxon Co. U.S.A., Thousand Oaks, CA. 25 p.
- Au, W.W.L. 1993. *The Sonar of Dolphins*. Springer-Verlag, New York, NY. 277 p.
- Au, W.W.L. and D.L. Herzing. 2003. Echolocation signals of wild Atlantic spotted dolphin (*Stenella frontalis*). *Journal of the Acoustical Society of America* 113(1):598-604.
- Au, W.W.L. and P.W.B. Moore. 1988. Detection of complex echoes in noise by an echolocating dolphin. *J. Acoust. Soc. Am.* 83: 662-668.

- Au, W.W.L., and P.W.B. Moore. 1990. Critical ratio and critical bandwidth for the Atlantic bottlenose dolphin. *J. Acoust. Soc. Am.* 88: 1635-1638.
- Au, D. and W. Perryman. 1982. Movement and speed of dolphin schools responding to an approaching ship. *Fish. Bull* 80(2):371-379.
- Au, W.W.L., D.A. Carder, R.H. Penner and B.L. Scronce. 1985. Demonstration of adaptation in beluga whale echolocation signals. *J. Acoust. Soc. Am.* 77: 726-730.
- Au, W.W.L., Lemonds, D.W., Vlachos, S., P.E. Nachtigall and H.L. Roitblat. 2002. Atlantic bottlenose dolphin (*Tursiops truncatus*) hearing threshold for brief broadband signals. *J. Compar. Psychol.* 116(2):151-157.
- Au, W.W.L., R.W. Floyd, R.H. Penner and A.E. Murchison. 1974. Measurement of echolocation signals of the Atlantic bottlenose dolphin, *Tursiops truncatus* Montagu, in open waters. *J. Acoust. Soc. Am.* 56: 1280-1290.
- Bain, D.E. and M.E. Dahlheim. 1994. Effects of masking noise on detection thresholds of killer whales. p. 243-256. In: T.R. Loughlin (ed.), *Marine Mammals and the Exxon Valdez*. Academic Press, San Diego, CA. 395 p.
- Bain, D.E., B. Kriete and M.E. Dahlheim. 1993. Hearing abilities of killer whales (*Orcinus orca*). *J. Acoust. Soc. Am.* 94: 1829.
- Barlow, J. 1988. Harbor porpoise, *Phocoena phocoena*, abundance estimation for California, Oregon, and Washington. I: Ship surveys. *Fish. Bull.* 86(3):417-432.
- Bartol, S.M. and D.R. Ketten. 2006. Turtle and tuna hearing. p. 98-103 In: Y. Swimmer and R. Brill (eds.), *Sea turtle and pelagic fish sensory biology: developing techniques to reduce sea turtle bycatch in longline fisheries*. NOAA Tech. Memo. NMFS-PIFSC-7. NMFS, Pacific Islands Fisheries Science Center, Honolulu, HI.
- Bartol, S.M., J.A. Musick and M.L. Lenhardt. 1999. Auditory evoked potentials of the loggerhead sea turtle (*Caretta caretta*). *Copeia* 1999(3):836-840.
- Blane, J.M. and R. Jaakson. 1994. The impact of ecotourism boats on the St. Lawrence beluga whales. *Environ. Conserv.* 21(3):267-269.
- Bowles, A.E., M. Smultea, B. Würsig, D.P. DeMaster and D. Palka. 1994. Relative abundance and behavior of marine mammals exposed to transmissions for the Heard Island feasibility test. *J. Acoust. Soc. Am.* 96: 2469-2484.
- Brill, R.L., P.W.B. Moore and L.A. Dankiewicz. 2001. Assessment of dolphin (*Tursiops truncatus*) auditory sensitivity and hearing loss using jawphones. *J. Acoust. Soc. Am.* 109(4):1717-1722.
- Calambokidis, J. and S.D. Osmek. 1998. Marine mammal research and mitigation in conjunction with air gun operation for the USGS 'SHIPS' seismic surveys in 1998. Draft Rep. from Cascadia Research, Olympia, WA, for U.S. Geol. Surv., Nat. Mar. Fish. Serv., and Minerals Management Service Var. pag.

- Chapman, D.M.F., F. Desharnais and G. Heard. 1998. Scotian Shelf acoustic study. Rep. by the Defence Research Establishment Atlantic, Dartmouth, NS, for LGL Limited, environmental research associates, King City, ON., Dartmouth, NS. 15 p + App.
- Constantine, R., D.H. Brunton and T. Dennis. 2004. Dolphin-watching tour boats change bottlenose dolphin (*Tursiops truncatus*) behaviour. Biol. Cons. 117:299-307.
- Cope, M., D. St. Aubin and J. Thomas. 1999. The effect of boat activity on the behavior of bottlenose dolphins (*Tursiops truncatus*) in the nearshore waters of Hilton Head, South Carolina. Presented at the 13th Biennial Conference on the Biology of Marine Mammals, November 28-December 3, 1999, Wailea, Hawaii. p. 37-38.
- Croll, D.A., B.R. Tershy, A. Acevedo, and P. Levin. 1999. Marine vertebrates and low frequency sound. Technical Report for LFA EIS. Marine Mammals and Seabird Ecology Group, Institute of Marine Sciences, University of California, Santa Cruz, CA.
- Dahlheim, M.E 1987. Bio-acoustics of the gray whale (*Eschrichtius robustus*). Ph.D. Thesis, Univ. of BC, Vancouver, BC. 315 p.
- Davis, R.W., G.S. Fargion, N. May, T.D. Leming, M. Baumgartner, W.E. Evans, L.J. Hansen and K. Mullin. 1998. Physical habitat of cetaceans along the continental slope in the north-central and western Gulf of Mexico. **Mar. Mamm. Sci.** 14(3):490-507.
- Davis, R.W., W.E. Evans and B. Würsig, eds. 2000. Cetaceans, sea turtles and seabirds in the northern Gulf of Mexico: distribution, abundance and habitat associations. Volume II: Technical Report. Prepared by Texas A&M University at Galveston and the National Marine Fisheries Service. U.S. Department of the Interior, Geological Survey, Biological Resources Division, USGS/BRD/CR-1999-0006 and Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2000-003. 346 pp. Available at: <http://www.mms.gov/itd/pub/2000/2000-003/pdf>.
- Desharnais, F., G.J. Heard, M.G. Hazen and I.A. Fraser. 1999. The underwater acoustic noise field on Sable Bank. Can. Acoust. 27: 30-31.
- Dubrovskiy, N.A. 1990. On the two auditory subsystems in dolphins. p. 233-254. In: J.A. Thomas, and R.A. Kastelein (eds.), Sensory Abilities of Cetaceans/Laboratory and Field Evidence. Plenum Press, New York. 710 p.
- Duncan, P.M. 1985. Seismic sources in a marine environment. p. 56-88. In: Proc. Workshop on Effects of Explosives Use in the Marine Environment, Jan. 1985, Halifax, N.S. Tech. Rep. 5. Can. Oil & Gas Lands Admin. Envir. Prot. Br., Ottawa, ON. 398 p.
- Finley, K.J., G.W. Miller, R.A. Davis and C.R. Greene. 1990. Reactions of belugas, *Delphinapterus leucas*, and narwhals, *Monodon monoceros*, to ice-breaking ships in the Canadian high Arctic. Can. Bull. Fish. Aquat. Sci. 224:97-117.

- Finneran, J.J., C.E. Schlundt, D.A. Carder, J.A. Clark, J.A. Young, J.B. Gaspin and S.H. Ridgway. 2000. Auditory and behavioral responses of bottlenose dolphins (*Tursiops truncatus*) and a beluga whale (*Delphinapterus leucas*) to impulsive sounds resembling distant signatures of underwater explosions. *J. Acoust. Soc. Am.* 108: 417-431.
- Finneran, J.J., C.E. Schlundt, R. Dear, D.A. Carder and S.H. Ridgway. 2002. Temporary shift in masked hearing thresholds in odontocetes after exposure to single underwater impulses from a seismic watergun. *J. Acoust. Soc. Amer.* 111: 2929-2940.
- Fraker, M.A. and P.N. Fraker. 1979. The 1979 whale monitoring program/Mackenzie Estuary. Rep. by LGL Ltd. for Esso Resources Canada Ltd., Edmonton, AB. 51 p.
- Fraker, P.N. and M.A. Fraker. 1981. The 1980 whale monitoring program, Mackenzie Estuary. Rep. by LGL Ltd. for Esso Resources Canada Ltd., Calgary, AB. 98 p.
- Frisch, S. and K. Frisch. 2003. Low frequency vocalizations in the Florida manatee (*Trichechus manatus latirostris*). Page 55 in Abstracts, Fifteenth Biennial Conference on the Biology of Marine Mammals. 14-19 December 2003. Greensboro, North Carolina.
- Gaboury, I., R. Gaboury, M. Zykov and S. Carr. 2008. Port Dolphin Energy LLC Deep Water Port: Assessment of Underwater Noise. Rep. by JASCO Research Ltd., Halifax, NS for CSA International, Inc., Jupiter, FL. 46 p.
- Gerstein, E.R., L. Gerstein, S.E. Forsythe, and J.E. Blue. 1999. The underwater audiogram of the West Indian manatee (*Trichechus manatus*). *Journal of the Acoustical Society of America* 105(6):3575-3583.
- Goold, J.C. 1996a. Acoustic assessment of common dolphins off the west Wales coast, in conjunction with 16th round seismic surveying. Rep. to Chevron UK Ltd, Repsol Exploration (UK) Ltd and Aran Energy Exploration Ltd from School of Ocean Sciences, University of Wales, Bangor, Wales. 22 p.
- Goold, J.C. 1996b. Acoustic assessment of populations of common dolphin *Delphinus delphis* in conjunction with seismic surveying. *J. Mar. Biol. Assoc. U.K.* 76: 811-820.
- Goold, J.C. 1996c. Acoustic cetacean monitoring off the west Wales coast. Rep. to Chevron UK Limited, Repsol Exploration (UK) Ltd and Aran Energy Exploration Ltd from School of Ocean Sciences, University of Wales, Bangor, Wales. 20 p.
- Greene Jr., C.R. 1985. Characteristics of waterborne industrial noise, 1980-84. p. 197-253. In: W.J. Richardson (ed.), Behavior, disturbance responses and distribution of bowhead whales *Balaena mysticetus* in the eastern Beaufort Sea, 1980-84. OCS Study MMS 85-0034. Rep. from LGL Ecol. Res. Assoc. Inc., Bryan, TX, for U.S. Minerals Management Service, Reston, VA. 306 p. NTIS PB87-124376.
- Greene Jr., C.R. 1987. Characteristics of oil industry dredge and drilling sounds in the Beaufort Sea. *J. Acoust. Soc. Am.* 82: 1315-1324.
- Greene, C.R., Jr. and M.W. McLennan. 2000. Sound levels from a 1210 in<sup>3</sup> airgun array. p. 3-1-3-9. In: W.J. Richardson (ed.), Marine mammal and acoustical monitoring of Western

- Geophysical's open-water seismic program in the Alaskan Beaufort Sea, 2000: 90-day report. Rep. TA2424-3. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for Western Geophysical, Anchorage, AK, and Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 121 p.
- Hewitt, R.P. 1985. Reaction of dolphins to a survey vessel: effects on census data. *Fish. Bull.* 83(2):187-193.
- Hooker, S.K., R.W. Baird, S. Al-Omari, S. Gowans and H. Whitehead. 2001. Behavioural reactions of northern bottlenose whales (*Hyperoodon ampullatus*) to biopsy darting and tag attachment procedures. *Fish. Bull.* 99: 303-308.
- Janik, V.M. and P.M. Thompson. 1996. Changes in surfacing patterns of bottlenose dolphins in response to boat traffic. *Mar. Mamm. Sci.* 12(4):597-602.
- Jochens, A.E. and D.C. Biggs, editors. 2003. Sperm whale seismic study in the Gulf of Mexico. Annual report: Year 1. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2003-069. 139 pp. Available at: <http://www.gomr.mms.gov/homepg/regulate/envIRON/studies/2003/2003-069.pdf>.
- Johnson, C.S. 1967. Sound detection thresholds in marine mammals. In: Tavolga, W.N., ed. *Marine Bioacoustics*. Pergamon, New York. p. 247-260.
- Kapel, F.O. 1979. Exploitation of large whales in West Greenland in the twentieth century. Rep. *Int. Whal. Comm.* 29: 197-214.
- Kasuya, T. 1986. Distribution and behavior of Baird's beaked whales off the Pacific coast of Japan. *The Scientific Reports of the Whales Research Institute* 37: 61-83.
- Ketten, D.R. 1995. Estimates of blast injury and acoustic trauma zones for marine mammals from underwater explosions. p. 391-406. In: J.A. Kastelein, P.E. Thomas, and P.E. Nachtigall (eds.), *Sensory Systems of Aquatic Mammals*. De Spil, Woerden.
- Ketten, D.R. 2000. Cetacean ears. pp. 43-108 In: Au, W.W.L., A.N. Popper and R.R. Fay, editors. *Hearing by Whales and Dolphins*. Springer-Verlag New York Inc., New York.
- Koschinski, S., B.M. Culik, O. Damsgaard Henriksen, N. Tregenza, G. Ellis, C. Jansen and G. Kathe. 2003. Behavioural reactions of free-ranging porpoises and seals to the noise of a simulated 2 MW windpower generator. *Mar. Ecol. Prog. Ser.* 265:263-273.
- Kryter, K.D. 1985. *The Effects of Noise on Man*. Academic Press, Inc., Orlando, FL. 688 p.
- Kryter, K.D. 1994. *The Handbook of Hearing and the Effects of Noise*. Academic Press, Inc., Orlando, FL. 673 p.
- Lenhardt, M.L. 1994. Seismic and very low frequency sound induced behaviors in captive loggerhead marine turtles (*Caretta caretta*). p. 238-241 In: K.A. Bjorndal, A.B. Bolten, D.A. Johnson, and P.J. Eliazar (compilers), *Proceedings of the Fourteenth Annual*



- Symposium on Sea Turtle Biology and Conservation. NOAA Tech. Memo. NMFS-SEFSC-351. NMFS, Southeast Fisheries Science Center, Miami, FL.
- Lenhardt, M.L., S. Bellmund, R.A. Byles, S.W. Harkins, and J.A. Musick. 1983. Marine turtle reception of bone-conducted sound. *Journal of Auditory Research* 23:119-125.
- Lesage, V., C. Barrette, M.C.S. Kingsley and B. Sjare. 1999. The effect of vessel noise on the vocal behavior of belugas in the St. Lawrence River Estuary, Canada. *Mar. Mamm. Sci.* 15: 65-84.
- LGL and JASCO. 2005. Assessment of the effects of underwater noise from the proposed Neptune LNG project. Rep. by LGL Limited, King City, ON and JASCO Research Ltd., Halifax, NS for Ecology and Environment, Inc., Arlington, VA.
- Ljungblad, D.K., P.D. Scoggins and W.G. Gilmartin. 1982. Auditory thresholds of a captive Eastern Pacific bottle-nosed dolphin, *Tursiops* spp. *J. Acoust. Soc. Am.* 72(6):1726-1729.
- Madsen, P.T., B. Mohl, B.K. Nielsen and M. Wahlberg. 2002. Male sperm whale behavior during exposures to distant seismic survey pulses. *Aquat. Mamm.* 28(3):231-240.
- Magalhães, S., R. Prieto, M.A. Silva, J. Gonçalves, M. Afonso-Dian and R.S. Santos. 2002. Short-term reactions of sperm whales (*Physeter macrocephalus*) to whale-watching vessels in the Azores. *Aquat. Mamm.* 28(3):267-274.
- Malme, C.I., P.R. Miles, C.W. Clark, P. 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. BBN Rep. 5586. Bolt, Beranek and Newman Rep. for Minerals Management Service, U.S. Dept. of the Interior, Washington, DC. Var. pag.
- McCall Howard, M.P. 1999. Sperm whales *Physeter macrocephalus* in the Gully, Nova Scotia: Population, distribution, and response to seismic surveying. B.Sc. (Honours) Thesis. Dalhousie University, Halifax, Nova Scotia.
- McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch, and K. McCabe. 2000. Marine seismic surveys: Analysis and propagation of air-gun signals; and effects of air-gun exposure on humpback whales, sea turtles, fishes and squid. Prepared for Australian Petroleum Production and Exploration Association (APPEA), Centre for Marine Science and Technology, Curtin University, Perth, Australia, 198 p.
- McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.-N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch and K.A. McCabe. 2000. Marine seismic surveys—A study of environmental implications. *APPEA J.* 40: 692-708.
- McCauley, R.D., J. Fewtrell, and A.N. Popper. 2003. High intensity anthropogenic sound damages fish ears. *J. Acoust. Soc. Am.*, 113, 1: 638-642.

- McDonald, M.A., J.A. Hildebrand and S.C. Webb. 1995. Blue and fin whales observed on a seafloor array in the Northeast Pacific. *J. Acoust. Soc. Am.* 98: 712-721.
- Moein, S.E., J.A. Musick, J.A. Keinath, D.E. Barnard, M. Lenhardt, and R. George. 1994. Evaluation of seismic sources for repelling sea turtles from hopper dredges. Rep. from Virginia Inst. Mar. Sci., [Gloucester Point], VA, for U.S. Army Corps of Engineers. 33 p.
- Moore, P.W.B. and D.A. Pawloski. 1990. Investigations on the control of echolocation pulses in the dolphin (*Tursiops truncatus*). p. 305-316. In: J.A. Thomas, and R.A. Kastelein (eds.), *Sensory Abilities of Cetaceans/Laboratory and Field Evidence*. Plenum Press, New York. 710 p.
- Mrosovksy, N. 1972. Spectrographs of the sounds of leatherback turtles. *Herpetologica* 28:256-258.
- Myrberg, A.A., Jr. 1978. Ocean noise and the behavior of marine animals: relationships and implications. p. 169-208. In: J.L. Fletcher, and R.G. Busnel (eds.), *Effects of noise on wildlife*. Academic Press, New York.
- Nachtigall, P.E., J.L. Pawloski and W.W.L. Au. 2003. Temporary threshold shifts and recovery following noise exposure in the Atlantic bottlenosed dolphin (*Tursiops truncatus*). *J. Acoust. Soc. Am.* 113(6):3425-3429.
- Niezrecki, C., R. Phillips, M. Meyer, and D.O. Beusse. 2003. Acoustic detection of manatee vocalizations. *Journal of the Acoustical Society of America* 114(3):1640-1647.
- NMFS. 2000. Taking and importing marine mammals; Taking marine mammals incidental to Naval activities/Proposed rule. *Fed. Regist.* 65(239 12 December): 77546-77553.
- Nowacek, S.M., R.S. Wells and A.R. Solow. 2001. Short-term effects of boat traffic on bottlenose dolphins, *Tursiops truncatus*, in Sarasota Bay, Florida. *Mar. Mamm. Sci.* 17(4):673-688.
- Nowacek, D.P., B.M. Casper, R.S. Wells, S.M. Nowacek, and D.A. Mann. 2003. Intraspecific and geographic variation of West Indian manatee (*Trichechus manatus spp.*) vocalizations. *Journal of the Acoustical Society of America* 114(1):66-69.
- O'Hara, J. and J.R. Wilcox. 1990. Avoidance responses of loggerhead turtles, *Caretta caretta*, to low frequency sound. *Copeia* 1990(2):563-567.
- O'Shea, T.J. and L.B. Pøche. 2006. Aspects of underwater sound communication in Florida manatees (*Trichechus manatus latirostris*). *Journal of Mammalogy* 87(6):1061-1071.
- Papastavrou, V., S.C. Smith and H. Whitehead. 1989. Diving behaviour of the sperm whale, *Physeter macrocephalus*, off the Galapagos Islands. *Can. J. Zool.* 67:839-846.
- Penner, R.H., C.W. Turl and W.W. Au. 1986. Target detection by the beluga using a surface-reflected path. *J. Acoust. Soc. Am.* 80: 1842-1843.

- Phillips, R., C. Niezrecki, and D.O. Beusse. 2004. Determination of West Indian manatee vocalization levels and rate. *Journal of the Acoustical Society of America* 115(1):422-428.
- Polacheck, T. and L. Thorpe. 1990. The swimming direction of harbor porpoise in relationship to a survey vessel. *Rep. Int. Whal. Commn* 40:463-470.
- Reeves, R.R., E. Mitchell and H. Whitehead. 1993. Status of the Northern Bottlenose Whale, *Hyperoodon ampullatus*. *Can. Field-Naturalist* 107: 491-509.
- Richardson, W.J., B.W. Würsig and C.R. Greene Jr. 1986. Reactions of bowhead whales, *Balaena mysticetus*, to seismic exploration in the Canadian Beaufort Sea. *J. Acoust. Soc. Am.* 79: 1117-1128.
- Richardson, W.J., D.H. Thomson, C.R. Green Jr. and C.I. Malme. 1995. *Marine mammals and noise*. Academic Press, Inc., San Diego, CA. 576 p.
- Richardson, W.J., R.A. Davis, C.R. Evans, D.K. Ljungblad and P. Norton. 1987. Summer distribution of bowhead whales, *Balaena mysticetus*, relative to oil industry activities in the Canadian Beaufort Sea, 1980-84. *Arctic* 40: 93-104.
- Richter, C.F., S.M. Dawson and E. Slooten. 2003. Sperm whale watching off Kaikoura, New Zealand: effects of current activities on surfacing and vocalisation patterns. *Science for Conservation* 219. Department of Conservation, Wellington. 78 p. Available at <http://www.doc.govt.nz/Publications/004~Science-and-Research/Science-for-Conservation/PDF/SFC219.pdf>
- Ridgway, S.H. and D.A. Carder. 1997. Hearing deficits measured in some *Tursiops truncatus*, and discovery of a deaf/mute dolphin. *J. Acoust. Soc. Am.* 101(1):590-594.
- Ridgway, S.H., D.A. Carder, R.R. Smith, T. Kamolnick, C.E. Schlundt and W.R. Elseberry. 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  $\mu$ Pa. Tech. Rep. 1751, Revision 1. Tech. Rep. to Naval Command, Control and Ocean Surveillance Center (NCCOSC), RDT&E DIV D3503, San Diego, CA. 27 p.
- Ridgway, S.H., E.G. Wever, J.G. McCormick, J. Palin and J.H. Anderson. 1969. Hearing in the giant sea turtle, *Chelonia mydas*. *Proc. Natl. Acad. Sci.* 64:884-890.
- Romanenko, E.V. and V.Ya. Kitain. 1992. The functioning of the echolocation system of *Tursiops truncatus* during noise masking. p. 415-419. In: J.A. Thomas, R.A. Kastelein and A.Ya. Supin (eds.), *Marine Mammal Sensory Systems*. Plenum, New York. 773 p.
- Romano, T.A., M.J. Keogh, C. Kelly, P. Feng, L. Berk, C.E. Schlundt, D.A. Carder and J.J. Finneran. 2004. Anthropogenic sound and marine mammal health: measures of the nervous and immune systems before and after intense sound exposure. *Can. J. Fish. Aquat. Sci.* 61:1124-1134.

- Scarpaci, C., S.W. Bigger, P.J. Corkeron and D. Nugegoda. 2000. Bottlenose dolphins (*Tursiops truncatus*) increase whistling in the presence of 'swim-with-dolphin' tour operations. *J. Cetacean Res. Manage.* 2(3):183-185.
- Schlundt, C.E., J.J. Finneran, D.A. Carder and S.H. Ridgway. 2000. Temporary shift in masked hearing thresholds of bottlenose dolphins, *Tursiops truncatus*, and white whales, *Delphinapterus leucas*, after exposure to intense tones. *J. Acoust. Soc. Am.* 107: 3496-3508.
- Shane, S.H., R.S. Wells and B. Wursig. 1986. Ecology, behavior and social organization of the bottlenose dolphin: a review. **Mar. Mamm. Sci.** 2(1):34-63.
- Stewart, B.S., W.E. Evans and F.T. Awbrey. 1982. Effects of man-made waterborne noise on behavior of belukha whales (*Delphinapterus leucas*) in Bristol Bay, Alaska. HSWRI Tech. Rep. 82-145. Rep. from Hubbs/Sea World Res. Inst., San Diego, CA, for Nat. Oceanic & Atmosph. Admin., Juneau, AK. 29 p.
- Stone, C.J. 2003. The effects of seismic activity on marine mammals in UK waters, 1998-2000. JNCC Report No. 323, Joint Nature Conservation Committee, Peterborough, UK. 43 pp. + appendices.
- Terhune, J.M. 1999. Pitch separation as a possible jamming-avoidance mechanism in underwater calls of bearded seals (*Erignathus barbatus*). *Can. J. Zool.* 77: 1025-1034.
- Thomas, J.A. and C.W. Turl. 1990. Echolocation characteristics and range detection threshold of a false killer whale (*Pseudorca crassidens*). p. 321-334. In: J.A. Thomas and R.A. Kastelein (eds.), *Sensory abilities of cetaceans/Laboratory and field evidence*. Plenum, New York. 710 p.
- Thomas, J.A., R.A. Kastelein and F.T. Awbrey. 1990. Behavior and blood catecholamines of captive belugas during playbacks of noise from an oil drilling platform. *Zoo Biol.* 9(5):393-402.
- Thompson, P.O. 1965. Marine biological sound west of San Clemente Island. NEL Res. Rep. 1290. U.S. Navy Electronics Laboratory, San Diego, CA. 42 p.
- Turl, C.W. 1993. Low-frequency sound detection by a bottlenose dolphin. *J. Acoust. Soc. Am.* 94(5):3006-3008.
- Watkins, W.A. and W.E. Schevill. 1975. Sperm whales (*Physeter catodon*) react to pingers. *Deep-Sea Res.* 22: 123-129.
- Watkins, W.A., K.E. Moore and P. Tyack. 1985. Sperm whale acoustic behaviors in the southeast Caribbean. *Cetology* 49: 1-15.
- Würsig, B., C.R. Greene Jr. and T.A. Jefferson. 2000. Development of an air bubble curtain to reduce underwater noise of percussive piling. *Mar. Environ. Res.* 48: 1-15.
- 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. *Aquat. Mamm.* 24: 41-50.

Zaitseva, K.A., V.P. Morozov and A.I. Akopian. 1980. Comparative characteristics of spatial hearing in the dolphin *Tursiops truncatus* and man. *Neurosci. Behav. Physiol.* 10: 180-182 (Transl. from *Zh. Evol. Biokhim. Fiziol.* 14(1): 80-83, 1978).

***Response to e<sup>2</sup>M Request for Clarification and References – June 2007 (Data Gaps and Scoping)***

<b><i>Project Description and Alternatives</i></b>	
<b>64</b>	Appendix A: Archaeological Assessment, pages 3-6: In accordance with the U.S. Secretary of the Interior's Standards and Guidelines for Archaeology and Historic Preservation (48 FR 44716, September 29, 1983), standards set forth in Chapter 1A-46 of the Florida Administrative Code, and the Florida Division of Historical Resources' (FDHR's) Performance Standards for Submerged Remote Sensing Surveys (Version 2.1, last updated 05/17/01), provide a more fully developed cultural context that organizes the project area's cultural history into prehistoric and historic cultural themes with a chronologically arranged narrative of the prehistory and history of the project area and of the significant historical events or developments, including important individuals and institutions. The context provides a framework for making decisions about the evaluation, registration, and treatment of historic properties located within the Project Area of Potential Effect.
<b>Response</b>	This context is provided as an attached document.

# ARCHAEOLOGICAL ASSESSMENT

## HÖEGH LNG PROJECT

### PROPOSED LNG FACILITY AND PROPOSED 36-INCH GAS PIPELINE

#### BLOCK 545, ST PETERSBURG AREA, GULF OF MEXICO,

#### TO

#### TAMPA BAY, FLORIDA

#### ADDENDUM TO REPORT

### Geographic and Cultural Contexts

#### Geologic Setting

The project area is situated on the broad Gulf inner continental shelf off the west coast of Florida and extends into the shallow estuary of Tampa Bay, which is comprised of a system of interconnected bays and lagoons bordered by coastal barrier islands (Brooks and Doyle 1998). The present day coastal configuration has been determined by pre-Holocene geologic history (Hines et al. 2001; Hines 1997). Tampa Bay occupies a local structural depression that has most probably resulted from the dissolution of underlying limestones within the Florida Platform during the late Paleogene and early Neogene (Hine 1997). Seismic reflections indicate that a major east-west paleofluvial channel extended from beneath modern Tampa Bay, flowing north of Egmont Key, across the inner continental shelf to approximately 40 km (~24 miles) seaward of the present day coastline at Tampa Bay (Willis 1984; Duncan 1992; Hine 1997; Hine et al. 2001). Buried relict channeling in profiles from within the Bay appears extensively truncated with cut and fill structures (Brooks and Doyle 1998). Sediments near the modern coastline are predominantly quartz-sands which have contributed to the formation of the coastal barrier island system. Sediments that occupy the lower end of Tampa Bay are predominantly carbonate-rich, marine-derived sands and gravels derived from Pleistocene terrace deposits and biogenic carbonates that formed in situ or were transported in from the Gulf of Mexico (Doyle and Brooks 1998).

The seaward limit of the inner continental shelf has been defined along its western boundary by the 20-meter (~65-foot) isobath (Hine, et al. 2001). The quartz-sands of the nearshore sand belt that characterizes the inner shelf along the coastline thin to the west, trending, sometimes abruptly, into unconsolidated siliclastic-carbonates above a phosphatic, dolomitic limestone with a karst surface (Hine et al. 2001). These unconsolidated sediments along the inner continental shelf typically comprise thin units ranging from less than 1 meter to about 3 meters (~3 to 10 feet) thick (Brooks and Doyle 1998). Large expanses of the exposed limestone support benthic communities. On the inner shelf, aligned sinkholes and linear ridges and depressions have formed where the Tertiary limestones are exposed, both related to spring discharges that migrated landward during times of marine transgression (Hines 1997). Sediment facies generally parallel the coast. Hines et al. (1997) report that little active sinkhole development occurs today on the inner shelf. Quaternary sea level transgressions/regression sequences have effectively planed off the older topography, with the infilling of pits and depressions occurring during the Holocene marine transgression.

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Previous geological and archeological studies have examined the sea level fluctuations of the late Pleistocene and early Holocene epochs (Curry 1960; Coleman and Smith 1964; Scholl, Craighead, and Stuiver 1967; Colquhoun and Brooks 1986; Coastal Environments, Inc. 1977, 1982, 1986; Garrison 1992). While complexities and differences occur between models based on local studies (Colquhoun et al. 1981; Colquhoun and Brooks 1986), the Holocene marine transgression is generally summarized as a rapid rise from 14,000 years B.P. to 6,000 B.P., with a slower transgression marked by periodic fluctuations from 6,000 B.P. to the present. Dunbar et al. (1992) and Faught and Donoghue (1997) suggest that the 40-meter (~130-foot) isobath offshore the western coast of Florida (outside of the survey area) represents a Paleo Indian or "Clovis Shoreline." By about 3,000 B.P. sea level reached its current stand.

Between 5,000 and 3,000 B.P., in response to the declining rate of sea level rise, the barrier islands across the mouth of Tampa Bay began to take on their present configurations. The regional west coast study reported on by Hines et al. (2001:25) showed that the barriers essentially exhibit the same basic stratigraphy, that of development by initial upward shoaling on a Holocene bedrock foundation dating to about 4,000 B.P., followed by the aggradation of sediments, and in some areas, by the progradation of sediments.

Predictive models based on correlations between prehistoric archaeological sites and geomorphic landforms, that have been proposed by Coastal Environments, Inc. (1977, 1982, 1986), Colquhoun, et al. (1981), Aten (1983), Kraft, et al. (1983), Gagliano (1984), Dunbar et al. (1989a and 1989b, 1991), Faught (2003, 2004), Stright (1986, 1987, 1990) and others, suggest that submerged Paleo Indian and Archaic period sites in Florida may be associated with the natural levees, margins, point bars, and terraces of alluvial streams, the margins of bays, lakes and estuaries, sinkholes, and relict beach ridges. Numerous reports on investigations of Paleo Indian, Archaic, and later cultural occupations of now submerged landforms have examined these early land-man relationships off the coasts of Florida (Goggin 1964; Ruppe 1980; Stright 1987; Dunbar 1983, 1991; Dunbar, Webb, and Faught 1989; Murphy 1990; Milanich 1994:23). The identification of these or related landforms in presently submerged areas would represent high probability areas for the occurrence of prehistoric archeological sites.

Major features characterizing prehistoric site locations in coastal areas are accumulations of oyster (*Crassostrea virginica*) and clam (*Rangia cuneata*) shells, or shell middens. These commonly form large mounds, with some following linear trends of more than a half mile, and heights of more than 20 feet. The acoustic signature of such a site would be similar to that produced across a buried oyster reef: a high amplitude reflection on the upper surface with an acoustic void or wipe out below (CEI 1982; Berryhill, et al. 1984). In coastal areas, these mounds are found on the margins of channels and bays in brackish, or formerly brackish, water areas. Numerous sites have been recorded in coastal Florida. Their geographical location in relation to the bodies of water generally precludes their being mistaken for relict oyster reefs in the pinger or seismic profiles. At the scale used in the pinger profiles for this project, a large midden could be readily identified.

Migration of the shoreline and its related features resulted from marine transgression and regression sequences. Typically, as sea level rose, the formerly upland landscape evolved through a sequence of fringing marsh, estuaries and lagoons, beach ridges, and eventually seafloor. Inundated sites are subjected to erosion from wave action, longshore drift, and processes associated with barrier island formation and migration (Murphy 1990:13; CEI 1977; Emory and Edwards 1966). The seaward faces erode during marine transgression while back barrier marshes and lagoons covered by sediments derived from the overwash and migrating barriers tend to evidence better preservation (Belknap and Kraft 1981:430). Sites covered by sediments in a low-energy environment such as lagoons should be well preserved. Silts and clays provide greater cohesiveness and stability as a matrix surrounding site components and such sediments can delay or prevent degradation from oxidation and decay of organic remains (Stright 1986; Grebmeier 1983). Sites associated with sands and gravels, indicative of higher-



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energy environments, are not as likely to be preserved in situ, although prehistoric artifacts can be present as lag deposits.

Murphy's discussion of the processes impacting a combined historic shipwreck/Archaic Period underwater archaeological site, 8SL20, indicates that large dense objects will not be significantly laterally displaced, but will move vertically downward to rest on stable bottom sediments and are subsequently buried by increasingly less dense lighter sediments (Murphy 1990:15). Offshore sinkholes, similar to the Ray Hole Spring site situated in Federal waters about 32 km off the Florida Coast (Anuskiewicz 1988; Dunbar, Webb, Faught, Anuskiewicz and Stright 1989) may present in situ stratigraphy with associated archaeological features that describe environmental conditions and geohydraulic history at their time of subaerial exposure and during the subsequent inundation.

### Prehistoric Cultural Context

The archaeological culture history of this area has been presented in depth by numerous sources (Bense 1994, Milanich 1994, and others), with one of the earliest cultural syntheses provided by Gordan Willey in 1949, and for an introduction to inundated site potential, by John Goggin in 1947. More recent frameworks of the Paleo Indian and Archaic stages, which artifact assemblages would be represented off the present west Florida Gulf of Mexico coast, have been described by Ruppe (1980), Stright (1987), Dunbar, Webb, Faught, Anuskiewicz and Stright (1989); and Murphy (1990), among others. Because sea level reached its current stand about 3,000 B.P., archaeological cultural complexes younger than this date are unlikely to be present in now submerged areas and are not discussed in this report. However, it is possible that isolated finds of dugout canoes or artifacts used for exploiting marine resources by more recent cultures could be present.

The Paleo Indian stage is dated roughly to the period between about 12,000 and 8,000 B.P. The late Pleistocene period was characterized geographically by greatly lowered sea levels, with the Florida Gulf coastline located some 40 to 85 miles west of its present site (Faught 1996). Arid conditions prevailed with much lower groundwater tables. Many Paleo Indian sites in Florida are situated adjacent to Tertiary karst and Marginal Karst water sources represented by deep springs and still water retention basins, and a model for this settlement pattern, the Oasis model, has been proposed by James Dunbar and S. David Webb (Dunbar 1983, 1991; Webb, et al. 1984; Dunbar, Webb and Cring 1989), which built upon the earlier premise of Wilfred T. Neill (1964). Resources found at these sinks would have included chert sources and fauna. Clovis, Suwannee, and Simpson lanceolate projectile points are typical diagnostic tools, and are sometimes associated with the remains of Pleistocene megafauna. Evidence of now inundated sites dating from the Paleo Indian and Archaic stages has been found on the Continental Shelf off of the Big Bend region of Florida (Anuskiewicz 1988; Dunbar, Webb, Faught, Anuskiewicz and Stright 1989). Possible Paleo Indian shell middens in Tampa Bay have been reported on by Goodyear with others in 1972, 1980, and 1983. A prominent excavation of a Paleo Indian site in the Tampa Bay area was conducted at Harney Flats (Daniel and Wisenbaker 1987).

The Archaic Stage defines the cultures that adapted to the post-Pleistocene environmental changes and economic strategies necessitated by climatic shifts. Three stages have been defined: early Archaic from about 8,000 to 7,000 B.P., the middle Archaic from 7,000 to about 4,500 B.P., and the late Archaic from about 4,500 to about 3,200 B.P. (Bense 1994; Milanich 1994). Climatic conditions became wetter as a result of post glacial warming, and marine transgression inundated the Continental Shelf, reaching its current position some 3,000 years ago during the late Archaic stage. Pollen analyses reflect variations in local ecologies and the shift in coastal environments. With stabilizing and more easily accessible water sources, an increase in population occupying established base camps is associated with the early Archaic stage. In Florida, as elsewhere, the archaeological convention ends this tradition characterized by hunting and gathering with the development of more complex technologies, including ceramics; however,

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hunting and gathering strategies persisted along the Florida coast through later prehistoric cultures until European contact.

New technologies introduced during the Archaic Period reflect a more settled population, and include the use of more diverse lithic assemblages used for a multitude of tasks (Milanich 1994:65-75). Noted in the Archaic artifact assemblages are milling implements, hearths and baking pits, polished stone artifacts, mortuary rituals with cemeteries, including the earliest mound building, horticulture, textiles for clothing, nets, and baskets, and, at the end of the period during the transition to Late Prehistoric or Woodland period, the introduction of ceramics around 2,100 B.P. (Bense 1994; Mistovich 1994; Purdy 1981). Diagnostic lithic artifacts of the Early Archaic period include Bolen-Kirk, Dalton, and Kirk projectile points, while those of the Middle Archaic include Newnan and Eva points. The ceramic sequence on the upper northwest Florida coast begins about 2,100 B.P. with fiber tempered wares assigned to the Norwood series (Bense 1994; Mistovich 1994).

### Historical Context

Tampa Bay and its offshore approaches are the primary locations for possible shipwrecks, and many wrecks have been reported and documented in the bay and along the west Florida coast that are representative of vessels dating from the Spanish and British periods of European colonization, through the American period of colonization and immigration of the 19th century, to the present day. Colonial and historic period shipping routes commonly traversed this area, typically hugging the coast to provide access to trade and provisioning centers such as developed in Tampa, Pensacola, Mobile Bay, Biloxi, and Galveston (CEI 1977; Garrison et al. 1989). Overland transport of goods and materials was difficult until the mid and late 19th century when railroad and canal networks were established and the early 1900s when roads were improved.

Settlers were dependent upon a variety of different vessel types to support their transportation needs. For more than 200 years, many versions of canoes, skiffs, and flatboats were used for lightering goods and people in shoaler waters. Caravels, galleons, and frigates were the principal vessel types of the Spanish and British colonial periods. During the late 18th century and early 19th century, schooners were the principal sailing rigs used for fishing and the transport of passengers and freight, and were popular as pleasure craft. By the 1830s steamboats were becoming increasingly common offshore, as well as on the inland waterways.

Garrison et al. (1989) presented a regional historic framework for the northern Gulf of Mexico outlining historic and technological changes in their synthesis of archaeological, environmental, and geographic data relevant to shipwreck occurrence in the Gulf of Mexico. These periods include the New Spain Period (1500-1699), the Colonial period (1700-1803), the American Period (1803-1865), the Victorian Period (1866-1899), and the 20th Century Period (1900-present). As these periods have been well described in regional literature pertinent to the west coast of Florida (Tebeau 1914; WPA 1939; Dovell 1952; Gannon 1996;), as well as on a broader scale (Coastal Environments, Inc. 1977; Weddle 1985, 1991, 1995; Hoffman 1980), they are only briefly described below, incorporating particular references to the Tampa Bay area.

### New Spain Period (1500-1699)

This period chronicles the exploration, conquest and exploitation of New Spain in the lands bordering the northern Gulf of Mexico. In the early quarter of the 16th century, the northern Gulf Coast was discovered and explored on different occasions by Spanish navigators, the earliest being Ponce de Leon in 1513. Panfilo de Narvaez is credited with the first recorded exploration of Tampa Bay in 1528, followed by Hernando de Soto in 1539. By 1765, the Spanish had established the colony at St. Augustine.

During this period the Spanish fleet traversed the Gulf of Mexico from Vera Cruz to Havana following the the southeasterly tradewinds across the Gulf and the strong southward flow along

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the eastern margin of the Loop Current off the Florida west coast (Garrison et al. 1989). Trade centers onshore included the mouth of the Mississippi River, Mobile Bay, Pensacola, and Tampa. French exploration of the Gulf of Mexico and its borderlands is included in this period.

### **Colonial Period (1700-1803)**

The historical period of the 18th century and early 19th centuries led to the establishment of territorial claims along the Gulf coast by Spain, France, and Britain, with major Spanish posts on the east and west coasts of Florida. Rivalry was intense. In 1763, as an ally of France, Spain's holdings in Florida were ceded to the British by the First Treaty of Paris, which marked the end of the French and Indian War (in Europe, referred to as the Seven Years' War), and in turn, Britain returned Havana, Cuba, to Spain, which had been captured during the Seven Years' War. France also ceded the City of New Orleans, including the port and control of the Mississippi River, and all of French Louisiana west of the Mississippi River to the Spanish. Under the British, Florida was divided into two provinces, East Florida and West Florida, with administration centers, essentially small garrisons, established in St. Augustine and Pensacola. West Florida extended across the northern Gulf from west of the Apalachicola River to the Mississippi River's eastern bank north of Lake Pontchartrain. East Florida included the remainder of the present state of Florida, including Tampa Bay. Despite the northern borders of these colonies remaining in dispute, local economic development encouraged the emergence of a renewed maritime trade in the Gulf, with Spain, Britain and the Netherlands maintaining a strong presence (Chavez 2002).

During this period of British administration, the Creeks began emigrating to Florida from south Carolina and were joined by tribal remnants from the north, as well as runaway Negro slaves. The first Creeks, called Seminoles by the British, arrived in the Tampa Bay area about 1767.

During the last quarter of the 18th century, Spanish, French, and British rivalries were again in force. In response to the American colonies declaring independence from Great Britain in 1776, France began to provide troops, ships, and weapons to the northeastern colonies in 1778. In 1779, Spain's Carlos III commissioned the Louisiana Governor, Bernardo de Galvez, to organize attacks by land and sea against British holdings along the Gulf in Mobile and West Florida. These ultimately resulted in the capture of Pensacola from the British in 1781. Galvez expanded his efforts eastward, controlling the waterways to the Caribbean and Gulf of Mexico, which were considered essential to the Spanish Empire's valuable holdings in Mexico (Weddle 1992).

### **American Period (1803-1865)**

Although colonialization was encouraged under the second period of Spanish administration, which lasted until 1821, many of the emigrants to Florida were from the United States. The young country population was expanding westward from the seaboard states, as well as south into Florida. In response to the United States' purchase of the Louisiana Territory from France in 1803, American settlers in West Florida rebelled for independence from Spain, fearing appropriation of the territory by France, and were eventually ceded to the United States in 1810, at the end of the Napoleonic wars. The lands below the 31st parallel east of the Mississippi River and west of the Pearl River were annexed to Louisiana. Those lands between the Pearl and Perdido Rivers became a part of the Mississippi territory. Spain still held East Florida.

Following the defeat of Napoleon in 1810, England attempted to retain her colonial holdings in North America. To confirm a more solid footing in the southeast, the United States requested and was denied a base of military operations in East Florida, but seized Fernandina anyway. American settlers and the Seminole Indians rebelled against the British presence in North America, despite British capture and occupation of Pensacola in 1814, as well as Apalachicola. Continuing skirmishes between Americans in Florida and the Indians, who were believed to be backed by the Spanish, led to General Andrew Jackson recapturing Pensacola in 1818, which he had lost in 1814 after retreating to New Orleans. Eventually, the treaty of 1819 formally ceded East and West Florida to the United States, with the U.S. taking formal possession in 1821

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(Tebeau 1980). By this time East Florida's population was comprised of runaway slaves, renegade whites, Seminole allies of Britain, and other adventurers.

It was also during this time that maritime trade expanded across the Gulf (Garrison et al. 1989; Tebeau 1980). Pirates and patriots, with privateering covering any number of maritime encounters, supported the Gulf ports, especially in the New Orleans-Barataria region; Tampa Bay was also noted as a welcome harbor to the mariners (CEI 1977).

In 1821, the treaty exacted at the end of the First Seminole War allocated a large portion of south Florida in the Everglades to the Seminoles, who eventually settled east and southeast of Tampa. In 1824, Col. George M. Brooke of the U.S. Army selected a site at the mouth of the Hillsborough River on Tampa Bay to build a fort to help implement the terms of the 1823 Treaty of Fort Moultrie to implement the terms of the treaty. Between 1835 and 1842, the military was engaged in the Second Seminole War, based on boundary disputes and refusal of a large group of Seminoles to abandon Florida for lands west of the Mississippi. An uneasy truce prevailed until 1855 when Billy Bowlegs responded to a raid on his plantation by U.S. Army surveyors. The end of the Third Seminole Wars, characterized by three years of guerilla warfare by the Seminoles, resulted in the forceful migration of Chief Billy Bowlegs and other tribal members to reservations in Oklahoma, leaving several hundred in Big Cypress and other isolated parts of Florida.

The civilian settlement that eventually grew up around Fort Brooke ultimately developed into the town of Tampa Bay, when a post office was first constructed in 1831 (Garrison et al. 1989). Florida was accepted as a state in 1845. By 1855 Tampa was firmly established as a port, anchoring the eastern margin of the US maritime presence in the Gulf. This time period is often referred to as the "Golden Era" of the merchant marine of the US (Garrison et al. 1989). Tampa served as a major marketing port for American shipping activities supporting the export of local agricultural products produced by small and large farmsteads and plantations, including cotton, sugar, tobacco, cattle, lumber, and seafood (Sitterson 1953; Massey 1960; Tebeau 1985; Hilliard 1984). Manufactured goods and finished agricultural products were imported from the eastern United States and Europe (CEI 1977). Also during this period, the expanding network of railroads supported the growth of the timber and naval stores industry (Massey 1960) and the citrus industry realized moderate development, continuing an aspect of the Florida economy in place for more than 100 years (Ziegler and Wolfe 1961; Hilliard 1984).

In January 1861, Florida officially seceded from the Union, and Federal troops moved quickly to occupy forts and arsenals. The 20th Regiment of the Florida Militia was based at Fort Brooks. By 1864, Union troops had established a presence in Tampa and the harbor entrance to Tampa Bay had been blockaded since 1861. Few wrecks from the War period (1861-1865) are recorded within the survey area, although bombardments between U.S. Federal ships and Confederate blockade runners occurred at Gadsden Point and Fort Brooke (Garrison et al. 1989). However, the blockades imposed by the Federal Navy on southern ports around the Gulf resulted in a cessation of "normal" commerce in the Gulf. Successful blockade runners realized the high profits from delivering badly needed textiles, arms, and foodstuffs. In turn, beef, pork, fish, fruit and salt were supplied by local agrarians and industrialists in the vicinity of Tampa to the Confederate troops. In 1865, at the end of the war, President Andrew Johnson appointed a new provisional governor and the state government was reorganized and put into effect in 1868.

### **Victorian Period (1866-1899)**

Reconstruction led to thriving maritime activity, with coastal routes and trans-gulf direct routes followed by US merchant mariners as well as foreign based vessels. By 1885, the harbor at Tampa was improved by significant modifications to the channel, bay, and wharves, and was supported by a well established population and the south Florida railroad services (Smith, Miller, Kelley, and Harbin 1996). Phosphate, utilized as a fertilizer, was mined in the area and shipped from the port, becoming a major export. Cigar manufacturing was a key industrial development in Tampa, with Vicente Martinez Ybor, a tobacco processor establishing the industry in 1886 in what

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is now Ybor City. By 1884, industrialist Henry B. Plant finalized construction of the railroad connecting Tampa to Jacksonville and north Florida (Krieger 1998). Plant's construction of the fabulous Tampa Bay Hotel initiated an era of tourism promotion in Tampa. His steamship line further contributed to the stature of Tampa as a major Gulf port, connecting passengers and freight to U.S. and foreign ports around the Gulf and Caribbean.

By 1898, Spain's power and fortunes were in decline, and Cuba had been engaged in guerrilla rebellions for independence from Spain. The Cuban communities in Florida fully supported the cause for Cuban independence led by Jose Marti. The harbor at Tampa and a population of size enough to support military mobilization efforts facilitated the deployment of military troops and supplies during the Spanish-American War (1898), when Teddy Roosevelt led U.S. troops to Cuba to aid in their fight for independence. Although short lived, only a few months, the American victory led to the acknowledgment of the United States as a global power whose influence apparently knew few boundaries.

### **20th Century Period (1900-Present)**

The early 20th century saw the abandonment of commercial sailing craft, and the adoption of gasoline and diesel powered vessels. The railroad generally replaced sailing and steam vessels as a source of transportation for freight and passengers traveling along the Gulf Coastal Plain during the late 19<sup>th</sup> century, when initial development of the regional and national highway networks began (Pearson, et al. 1989). By 1900, steam and rail systems combined to provide the transportation networks necessitated by the expansion of settlements, tourism, and increase in industrial and agricultural activities, particularly vegetable truck farming and citrus production (Krieger 1998).

It was during the early part of the 20th century that Florida began to concertedly promote itself as a tourist destination, touting the mild climate and inexpensive housing (CEI 1977). Construction of a state road system, in tandem with the efficient railway coverage, encouraged the growth of tourism and the resulting expansion of the population base (Dovell 1952). A diversified economy, based on the expansion of agriculture and citrus cultivation as large-scale farming operations rather than smaller family farms, fishing, and, especially, tourism, was to continue to play a significant role in the development of the regional economy during the post-Depression years. It was during this first half of the 20<sup>th</sup> century that Florida exhibited an expansion of the industrial sector into shipbuilding. During World War I military training facilities were designated across Florida (Tebeau 1985; Dovell 1952). Commercial Gulf routes remained essentially the same, remaining unchanged until the threat of German U-boats during World War II brought about an awareness of coastal defense and considerable losses to the US merchant fleet.

Post 1950 maritime activities focused on the transport of agricultural and manufactured products in high volumes to other Gulf ports. Large deep water vessels mandated an on-going process of maintaining navigation by the dredging of the shallower passes to inland harbors and ports, modification of older passes, and the incision of new channels. Dredge spoil was commonly deposited offshore, as well as in shoaler waters of the Bay.

At the end of the 20<sup>th</sup> century, Tampa served as the largest port in Florida, and ranks eighth in volume tonnage in the United States. A number of cruise ship ventures depart the port for various locations in the Caribbean.

## ARCHAEOLOGICAL ASSESSMENT

### References

- Anuskiewicz, Richard J. 1988. Preliminary Archaeological Investigation at the Ray Hole Spring in the Eastern Gulf of Mexico. *Florida Anthropologist* 41:181-185.
- Aten, Lawrence. 1983. *Indians of the Upper Texas Coast*. Academic Press. New York, New York.
- Baurer, K. Jack. 1988. *A Maritime History of the United States*. University of South Carolina Press, Columbia.
- Berman, Bruce D. 1972. *Encyclopedia of American Shipwrecks*. The Mariners Press Incorporated. Boston, MA.
- Belknap, D.F. and J.C. Kraft. 1981. Preservation Potential of Transgressive Coastal Lithosomes on the U.S. Atlantic Shelf. *Marine Geology* 42:429-442.
- Bense, Judith A. 1994. *Archaeology of the Southeastern United States: Paleoindian to World War I*. Academic Press. San Diego, CA.
- Brooks, Gregg R. and Larry J. Doyle. 1998. Recent Sedimentary Development of Tampa Bay, Florida: A Microtidal Estuary Incised into Tertiary Platform Carbonates. *Estuaries*. Vol. 21, No. 3, pp. 391-406.
- Brown, Canter, Jr. 1996. The Civil War, 1861-1865. In *The New History of Florida*, edited by Michael Gannon. University Press of Florida, Gainesville.
- Bullen, R.P. 1975. *A Guide to the Identification of Florida Projectile Points*. Kendall Books. Gainesville, FL.
- Burgess, R.F., and C.J. Clausen. 1976. *Gold, Galleons, and Archaeology: A History of the 1715 Spanish Plate Fleet and the True Story of the Great Florida Treasure Find*. Indianapolis, Indiana.
- Central Gulf Coast Archaeological Society (The Tampa Bay Chapter of the Florida Anthropological Society). 1998. The Narvaez/Anderson Site (8Pi54): A Safety Harbor Culture Shell Mound and Midden – AD 1000 – 1600. Terrance L. Simpson, Principal Investigator. <http://www.cgcas.org/narvaez/>
- Chavez, T. E. 2002. *Spain and the Independence of the United States : An Intrinsic Gift*. University of New Mexico Press, Albuquerque.
- Church, Robert A., Laura A. Landry, Daniel J. Warren, and Jonathon S. Smith. 2003. The SS Alcoa Puritan: Deepwater Discovery and Investigation. Paper presented at the Underwater Intervention 2003 Conference, New Orleans.
- Clausen, Carl., H.K. Brooks, and A. B. Wesolowsky. 1975. Florida Spring Confirmed as 10,000-Year-Old Early Man Site. *Florida Anthropological Society Publications* 7. Gainesville, FL.
- Clausen, Carl., H.K. Brooks, and A. B. Wesolowsky. 1975. The Early Man Site at Warm Mineral Springs, Florida. *Journal of Field Archaeology* 2(3):191-213.
- Coastal Environments, Inc., (CEI). 1977. *Cultural Resources Evaluation of the Northern Gulf of Mexico*. Prepared for Interagency Archaeological Services, Office of Archaeology and Historical Preservation, National Park Service, U.S. Department of the Interior. Baton Rouge, Louisiana.

## ARCHAEOLOGICAL ASSESSMENT

Coastal Environments, Inc., (CEI). 1982. Sedimentary Studies of Prehistoric Archaeological Sites. Prepared for the Division of State Plans and Grants, National Park Service, U.S. Department of the Interior. Baton Rouge, Louisiana.

Coastal Environments, Inc., (CEI). 1986. Archaeological Investigations on the Outer Continental Shelf: A Study Within the Sabine River Valley, Offshore Louisiana and Texas. Prepared for the Minerals Management Service, U.S. Department of the Interior. Baton Rouge, Louisiana.

Coleman, J.M. and W.G. Smith. 1964. Late Recent Rise of Sea Level. Geological Society of America Bulletin 75:833-840.

Colquhoun, D.J. and M.J. Brooks. 1986. New Evidence from the Southeastern U.S. for Eustatic Components in the Late Holocene Sea Levels. Geoarchaeology 1 (3):275-291.

Colquhoun, D.J., M.J. Brooks, J. Michie, W.B. Abbott, F.W. Stapor, W. Newman, and R. Pardi. 1981. Location of Archaeological Sites with Respect to Sea Level in the Southeastern United States. Stria 14:145-150.

Cooke, C.W. 1945. Geology of Florida. Florida Geological Survey Bulletin No. 29. Tallahassee, Florida.

Curry, Joseph R. 1960. Sediments and History of Holocene Transgressions, Continental Shelf, Northwest Gulf of Mexico. In Recent Sediments, Northwest Gulf of Mexico, F. P. Shepard, et al., editors. American Association of Petroleum Geologists, Special Publication. Tulsa, Oklahoma.

Daniel, I. R., Jr., and M. Wisenbaker. 1987. Harney Flats: A Florida Paleo-Indian Site. Baywood Publishing Company, Inc. Farmingdale, NY.

Davis, William Watson. 1913 (1964). The Civil War and Reconstruction in Florida. Columbia University. New York. Reprint, University of Florida Press. Gainesville FL.

Derr, Mark. 1989. Some Kind of Paradise, A Chronicle of Man and the Land in Florida. William Morrow and Company, Inc. New York.

Dovell, J.E. 1952. Florida: Historic, Dramatic, Contemporary. 4 volumes. Lewis Historical Publishing Company, Inc. New York.

Duane, D.B. & Meisberger, E.P. 1969. Geomorphology and Sediments of the Near-shore Continental Shelf. U.S. Army Corps of Engineers. Washington, D.C.

Dunbar, J.S. 1983. A model for the Predictability of Clovis/Suwannee Paleo Indian Site Clusters in Florida—A Revival of the W. T. Neill's Oasis Hypothesis. Paper presented at the 35th Annual Meeting of the Florida Anthropological Society, Tallahassee.

Dunbar, J. S. 1991. Resource Orientation of Clovis and Suwannee Age Paleoindian Sites in Florida. In Clovis: Origins and Adaptations, edited by R. Bonnicksen and K. Turnmire, pp. 185-213. Sorvall: Center for the First Americans, Oregon State University.

Dunbar, J.S., M.K. Faught, and D.S. Webb. 1989. Culturally and Naturally Modified Bones from a Paleoindian Site in the Aucilla River, North Florida. In First International Bone Modification Conference, edited by R. Bonnicksen, pp. 473-497. Orono: Center for the Study of the First Americans, University of Maine.

Dunbar, J.S., S.D. Webb, and M. Faught. 1991. Inundated Prehistoric Sites in Apalachee Bay, Florida, and the Search for the Clovis Shoreline. In Paleoshorelines and Prehistory: An

## ARCHAEOLOGICAL ASSESSMENT

Investigation of Method, edited by Lucille Lewis Johnson, pp. 117-146. CRC Press, Boca Raton Florida.

Dunbar, J.S., S. D. Webb, M. Faught, R. J. Anuskiewicz, and M. Stright. 1989. Archaeological Sites in the Drowned Tertiary Karst Region of the Eastern Gulf of Mexico. Underwater Archaeology Proceedings from the Society for Historical Archaeology Conference, edited by J. Barto Arnold III, pp 25-31. Baltimore, Maryland.

Duncan, D. S. 1992. Neogene to Recent Seismic Stratigraphy of the lower Tampa Bay Estuary: West-Central Florida. Master's Thesis. University of south Florida, St. Petersburg.

Dunn, Hampton. 1985. Tampa: A Pictorial History. Donning Company Publishers. Virginia Beach, VA.

Emory, K.O. and R.L. Edwards. 1966. Archeological Potential of the Atlantic Continental Shelf. American Antiquity 31:733-737.

Faught, Michael K. 1996. Clovis Origins and Underwater Prehistoric Archaeology in Northwestern Florida. Ph.D. Dissertation, Department of Anthropology, University of Arizona, Tucson.

Faught, Michael K. 2004. The Underwater Archaeology of Paleolandscapes, Apalachee Bay, Florida. American Antiquity. Vol. 69, No. 2:235-249.

Faught, Michael K. 2003. Geophysical Remote Sensing and Underwater Cultural Resource Management of Submerged Prehisotric Sites in apalachee Bay: A Deep-Water Example, Site Predictive Models, and Site Discoveries. Proceedings: Twenty Second Annual Gulf of Mexico Information Transfer Meetings, 2002. Minerals Management Service, GOM, New Orleans, Louisiana.

Faye, S. 1940. Types of Privateer Vessels, their Armament and Flags, in the Gulf of Mexico. The Louisiana Historical Auqrterly 23:118-130.

Gagliano, Sherwood M. 1984. Geoarchaeology of the Northern Gulf Shore. In Perspectives on Gulf Coast Prehistory, Dave D. Davis, editor. University Presses of Florida, Gainesville, Florida.

Gannon, Michael V. 1996. The New History of Florida. University Press of Florida. Gainesville, FL.

Garrison, Ervin G., C. P. Giammona, F. J. Kelly, A. R. Tripp, and G. A. Wolff. 1989a. Historic Shipwrecks and Magnetic Anomalies of the Northern Gulf of Mexico: Reevaluation of Archeological Resource Management Zone 1. Volume II: Technical Narrative. OCS Study 89-0024. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Regional Office. New Orleans, Louisiana.

Garrison, Ervan G. 1992. Recent Archaeogeophysical Studies of Paleoshorelines of the Gulf of Mexico. In Paleoshorelines and Prehistory: An Investigation of Method. Lucille Lewis Johnson, editor, with Melanie Stright. CRC Press. Boca Raton, Florida.

Goggin, J.M. 1947. A Preliminary Definition of Archaeological Areas and Periods in Florida. American Antiquity 13:114-127.

Goggin, J. 1964. Florida Archeology and Recent Ecological Changes. In Indian and Spanish Selected Writings, pp. 299-309. University of Miami Press, Coral Gables.



## ARCHAEOLOGICAL ASSESSMENT

Goodyear, Albert C., and Lyman O. Warren. 1972. Further Observations on the Submarine Oyster Shell Deposits of Tampa Bay. *Florida Anthropologist* 25:52-66.

Goodyear, Albert C., Sam B. Uchurch, and Mark J. Brooks. 1980. Turtlecrawl Point: An Inundated Early Holocene Archeological Site on the West coast of Florida. In *Southeastern Geological Society Guidebook 22*, edited by Sam B. Upchurch, pp. 24-33. Tallahassee, FL.

Goodyear, Albert C., Sam B. Upchurch, Mark J. Brooks, and Nancy N. Goodyear. 1983. Paleoindian Manifestations in the Tampa Bay Region, Florida. *Florida Anthropologist* 36:40-66.

Grebmeier, Jacqueline M. 1983. Predictive Model for Marine Sites in Washington State, in *Proceedings Fourth Annual Gulf of Mexico Information Transfer Meeting*. Minerals Management Service, U. S. Department of the Interior. Metairie, Louisiana.

Hemphill, James E. 1998. *Beneath the Waters: A Guide to Civil War Shipwrecks*. Burd Street Press. Shippensburg, PA.

Hilliard, S. 1984. *Atlas of Antebellum Southern Agriculture*. Louisiana State University Press. Baton Rouge, LA.

Hine, A. C. 1997. Structural, stratigraphic, and paleoceanographic Development of the Margins of the Florida Platform. In *Geology of Florida*, edited by A. F. Randazzo and D. S. Jones. University Press of Florida.

Hine, A.C., Brooks, G.R., Davis, R.A., Jr., Doyle, L.J., Gelfenbaum, G., Locker, S.D., Twichell, D. C., and Weisberg, R.H. 2001. A Summary of Findings of the West-Central Florida Coastal Studies Project. USGS Open File Report 01-03.

Hoffman, Paul E. 1980. *The Spanish Crown and the Defense of the Caribbean, 1535-1585*. Louisiana State University Press. Baton Rouge, LA.

Hoffmeister, John. 1974. *Land From The Sea: The Geologic Story of South Florida*. University of Miami Press. Coral Gables.

Irion, Jack and Clell L. Bond. 1984. Identification and Evaluation of Submerged Anomalies, Mobile Harbor, Alabama. Prepared for the U.S. Army Corps of Engineers, Mobile District, NTIS Report Number COESAM/PD-EC-84-004. Espey Huston and Associates, Inc., Austin, Texas.

Irion, Jack B. 1986. Underwater Archaeological Investigations Mobile Bay Ship Channel. Prepared for the U.S. Army Corps of Engineers, Mobile District, NTIS Report Number COESAM/PSER-86-003. Espey Huston and Associates, Inc., Austin, Texas.

Irion, Jack B. 2001. Cultural Resource Management of Shipwrecks on the Gulf of Mexico Outer Continental Slope. Paper presented at the 2<sup>nd</sup> MIT Conference on Technology, Archaeology, and the Deep Sea. April, 2001.

Kraft, J.C., D.F. Belknap and I. Kayan. 1983. Potentials of Discovery of Human Occupation Sites on the Continental Shelves and Nearshore Coastal Zone. In *Quaternary Coastlines and Marine Archaeology*, edited by P.M. Masters and N.C. Flemming, pp. 87-120. Academic Press, London.

Krieger, Michael. 1998. *Where Rails Meet the Sea: America's Connection Between Ships and Trains*. Metro Books, Michael Friedman Publishing Group, Inc. New York.

Johnson, Cecil. 1942. *British West Florida, 1763-1783*. Yale University Press. New Haven, CN.

## ARCHAEOLOGICAL ASSESSMENT

Lyon, Eugene (1990) *The Enterprise of Florida - Pedro Menendez De Aviles and the Spanish Conquest of 1565-1568*. Gainesville, University of Florida Press.

Landry, Laura A. 1995. *Underwater Archaeological Survey of Panama City Harbor and Pass, Bay County, Florida*. Report submitted to the Mobile District U.S. Army Corps of Engineers, Mobile, Alabama.

Machel, Hans G. and Elizabeth A. Burton. Causes and Spatial Distribution of Anomalous Magnetization in Hydrocarbon Seepage Environments. In *AAPG Bulletin*, Vol. 75, No. 12.

Mahon, J. 1967. *History of the Second Seminole Indian War, 1835-1842*. University Press of Florida. Gainesville, FL.

Masters, P.M. and N.C. Flemming. 1983. *Quaternary Coastlines and Marine Archaeology*. Academic Press, London.

Marx, Robert. 1985. *Shipwrecks in Florida Waters*. The Mickler House. Chuluota, Florida.

Massey, Richard W. 1960. *A History of the Lumber Industry in Alabama and West Florida, 1880-1914*. Ph.D. Dissertation, Vanderbilt University.

McGoun, William E. 1993. *The Prehistoric Peoples of South Florida*. Birmingham, University of Alabama Press.

Milanich, J.T. 1994. *Archaeology of Precolumbian Florida*. University Press of Florida. Gainesville, Florida.

Milanich, J.T. and C.H. Fairbanks. 1980. *Florida Archaeology*. Academic Press. New York.

Missimer, T.M. 1984. The Geology of South Florida: A Summary. In *Environments of South Florida II*, edited by P.J. Gleason, pp. 385-404. Miami Geological Society, Coral Gables.

Murphy, L.E. 1990. 8SL17: Natural Site-Formation Processes of a Multiple-Component Underwater Site in Florida. Southwest Cultural Resources Center Professional Papers No. 39. Santa Fe, New Mexico.

Neill, Wilfred T. 1964. Trilisa Pond, An Early Site in Maanion County, Florida. *Florida Anthropologist* 17:187-200.

O'Connoer, Thomas J. 1980. The History of Maritime Trade in Florida. In *Florida's Maritime Heritage*, edited by Barbara Purdy. Florida State Museum,. Gainesville, FL.

Owsley, Frank Lawrence, Jr. 1980. *Struggle for the Gulf Borderlands: The Creek War and the Battle of New Orleans, 1812-1815*. University of Florida Press. Gainesville, FL.

Pearson, Charles E., George J. Castille, Donald Davis, Thomas E. Redard, and Allen R. Saltus. 1989. *A History of Waterborne Commerce and Transportation Within the U.S. Army Corps of Engineers New Orleans District and an Inventory of Known Underwater Cultural Resources*. Report submitted to the New Orleans District U.S. Army Corps of Engineers, New Orleans, Louisiana.

Pearson, Charles E. and Paul E. Hoffman. 1995. *The Last Voyage of El Nuevo Constante*. Louisiana State University Press. Baton Rouge, Louisiana.

## ARCHAEOLOGICAL ASSESSMENT

- Pearson, Charles, Stephen R., James, Jr., Michael C. Krivor, S. Dean El Darragi, and Lori Cunningham. 2003. Refining and Revising the Gulf of Mexico OCS Region High Probability Model for Historic Shipwrecks: Volumes I, II, and III. OCS Study/MMS 2003-060. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Regional Office, New Orleans, Louisiana.
- Potter, John (1988) The Treasure Divers Guide. Port Salerno, Florida Classics Press.
- Purdy, Barbara A. 1973. The Temporal and Spatial Distribution of Bone Points in the State of Florida. Florida Anthropologist 26:143-152.
- Purdy, Barbara A. 1981. Florida's Prehistoric Stone Tool Technology. University Press of Florida. Gainesville, FL.
- Purdy, Barbara A. 1988. Wet Site Archaeology. Telford. Caldwell, NJ.
- Purdy, Barbara A. 1996. How to do archaeology the Right Way. University Press of Florida. Gainesville, FL.
- Randazzo, Anthony F. and Douglas S. Jones. 1997. The Geology of Florida. University Press of Florida. Gainesville, FL.
- Rouse, I. 1951. A Survey of Indian River Archaeology, Florida. Yale University Publications in Anthropology 44. Yale University Press. New Haven, Connecticut.
- Ruppe, R.J. 1980. The Archaeology of Drowned Terrestrial Sites: A Preliminary Report. Florida Bureau of Historic Sites and Properties Bulletin 6:35-45.
- Sanford, S. 1909. Topography and Geology of Southern Florida. Florida Geological Survey 2nd Annual Report. Tallahassee, Florida.
- Scholl, David W., F. Craighead, and Minze Stuiver. 1967. Florida Submergence Curve Revisited: Its Relation to Coastal Sedimentation Rates. Science 163:562-64.
- Skowronek, Russell K. 1982. Trade Patterns of Eighteenth Century Frontier New Spain: The 1733 flota and St. Augustine. MA Thesis. Florida State University. Tallahassee FL.
- Siebert, W. 1929. Loyalists in East Florida. The Florida Historical Society. DeLand, FL.
- Singer, S.D. 1992. Shipwrecks of Florida. Pineapple Press, Sarasota, Florida.
- Sitterson, J. Carlyle. 1953. sugar country: The Cane Industry in the South, 1753-1950. University of Kentucky Press. Lexington, KY.
- Smith, Roger C. 1993. Vanguard of Empire: Ships of Exploration in the Age of Columbus. Oxford University Press. New York.
- Smith, Roger C., James J. Miller, Sean M. Kelley, Linda G. Harbin. 1997. An Atlas of Maritime Florida. Florida Bureau of Archaeological Research Division of Historical Resources. University press of Florida.
- Stright, M.J. 1986. Evaluation of Archaeological Site Potential on the Gulf of Mexico Continental Shelf Using High-Resolution Seismic Data. Geophysics 51 (3):605-622.

## ARCHAEOLOGICAL ASSESSMENT

Stright, M.J. 1987. Inundated Archaeological Sites of the Florida Coastal Region: A Regional Overview. Proceedings: Eighth Annual Gulf of Mexico Information Transfer Meeting. OCS-MMS 88-0035. New Orleans, Louisiana.

Stright, Melanie J. 1990. Archeological Sites on the North American Continental Shelf. In Archaeological Geology of North America, Centennial Special Volume 4, edited by Norman P. Lasca and Jack Donahue. The Geological Society of America. Boulder Colorado.

Taylor, Robert A. 1995. Rebel Storehouse: Florida in the Confederate Economy. University of Alabama Press. Tuscaloosa AL.

Tebeau, Charlton W. 1987. A History of Florida. Revised edition. University of Miami Press. Coral Gables, FL.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service.

U.S. Department of Commerce, National Ocean Service. 2007. Automated Wreck and Obstruction Information System. National Oceanic and Atmospheric Administration. Washington, D.C.

U.S. Department of the Interior, Minerals Management Service (USDI MMS). 2005. Notice to Lessees 2005-G07. Gulf of Mexico, OCS Regional Office. New Orleans, Louisiana.

U.S. Department of the Interior, Minerals Management Service (USDI MMS). 2006. Notice to Lessees 2006-G07. Gulf of Mexico, OCS Regional Office. New Orleans, Louisiana.

U. S. Department of the Interior, Minerals Management Service (USDI MMS). 1983. Visual 2. Geologic and Geomorphic Features. Gulf of Mexico, OCS Regional Office. Metairie, Louisiana.

U.S. Department of the Interior, Minerals Management Service (USDI MMS). 1983. Visual 3. Bottom Sediments and Endangered and Threatened Species. Gulf of Mexico, OCS Regional Office. New Orleans, Louisiana.

U.S. Department of Transportation, U.S. Coast Guard. 2001. Local Notices to Mariners. Seventh Coast Guard District. Miami, Florida.

Warren, L.O. 1964. Possibly Submerged Oyster Shell Middens of Upper Tampa Bay. Florida Anthropologist 17:227-230.

Waters, Michael R. 1992. Principles of Geoarchaeology: A North American Perspective. The University of Arizona Press.

Webb, S.D. 1974. Pleistocene Mammals of Florida. University of Florida Presses. Gainesville, FL.

Webb, S. David, Jerald T. Milanich, Roger Alexon, and James S. Dunbar. 1984. A *Bison Antiquus* Kill Site, Wacissa River, Jefferson County, Florida. American Antiquity 49:384-392.

Weddle, R.S. 1985. Spanish Sea: The Gulf of Mexico in North American Discover, 1500-1685. Texas A&M University Press. College Station, TX.

Weddle, R.S. 1991. The French Thorn: Rival Explorers in the Spanish Sea, 1682-1762. Texas A&M University Press. College Station, TX.

## ARCHAEOLOGICAL ASSESSMENT

Weddle, R.S. 1995. *Changing Tides: Twilight and Dawn in the Spanish Sea, 1763-1803*. Texas A&M University Press. College Station, TX.

Wiley, Gordan R. 1998. *Archaeology of the Florida Gulf Coast*. University Press of Florida. Gainesville, FL.

Works Progress Administration (WPA). 1939. *Florida: A Guide to the Southernmost State*. New York, NY.

Ziegler, Louis W., and Herbert S. Wolfe. 1961. *Citrus Growing in Florida*. University of Florida Press. Gainesville, FL.

***Response to e<sup>2</sup>M Request for Clarification and References – June 2007 (Data Gaps and Scoping)***

<b><i>Project Description and Alternatives</i></b>	
<b>65</b>	Appendix A: Archaeological Assessment, Conclusions and Recommendations, page 13: Provide a stand-alone Unanticipated Discovery Plan and protocol outlining specific step-by-step procedures (developed in consultation with SHPO) representing the basis of the approach that Port Dolphin will use to address unanticipated discoveries of possible archaeological sites and/or human remains during the construction process within the project's Area of Potential Effect.
<b>Response</b>	Please find attached the Unanticipated Discovery Plan.

**Unanticipated Discovery Plan – Cultural Resources  
Port Dolphin LLC  
Deepwater Port and Proposed 36-Inch Gas Pipeline  
St. Petersburg Area Block 545 to Tampa Bay, Florida**

Port Dolphin Energy LLC (Applicant) has undertaken a systematic review of the high resolution geophysical data for the proposed project area to minimize the discovery of cultural resources, either in the form of historic shipwrecks or high probability areas for prehistoric archaeological sites, that follows the guidelines posted in U.S. Department of the Interior Minerals Management Service (USDI MMS) Gulf of Mexico OCS Region NTL 2006-G07 and standards for cultural resources in the state of Florida. This assessment has been prepared because the proposed Port Dolphin deepwater port and pipeline is within portions of St. Petersburg blocks of the Outer Continental Shelf and Florida State Waters that have been designated as having a high potential for archaeological resources as described in the USDI MMS Gulf of Mexico OCS Region NTL 20065-G07. The following applicable statutes of the state of Florida concern Cultural resources:

Chapter 267 F.S., Florida Historical Resources Act

Emergency Archaeological Properties Acquisition Act of 1988  
(Chapter 253.027, Florida Statutes)

Offenses Concerning Dead Bodies and Graves (Chapter 872,  
Florida Statutes)

Performance Standards for Submerged Remote Sensing  
Surveys (May 17, 2001) issued by the Florida Department of  
State, Division of Historical Resources

The cultural resources assessment of these areas of potential effect did find evidence for potential historic and prehistoric cultural resources in the remote sensing data. These included three unidentified side scan sonar contacts and 15 unidentified magnetic anomalies as possibly significant historic cultural resources and buried relict fluvial channels that would represent high probability areas for prehistoric sites. The designation of avoidance zones around these features has been recommended.

However, it is possible that small features representing high probability areas for prehistoric archaeological sites and historic shipwreck materials may not be detected by the geophysical instruments or may not be detected during interpretation of the data sets. Prehistoric archaeological sites have been discovered in nearshore Florida State and OCS waters previously (Goggin 1964; Ruppe 1980; Stright 1987; Dunbar, Webb, and Faught 1989; Anuskiewicz 1988; Dunbar, Webb, Faught, Anuskiewicz and Stright 1989; Murphy 1990; Milanich 1994:23). Recently, historic period cultural resources have been discovered offshore during the process of post development inspections, rather than during the predevelopment phases in areas not determined to have a high potential for archaeological resources (Irion, 2001; Church, Landry, Warren and Smith, 2003). In order to be in full compliance with all Federal and Florida State regulations regarding the protection of cultural resources, this unanticipated discovery plan has been prepared.

Port Dolphin LLC is fully aware that the USDI MMS has posted guidelines for the conduct of investigations at the USDI MMS Internet website at <http://www.gomr.mms.gov/homepg/regulate/envIRON/archaeological/evaluation.html> and that failure to comply with the USDI MMS regulations with respect to archaeological resources can result in civil penalties under 0 CFR 250.1404. In addition, Section 110(k) of the National Historic Preservation Act (16 U.S.C. 470h-2[k]) prohibits a Federal agency from granting a loan, loan guarantee, permit, license, or other assistance to an applicant who, with the intent to avoid the requirements of Section 106 of the Act, has intentionally, significantly, and adversely affected a historic property to which the grant would relate, or having legal power to prevent it, has allowed

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such adverse effect to occur, unless the agency, after consultation with the Advisory Council for Historic Preservation, determines that circumstances justify granting such assistance despite the adverse effect created or permitted by the applicant (see 36 CFR 800.9[c][1]).

All project inspectors have the responsibility to monitor development and post development procedures for the inadvertent discovery of cultural resources. If during any of these phases, evidence of prehistoric or historic cultural remains is encountered, all activity in that area will cease immediately to preclude any further contact or damage to the resource (36 CFR 800.11 [b][3]). An avoidance zone of at least 1,000 feet (305 meters) for further work in that area will be established. If the cultural resource is discovered during the course of an investigation by a remotely operated vehicle (ROV), the USDI MMS has posted guidelines for the conduct of ROV investigations at the following web site

**[http://www.gomr.mms.gov/homepg/regulate/environ/archaeological/ROV\\_2005\\_1.pdf](http://www.gomr.mms.gov/homepg/regulate/environ/archaeological/ROV_2005_1.pdf)**. All ROV operators will be provided with these guidelines and will be required to comply with them. At no time will the ROV operators be permitted to disturb or pick up any artifacts, features, or components of the site.

If a discovery is made in Federal waters, the project inspector within 48 hours of the discovery will contact the Regional Supervisor, Leasing and Environment, and the archaeologists at the USDI MMS in New Orleans, as well as the U.S. Coast Guard (USCG), to notify them of the presence of such a cultural resource. If a discovery is made in Florida state waters, within the same period of time the project inspector will contact the State Historic Preservation Officer of Florida. After the initial consultation with the appropriate agencies, Port Dolphin LLC will contract an approved professional archaeologist to survey the findings and provide an immediate report to the appropriate agencies describing the type of resource discovered and its location and size. Such findings may include the following:

- Anomalous and distinct mounds of lithic material, which could represent ballast material from a shipwreck
- Intact articulated wooden ship timbers or sections of iron, steel, or metal clad hulls
- Substantial cargo remains, which may be scattered or closely grouped, that may include armaments, ammunitions, wooden crates and barrels, ceramics, glass, and other cultural materials, some of which may be heavily concreted and not readily identifiable
- A widely scattered debris field comprised of ship's rigging and other structural components, as well as cargo
- Anomalous mounds of mollusk shell that may include prehistoric lithic or worked shell material
- Human skeletal remains

A mitigation plan conducted under the direction of a professional archaeologist and using such equipment and techniques deemed necessary will be developed with the appropriate agencies to ascertain the eligibility of the resource for inclusion in the National Register of Historic Places. If the resource is determined to be ineligible for inclusion in the National Register of Historic Places, Port Dolphin LLC will proceed with the project only after written notification of compliance from the USDI MMS and the USCG or the Florida State Historic Preservation Officer. If the site is determined eligible for inclusion in the National Register of Historic Places, additional work that may include formal data recovery and the preparation of a determination of eligibility will be



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Port Dolphin LLC  
Deepwater Port and Proposed 36-Inch Gas Pipeline  
St. Petersburg Area Block 545 to Tampa Bay, Florida**

performed as required and approved by the appropriate agencies. Further work at the location of the discovery will be suspended until clearance to proceed is granted by the USDI MMS and the USCG or the Florida State Historic Preservation Officer.

The U.S. Department of the Interior Minerals Management Service contacts are listed below.

U.S. Department of the Interior  
Minerals Management Service  
Gulf of Mexico OCS Region  
Office of Leasing and Environment  
Attention: Social Sciences Unit (5411)  
1201 Elmwood Park Blvd.  
New Orleans, Louisiana 70123-2394

Dr. Jack Irion, (504) 736 1742, [jack.irion@mms.gov](mailto:jack.irion@mms.gov)

Mr. David Ball, (504) 736 2859, [david.ball@mms.gov](mailto:david.ball@mms.gov)

Dr. Chris Horrell, (504) 736 2796, [christopher.horrell@mms.gov](mailto:christopher.horrell@mms.gov)

The Florida State Historic Preservation Officer contact is listed below:

Frederick P. Gaske  
State Historic Preservation Officer  
or  
Barbara E. Mattick  
Deputy State Historic Preservation Officer

Bureau of Historic Preservation  
R.A. Gray Building, 4<sup>th</sup> Floor  
500 South Bronough St.  
Tallahassee, FL 32399-0250  
(850) 245 6333

**Unanticipated Discovery Plan – Cultural Resources  
Port Dolphin LLC  
Deepwater Port and Proposed 36-Inch Gas Pipeline  
St. Petersburg Area Block 545 to Tampa Bay, Florida**

**References**

- Anuskiewicz, Richard J. 1988. Preliminary Archaeological Investigation at the Ray Hole Spring in the Eastern Gulf of Mexico. *Florida Anthropologist* 41:181-185.
- Dunbar, J.S., S. D. Webb, M. Faught, R. J. Anuskiewicz, and M. Stright. 1989. Archaeological Sites in the Drowned Tertiary Karst Region of the Eastern Gulf of Mexico. *Underwater Archaeology Proceedings from the Society for Historical Archaeology Conference*, edited by J. Barto Arnold III, pp 25-31. Baltimore, Maryland.
- Goggin, J. 1964. Florida Archeology and Recent Ecological Changes. In *Indian and Spanish Selected Writings*, pp. 299-309. University of Miami Press, Coral Gables.
- Irion, Jack B. 2001. Cultural Resource Management of Shipwrecks on the Gulf of Mexico Outer Continental Slope. Paper presented at the 2<sup>nd</sup> MIT Conference on Technology, Archaeology, and the Deep Sea. April, 2001.
- Milanich, J.T. 1994. *Archaeology of Precolumbian Florida*. University Press of Florida. Gainesville, Florida.
- Murphy, L.E. 1990. 8SL17: Natural Site-Formation Processes of a Multiple-Component Underwater Site in Florida. Southwest Cultural Resources Center Professional Papers No. 39. Santa Fe, New Mexico.
- Stright, M.J. 1987. Inundated Archaeological Sites of the Florida Coastal Region: A Regional Overview. *Proceedings: Eighth Annual Gulf of Mexico Information Transfer Meeting*. OCS-MMS 88-0035. New Orleans, Louisiana.
- Stright, Melanie J. 1990. Archeological Sites on the North American Continental Shelf. In *Archaeological Geology of North America, Centennial Special Volume 4*, edited by Norman P. Lasca and Jack Donahue. The Geological Society of America. Boulder Colorado.

**Response to e<sup>2</sup>M Request for Clarification and References – June 2007 (Data Gaps and Scoping)**

<i>Project Description and Alternatives</i>	
<b>66</b>	Deepwater Port License Application – Section 5 (Cultural Resources), 5.1.1 - Federal, page 5-7, paragraph 4: Provide a reference(s) for the MMS baseline studies defining the areas in which the Port Dolphin project is located as “high-probability areas for prehistoric and historic cultural resources”.
<b>Response</b>	<ol style="list-style-type: none"> <li>1. Coastal Environments, Inc., (CEI). 1977. Cultural Resources Evaluation of the Northern Gulf of Mexico. Prepared for Interagency Archaeological Services, Office of Archaeology and Historical Preservation, National Park Service, U.S. Department of the Interior. Baton Rouge, Louisiana.</li> <li>2. Garrison, Ervin G., C. P. Giammona, F. J. Kelly, A. R. Tripp, and G. A. Wolff. 1989a. Historic Shipwrecks and Magnetic Anomalies of the Northern Gulf of Mexico: Reevaluation of Archeological Resource Management Zone 1. Volume II: Technical Narrative. Volume III: Appendices. OCS Study 89-0024. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Regional Office. New Orleans, Louisiana.</li> <li>3. Irion, Jack B. 2001. Cultural Resource Management of Shipwrecks on the Gulf of Mexico Outer Continental Slope. Paper presented at the 2<sup>nd</sup> MIT Conference on Technology, Archaeology, and the Deep Sea. April, 2001.</li> <li>4. Pearson, Charles, Stephen R., James, Jr., Michael C. Krivor, S. Dean El Darragi, and Lori Cunningham. 2003. Refining and Revising the Gulf of Mexico OCS Region High Probability Model for Historic Shipwrecks: Volumes I, II, and III. OCS Study/MMS 2003-060. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Regional Office, New Orleans, Louisiana.</li> <li>5. U.S. Department of the Interior, Minerals Management Service (USDI MMS). 2006. Notice to Lessees 2006-G07. Gulf of Mexico, OCS Regional Office. New Orleans, Louisiana.</li> </ol>

***Response to e<sup>2</sup>M Request for Clarification and References – June 2007 (Data Gaps and Scoping)***

<b><i>Project Description and Alternatives</i></b>	
<b>67</b>	Deepwater Port License Application – Section 5 (Cultural Resources), 5.2.2 - Historic Cultural Resources, pages 5-9 and 5-10, paragraph 2: No reference is made to archival research being conducted at the Florida Division of Historical Resources (FDHR), as required by Section (1) Archival Research - of the FDHR's Performance Standards for Submerged Resource Surveys (Version 2.1 – last updated 05/17/01). Was this research conducted? If so, add a statement to the report that this research was conducted and provide copies of FDHR correspondence to document compliance with Section (1)(b) of the FDHR standards.
<b>Response</b>	This research was conducted. There is no correspondence with the FDHR.

**Response to e<sup>2</sup>M Request for Clarification and References – June 2007 (Data Gaps and Scoping)**

<b><i>Project Description and Alternatives</i></b>	
<b>68</b>	<p>Archaeological, Engineering &amp; Hazard Survey report, page 4, paragraphs 1 and 2: the reported 100-kHz side scan sonar frequency settings are inconsistent with those reported in the Appendix A: Archaeological Assessment, and Deepwater Port License Application – Section 5 (Cultural Resources) documents, which state the side scan sonar operating frequencies at 100 and 500 kHz. Provide confirmation as to which documented side scan sonar frequency setting is correct.</p> <p>Appendix A: Archaeological Assessment, page 1: in-text references to Minerals Management Service (MMS) Notice to Lessees (NTL's) are incorrect and should be referenced as NTL's 2005-G07 and 2006-G07.</p>
<b>Response</b>	<p>Archaeological, Engineering &amp; Hazard Survey report, page 4, paragraphs 1 and 2 should read: <i>with a frequency setting of 100 kHz and 500 kHz</i>. A Klein System 3000 Dual frequency 100 kHz and 500 kHz digital side scan sonar was used in both the offshore and Tampa Bay surveys and is documented in the Survey Personnel, Equipment, Vessel and Sensor Configuration section in Appendix E.</p> <p>Corrections regarding the Appendix A: Archaeological Assessment, page 1: in-text references to Minerals Management Service (MMS) Notice to Lessees (NTL's) are incorrect and should be referenced as NTL's 2005-G07 and 2006-G07 as USCG elucidated and as is correct.</p>

**Response to e<sup>2</sup>M Request for Clarification and References – June 2007 (Data Gaps and Scoping)**

<i>Project Description and Alternatives</i>	
<b>69</b>	<p>Appendix A: Archaeological Assessment, Conclusions and Recommendations, page 3: provide an explanation for the rationale for using a 100-m track line spacing in the buoy mooring area relative to MMS's apparently conflicting track line spacing requirement of 50 m or less in high-probability areas for prehistoric and historic cultural resources waters less than 200 m deep (the buoy area is ca. 117 ft deep), as described in Appendix 1 of MMS NTL 2005-G07, and the 300 m track line spacing requirement for St. Petersburg Area Blocks 545 and 589 (where the buoy area is located) listed in MMS NTL 2006-G07.</p>
<b>Response</b>	<p>MMS NTL 2005-G07 states “To determine whether you need to conduct an archaeological resource survey (as authorized by <a href="#">250.203(o)</a>, <a href="#">250.204(s)</a>, and <a href="#">250.1007(a)(5)</a>) and submit an archaeological resource report (as required by <a href="#">250.203(b)(15)</a>, <a href="#">250.204(b)(8)(v)(A)</a>, and <a href="#">250.1007(a)(5)</a>), consult the list on the MMS Internet website at: <a href="http://www.gomr.mms.gov/homepg/regulate/environ/archaeological/surveyblocks.pdf">http://www.gomr.mms.gov/homepg/regulate/environ/archaeological/surveyblocks.pdf</a>. The website listing serves as the written notification the MMS GOMR makes according to <a href="#">30 CFR 250.194(a)</a>. Conduct the survey and prepare the report if the OCS block(s) covered by your lease or pipeline right-of-way appears on the list.”</p> <p>The list that is referenced is in fact the appendix to NTL 2006-G07. MMS NTL 2006-G07 specifies line spacing to be used for Archaeological Surveys in St. Petersburg blocks 545 and 589 be 300 meters. Thus this is the requirement levied by MMS based on its assessment of whether or not these blocks are high-probability for historical and cultural resources. This is supported by language in NTL 2005-G07 Appendix I Section III which says “The MMS Internet website list will tell you whether to conduct the archaeological resource survey at a line spacing of no more than 50 meters (164 feet) or no more than 300 meters (984 feet). For OCS blocks that have a high probability for containing historic resources in water depths 200 meters or less, the survey line-spacing interval is no more than 50 meters. For OCS blocks that have a high probability for containing prehistoric archaeological resources, or historic resources in water depths greater than 200 meters (656 feet), the survey line-spacing interval is no more than 300 meters.” There does not appear to be a conflict in the language of these NTLs since the 50 meter line spacing is not only dependent upon water depth but also the probability of containing resources. The Appendix to MMS NTL 2006-G077 <a href="http://www.gomr.mms.gov/homepg/regulate/environ/archaeological/surveyblocks.pdf">http://www.gomr.mms.gov/homepg/regulate/environ/archaeological/surveyblocks.pdf</a> requires a maximum 300-meter line spacing for St. Petersburg Area Blocks 545 and 589, which are considered to be high probability areas for prehistoric sites. While historic shipwrecks could occur in these blocks, they are not considered high probability areas for historic cultural resources. Lines surveyed in these blocks cannot be spaced more than 300 meters apart but may be spaced more closely.</p> <p>Therefore the governing NTL for these blocks states that the maximum required line spacing be 300 meters. The 100-meter line spacing used in St. Petersburg Area Blocks 545 and 589 provides a greater degree of sampling over these blocks while following the requirements of NTL 2005-G07 requiring complete sonar coverage of the seafloor.</p>

**Response to e<sup>2</sup>M Request for Clarification and References – June 2007 (Data Gaps and Scoping)**

<b><i>Cultural Resources</i></b>	
70	The Introductory paragraphs of Resource Report 4 should clarify that the corridor surveyed by SEARCH, Inc., was restricted to the route specified as Option A in the application. Further, it should be noted that the cultural resources survey corridor did not include any extra works spaces or staging areas, apart from the footprints specified for the Gulfstream and TECO interconnection stations and the valve station.
<b>Response</b>	<p>Below is the referenced introductory paragraph of Resource Report 4 modified to provide the requested clarifications.</p> <p>The APE for Port Dolphin Pipeline is 5.8 miles (30,797.06 feet) long. The western end of the Pipeline corridor begins at the pier bulkhead at Port Manatee and traverses 3.68 miles (19,454.68 feet) to an interconnect with the Gulfstream Natural Gas System, LLC pipeline system and an additional 2.14 miles (11,342.38 feet) through the TECO Interconnection Station to the proposed TECO Bayside Gate Station near I-75. The APE was restricted to the route specified as Option A or the Preferred Route A in the application and was defined as the length of the corridor and a 50-foot buffer on both sides of the Pipeline centerline. There are three rectangular areas in addition to this corridor. One area lays approximately half way along the Pipeline route beside the Buckeye Road: the Gulfstream Interconnection Station. This area is 250 feet by 400 feet and is approximately 2.3 acres. The other two areas are located near the eastern end of the Pipeline corridor and represent the TECO Interconnection Station. The TECO Interconnection Station is a 200 foot by 200 foot square comprising approximately 0.92 acres. Therefore, the APE for the Pipeline cultural resource survey measures 5.8 miles (30,797.06 feet) with the 50-foot buffer, and, combined with the three rectangular areas, totals approximately 72.4 acres. This survey corridor does not include any extra work spaces or staging areas. Once the final staging and pullout areas have been determined, they will be reviewed by the cultural resource specialists to ensure that they have been adequately sampled. Further investigation and sampling will be executed as required</p>

***Response to e<sup>2</sup>M Request for Clarification and References – June 2007 (Data Gaps and Scoping)***

<b><i>Cultural Resources</i></b>	
71	At some point, potentially on the cover page for Resource Report 4, it should be clarified that the maps provided by the applicant in Exhibit F were prepared subsequent to the cultural resources survey (maps in Exhibit 4 are dated March 2007, whereas the cultural resources survey fieldwork was conducted in January 2007). The need for a clarifying remark stems from the depiction of numerous extra work spaces on the maps in Exhibit F that are not depicted on the maps in Resource Report 4.
<b>Response</b>	Attached is a page to be inserted into Resource Report 4 to address the concern.



*The maps included in Exhibit F of the Application were finalized subsequent to the completion of the Preferred Route A corridor cultural resource survey. Therefore, the survey corridor represented in this report does not include any extra work spaces or staging areas. Prior to the installation of the pipeline along this corridor, the final staging and pullout areas will be reviewed by the cultural resource specialists to ensure that they have been adequately sampled. Further investigation and sampling will be executed as required.*

**Response to e<sup>2</sup>M Request for Clarification and References – June 2007 (Data Gaps and Scoping)**

<b><i>Cultural Resources</i></b>	
72	Examination of the locations of extra works spaces shown on the maps in Exhibit F suggest that additional cultural resource surveys will be required for some of the workspaces. In particular, the work space for Drill #1, depicted on the drawing for the South Dock Road Crossing, falls outside of the survey corridor. It also was not included in the survey area for previous surveys. Similarly, the extra work space shown to the east of the pipeline corridor on Figure 1-10 (Drawing 26017-D-2304) falls outside of the current survey corridor and that of previous surveys. Please describe how this additional survey work will be accomplished
<b>Response</b>	<p>The defined extra work spaces, staging areas and drill entry and exit corridors will be reviewed by cultural resource specialists. These additional areas will be georeferenced with the subsurface excavations conducted for the Preferred route A corridor recently surveyed, and with past surveys. A map of the soil drainage characteristics similar to Figure 4-3 submitted with the Report 4 will be produced for the additional areas to ascertain the probability of cultural resources being present on the differing additional areas. Areas of high archaeological probability usually contain better drained soils combined with access to water resources.</p> <p>Once the background research on the additional areas has been completed, a pedestrian and subsurface sampling strategy will be designed to adequately test these areas. The background research, sampling strategy and results will be presented in a Technical Addendum to the Resource Report 4 of the Port Dolphin Pipeline application. This Technical Addendum will conclude with recommendations for or against further cultural resource work within the additional areas.</p>

***Response to e<sup>2</sup>M Request for Clarification and References – June 2007 (Data Gaps and Scoping)***

<b><i>Project Description and Alternatives</i></b>	
<b>73</b>	At what point will the locations of all remaining work spaces and staging areas be defined?
<b>Response</b>	Port Dolphin has completed defining the proposed extra work spaces and areas for staging materials and equipment. Drawings identifying these spaces were included in Exhibit F of the FERC filing documents. These drawings are attached. However, Port Dolphin is currently looking at alternative routing for the terrestrial portion of the pipeline and the extra work spaces are subject to change.



4 ACRES  
CONCRETE  
MATTRESS PLANT  
AND STORAGE AREA

5 ACRES  
ADDITIONAL AREA FOR  
CONCRETE PIPE COATING  
PLANT AND STORAGE AREA

25 ACRES  
CONCRETE PIPE  
COATING PLANT AND  
STORAGE AREA

NOTES:  
THE ACRES SHOWN FOR EACH AREA ARE  
CONCEPTUAL ONLY, THEREFORE THE FINAL  
CONFIGURATIONS ARE SUBJECT TO CHANGE.

SEE SHEET  
26017-A-7014

EXISTING GULFSTREAM PIPELINE

EXISTING

BORE

OPEN TRENCH

REFERENCE DRAWINGS

REVISIONS

DRAWING STATUS

SCALE N/A



TITLE  
CONCRETE PLANTS & STORAGE AREAS  
AT PORT MANATEE  
PORT DOLPHIN PIPELINE  
MANATEE COUNTY, FLORIDA

NO. 26017-B-7801

REV. B



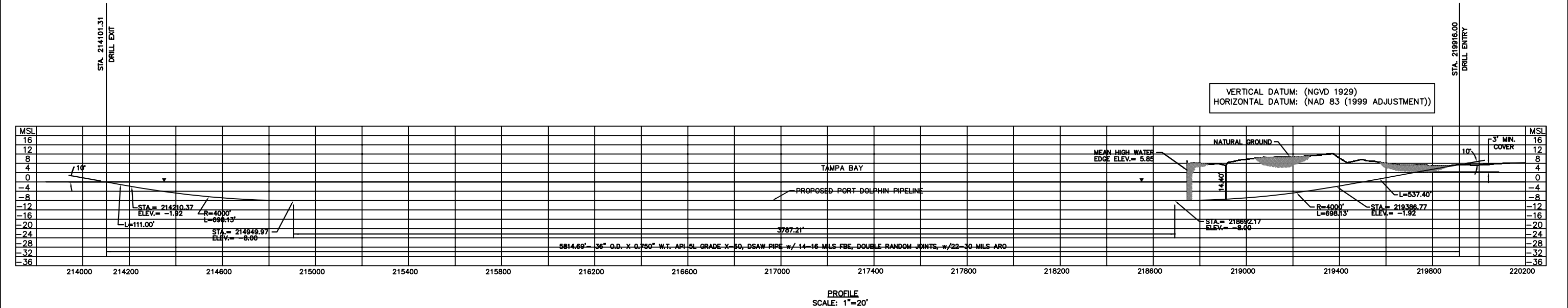
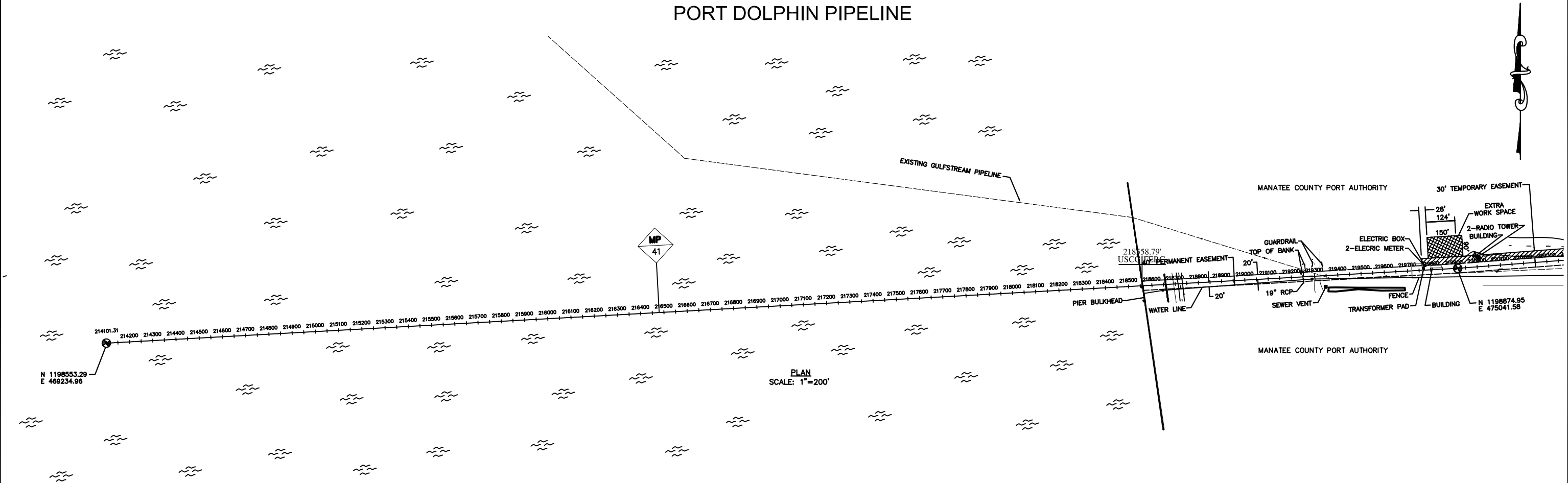
13831 NORTHWEST FRWY. #312  
HOUSTON, TEXAS 77040  
BUS: (713) 690-9111  
FAX: (713) 690-0060

ISSUED FOR	DATE	BY
BID		
CONST.		
AS- BUILT		



DRAWN EHF	DATE 8/01/07
CHK'D DJR	DATE 8/01/07
APPROVED	
PEST JOB NO.	26017
AFE/P.O.ND.	
CLIENT FILE NO.	1088
PEST FILE NO.	26017-7801-B



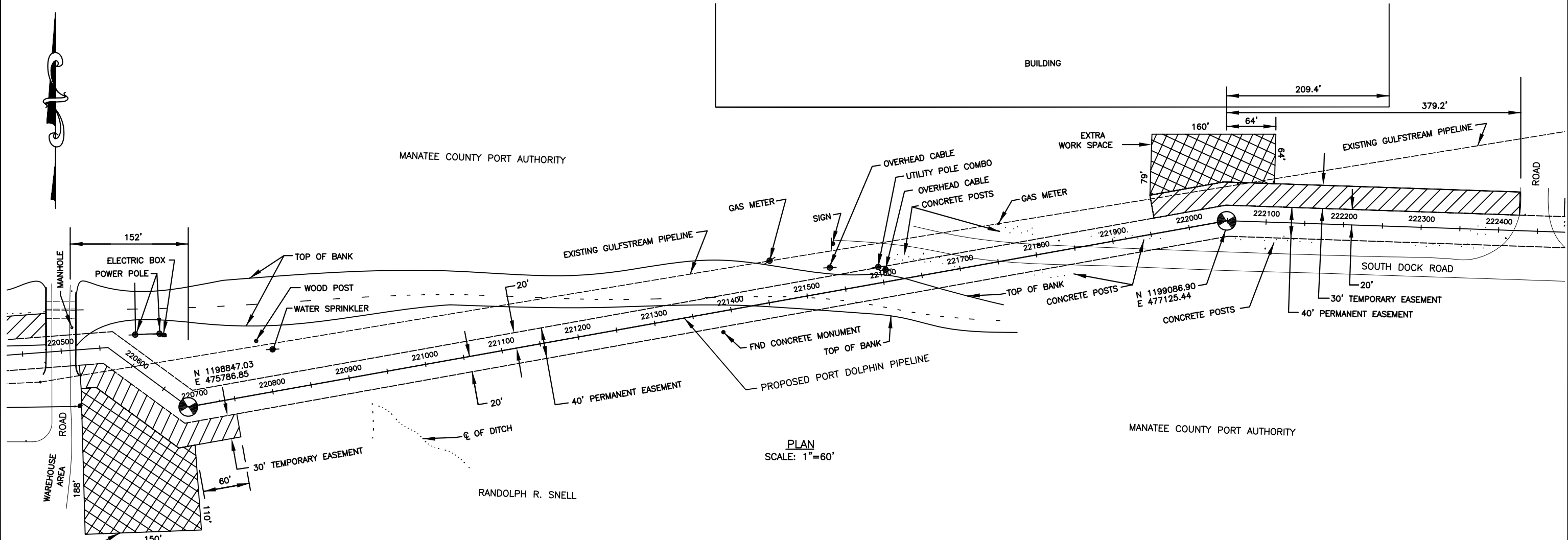
MANATEE COUNTY, FLORIDA  
PORT DOLPHIN PIPELINE



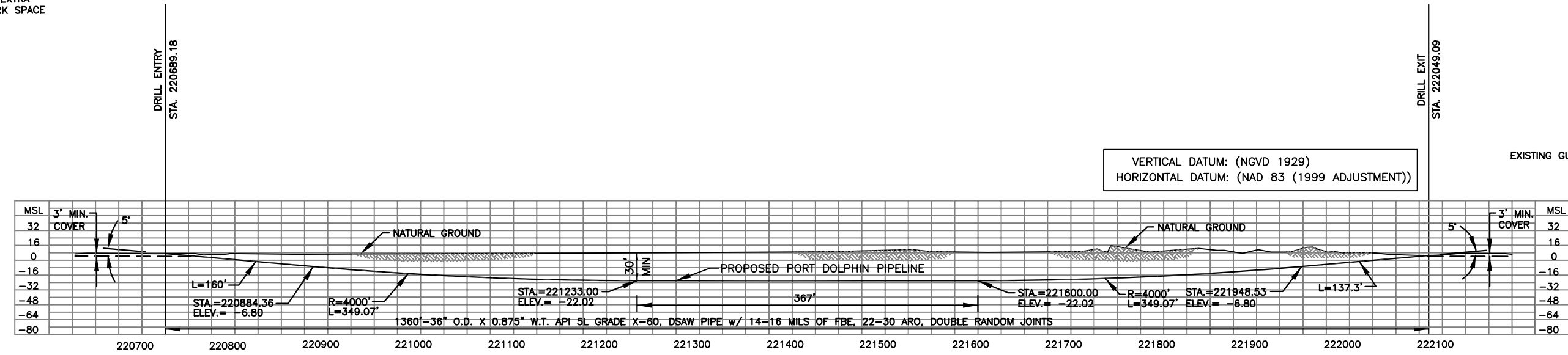
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												AS-BUILT			DATE	

MANATEE COUNTY, FLORIDA  
PORT DOLPHIN PIPELINE



PLAN  
SCALE: 1"=60'



PROFILE  
SCALE: 1"=60'

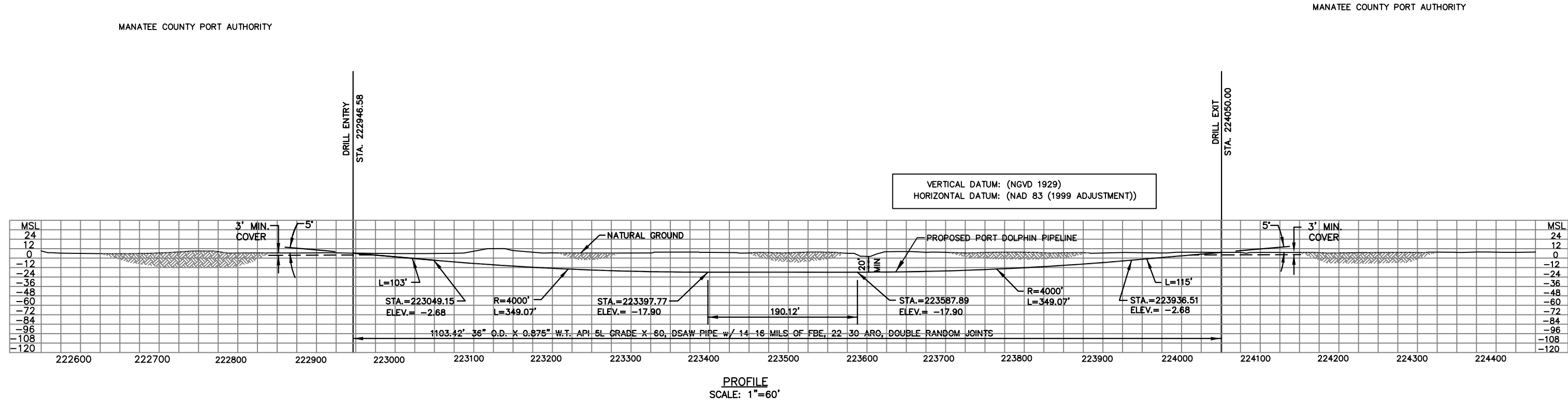
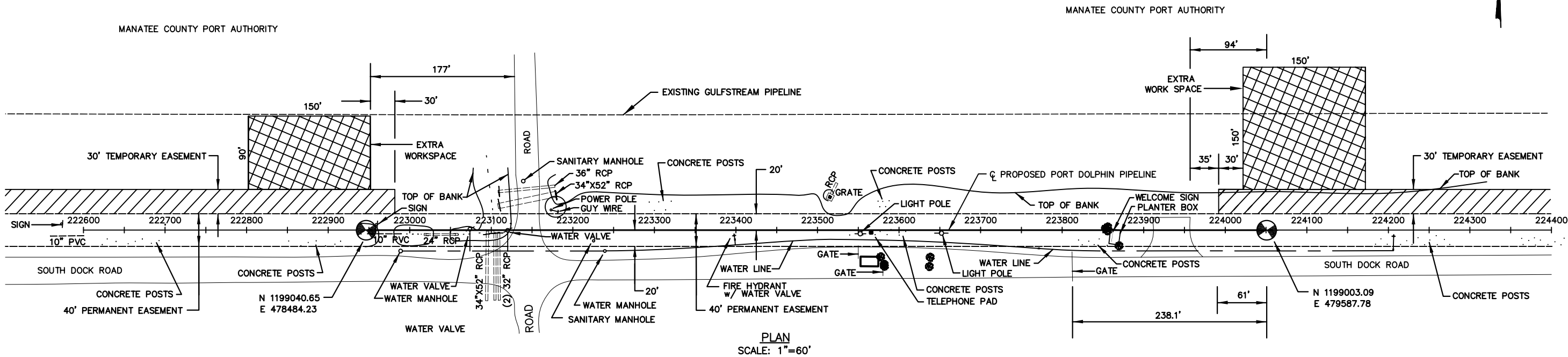
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HORIZONTAL DATUM: (NAD 83 (1999 ADJUSTMENT))

GENERAL NOTES		REFERENCE DRAWINGS		REFERENCE DRAWINGS		REVISIONS		REVISIONS		DRAWING STATUS		SCALE 1"=60'		TITLE		NO.		REV.	
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PETC  
PIPELINE ENGINEERING & TECHNOLOGY CORPORATION  
13831 NORTHWEST FRWY. #312  
HOUSTON, TEXAS 77040  
BUS: (713) 690-9111  
FAX: (713) 690-0060

SCALE 1"=60'	DATE 3/04/07
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APPROVED	DATE
PETC JOB NO. 26017	
AFE/P.O.NO.	
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PETC FILE NO. 26017-D-2302	

MANATEE COUNTY, FLORIDA  
PORT DOLPHIN PIPELINE



GENERAL NOTES		REFERENCE DRAWINGS		REFERENCE DRAWINGS		REVISIONS		REVISIONS		DRAWING STATUS		SCALE 1"=60'		TITLE		NO.		REV.	
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PETC  
PIPELINE ENGINEERING & TECHNOLOGY CORPORATION  
13831 NORTHWEST FRWY. #312  
HOUSTON, TEXAS 77040  
BUS: (713) 690-9111  
FAX: (713) 690-0060

SCALE 1"=60'

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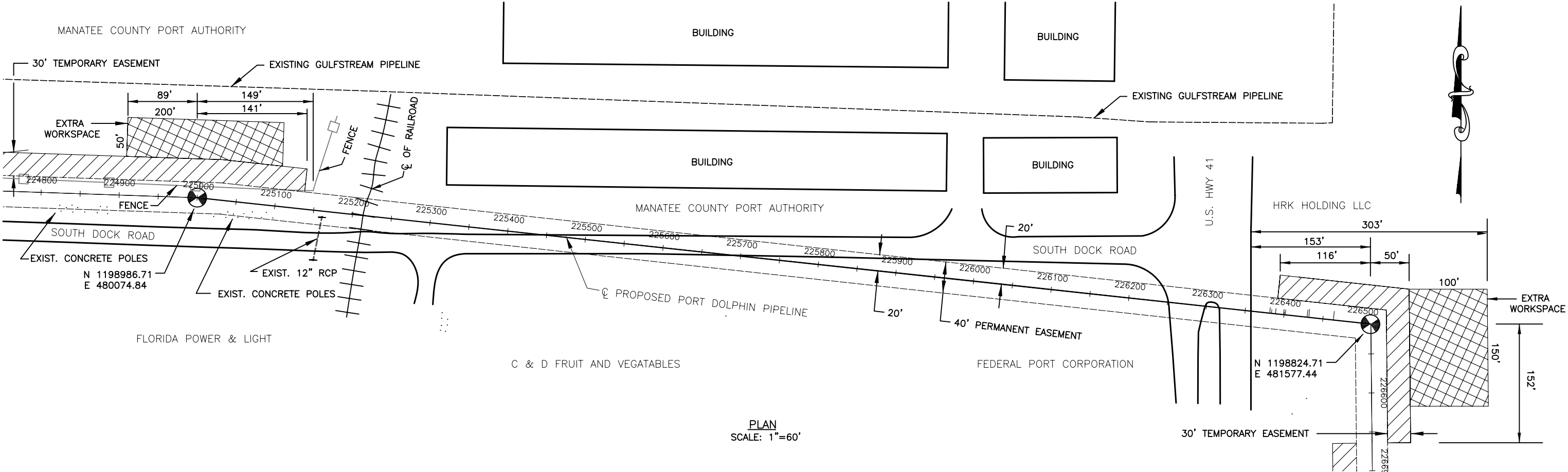
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CLIENT FILE NO.

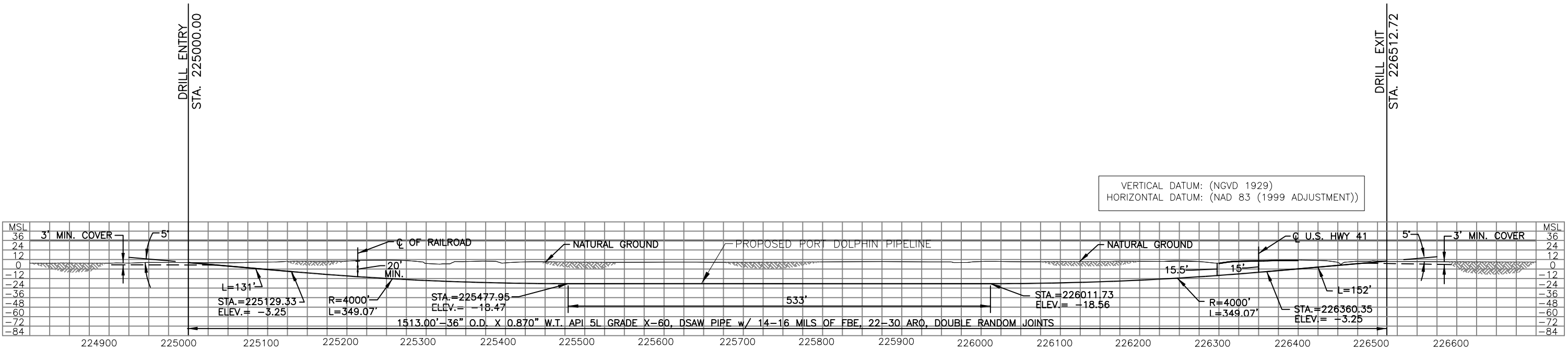
PETC FILE NO. 26017-D-2303

# MANATEE COUNTY, FLORIDA



# PORT DOLPHIN PIPELINE



PLAN  
SCALE: 1"=60



PROFILE  
SCALE: 1"=60'

GENERAL NOTES		REFERENCE DRAWINGS		REFERENCE DRAWINGS		REVISIONS			REVISIONS			<div><p><b>PETC</b></p><p>PIPELINE ENGINEERING &amp; TECHNOLOGY CORPORATION</p><hr/><p>13831 NORTHWEST FRWY. #312 HOUSTON, TEXAS 77040 BUS: (713) 690-9111 FAX: (713) 690-0060</p></div>	DRAWING STATUS			SCALE 1"=60'		<div><p>TITLE</p><p>DIRECTIONAL DRILL RAILROAD &amp; U.S. HWY 41 CROSSING PORT DOLPHIN PIPELINE MANATEE COUNTY, FLORIDA</p><p>NO. 26017-D-2304</p><p>REV. 0</p></div>
DWG.NO.	DESCRIPTION	DWG.NO.	DESCRIPTION	NO.	DATE	DESCRIPTION	NO.	DATE	DESCRIPTION	ISSUED FOR	DATE		BY	DRAWN	DATE			
				0	3/5/07	ISSUE FOR FILING				BID				B.J.L.	3/02/07			
														CHK'D	DATE			
														APPROVED	DATE			
										CONST.				PETC JOB NO.	26017			
														A/E/P.O.NO.				
														CLIENT FILE NO.				
										AS-BUILT				PETC FILE NO.	26017-D-2304			



***Response to e<sup>2</sup>M Request for Clarification and References – June 2007 (Data Gaps and Scoping)***

<b><i>Cultural Resources</i></b>	
<b>74</b>	The typical drawing (Figure #2, Drawing 26017-A-7701) for pipeline construction shows the pipeline construction ROW as 100 feet wide. Within the ROW, the spoil side (including the existing Gulfstream pipeline) measures 40 feet wide and the working side measures 60 feet wide. Given that configuration, why was the survey corridor, also measuring 100 feet wide, centered on the proposed pipeline centerline, rather than offset in the same manner as the typical?
<b>Response</b>	The Figure #2, Drawing 26017-A-7701 correctly depicts a typical configuration that Port Dolphin proposes to utilize during construction of the onshore pipeline. The terrestrial pipeline route is being currently revised and the centerline of the pipeline as shown on the alignment sheets will reflect its correct position within the 100-foot corridor as being the same as Figure #2 in the revised drawings. The environmental surveys that have been/are being carried out for characterizing conditions along the revised pipeline route cover 100% of the proposed 100-foot construction corridor.

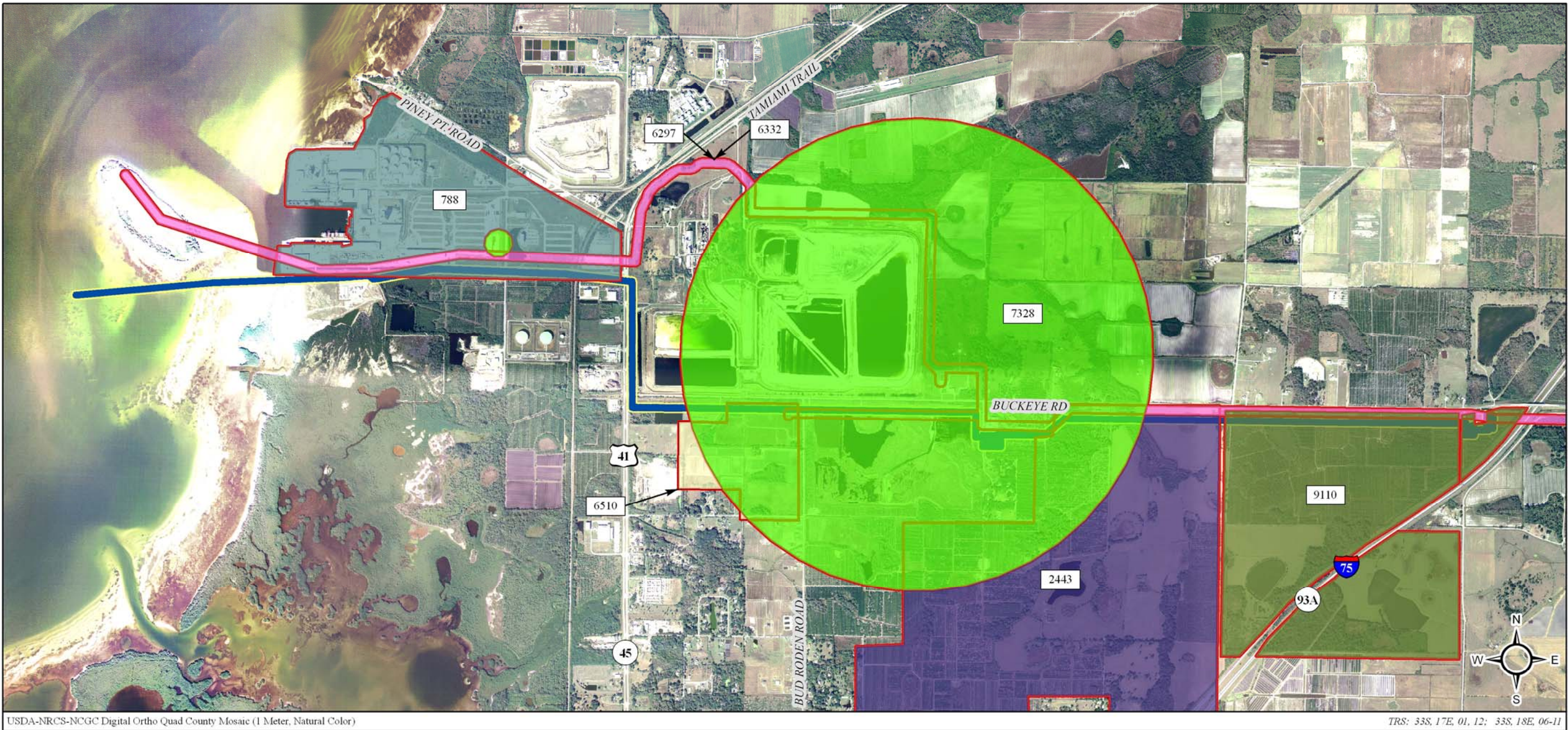
***Response to e<sup>2</sup>M Request for Clarification and References – June 2007 (Data Gaps and Scoping)***

<b><i>Cultural Resources</i></b>	
75	Please provide the survey coverage (site locations, shovel test locations) depicted at a scale comparable to that provided in the plan drawings in Exhibit F-1. At a larger scale, it would be easier to see the distribution of shovel tests and pedestrian transects within the survey corridor and determine whether survey coverage was adequate. This information may be provided as a GPS data layer.
<b>Response</b>	The GPS data layer has been placed on an FTP for download.

***Response to e<sup>2</sup>M Request for Clarification and References – June 2007 (Data Gaps and Scoping)***

<b><i>Cultural Resources</i></b>	
76	On Figure 4-5 of Resource Report 4, it would be helpful to label all of the polygons on the figure. Perhaps different survey areas could be depicted using different colors to better show the limits of each survey area. It should also be noted that the key for this figure indicates that the APE is shown in blue on the figure; however, the APE appears to be shown in white.
<b>Response</b>	A revised map is attached.





**Cultural Resource Surveys**

- Survey Number 788
- Survey Number 2443
- Survey Number 6297

- Survey Number 6332
- Survey Number 6510
- Survey Number 7328
- Survey Number 9110

Area of Potential Effect

Figure 4-5. The Port Dolphin Pipeline corridor and its vicinity have been subjected to several cultural resource surveys.





**Response to e<sup>2</sup>M Request for Clarification and References – June 2007 (Data Gaps and Scoping)**

<b><i>Cultural Resources</i></b>	
77	<p>The survey area for 7328 on Figure 4-5 is very oddly shaped for an archaeological survey. I could not locate the citation for that report in Section 4.8 (References) to determine whether the title of the report could indicate why the survey area had that shape. Please provide the citation, and if necessary to answer the question, please provide the complete report for this survey.</p>
<b>Response</b>	<p>The citation for the report is:</p> <p>Janus Research <i>2002 Cultural Resource Assessment Survey for the Gulfstream Monitor and Control System: 2002 In-Service (Supplemental Report #8).</i> Report on file at the Florida Master Site File Office, Survey # 7328.</p> <p>This report communicates the results of surveying several locations in Polk and Manatee Counties for proposed monopole and towers associated with the Gulfstream monitor and control system. The survey location in the vicinity of the Port Dolphin Pipeline is referred to as the Manatee Station 200. The survey area shape represents a 1-mile radius from the location of the then-proposed 195-foot tower. Archaeological survey was only conducted within the footprint of the proposed tower base. The one-mile radius survey was a cursory survey to identify NRHP-eligible historic structures. The SHPO concurred with the surveyor's findings that no resources listed or eligible for listing on the National Register of Historic Places would be affected by the installation of the Manatee Station 200.</p>