Explosive
Service
International Ltd.
A DIVISION OF
OLSCO, INC.

Effect of Depth Below Mudline of Charge Placement During Explosive Removal of Offshore Structures (EROS)

Final Report, July, 2009

Prepared By:

William T. Poe (ESI)

Craig F. Adams (Consultant)

With Contributions From:

Robert Janda (Sonalysts, Inc.)

Duff Kirklewski (Harbinger Studios)

Prepared for: Mr. Michael Else, U.S. Department of Interior, Minerals Management Service

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TAR Project # 570

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ABBREVIATIONS AND ACRONYMS

ARA	Advanced Research Associates
Composition B	Explosive formulation made of 59.5% RDX, 39.5% TNT and 1% wax
CTD	Conductivity, temperature and depth
DOI	Department of the Interior
DRDC-S or DRDC	Suffield Defence Research and Development Canada – Suffield
EROS	Explosive Removal of Offshore Structures
ESA	Endangered Species Act
ESI	Explosive Services International
GOM (or GoM)	Gulf of Mexico
HMX	His Majesty's Explosive (cyclotetramethylene tetranitramine)
LSC	Linear Shaped Charge
MMPA	Marine Mammal Protection Act
MMS	Mineral Management Services
NEW	Net Explosive Weight
NMFS	National Marine Fisheries Service
Nonel®[1]	Non-electric signal transmission tube
PETN	Pentaerythritol tetranitramine
Pentolite	50%/50% PETN and TNT - castable explosive
PVC	Polyvinyl chloride
RDX	Research Department Explosive (cyclotrimethylenetrinitramine or cyclonite)
SMS	Salt Mine Series
SNC TEC	SNC Technologies Inc.
SNC TEC Corp.	SNC Technologies Corporation; American branch of SNC TEC
TAR	Technology Assessment and Research
TNT	Trinitrotoluene
UWC	UnderWater Calculator

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[1] Nonel® is a registered trademark of Nitro Nobel Gyttorp, Sweden

DEFINITIONS

Core Load	The amount of explosive in a linear foot of explosive product usually expressed in grains per foot (gn/ft)
Farfield	Used to refer to the array downlines farther than 100’ from the structure under study
Gn/ft	Grains (of explosive) per linear foot
Nearfield	Used to refer to the array downlines closer than 100’ to the structure under study
Nonel®	Non-electric signal transmission tube (see Shock Tube)
Primaline®[2]	A low coreload detonating cord containing 4 grains of PETN explosive per linear foot
R/W	Range divided by Weight
Shock Tube	A non-disruptive signal transmission tube with a very fine core load (1 pound per 100k feet+) of HMX/Aluminum (also Nonel®)

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[2] Primaline® is a registered trademark of Dyno Nobel

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DISCLAIMER

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EXECUTIVE SUMMARY

The Minerals Management Service (MMS) is mandated under the Outer Continental Shelf Lands Act (OCSLA) to oversee leasing, exploration, development, and production of mineral and renewable energy resources on the Outer Continental Shelf (OCS). Under this authority, MMS is responsible for permitting and overseeing an array of offshore operations; some of which involve the underwater detonation of explosive charges. Explosives are most critical for their use in the severance of bottom-founded piles and well components during the decommissioning of OCS platforms and well abandonment work.

The MMS is tasked with ensuring that these decommissioning activities are carried out in an environmentally safe and efficient manner. Consequently, one of the principal concerns with the use of explosive-severance charges is the potential for impact to marine protected species (MPS) from the acoustic energy and pressure waves released during detonation. In order to effectively protect MPS and ensure compliance, MMS recognized that actual *in-situ* data would be key in developing predictive tools that could establish accurate 'impact' zones around the severance charges that would help establish levels below which MPS would not be threatened and set up monitoring/mitigation protocol.

In 2001, SNC TEC of Le Gardeur, Quebéc was originally contracted under MMS's Technology Assessment and Research (TAR) Project No. 429 (Contract No. 1435-01-01-CT-31136) to develop an engineered charge of less than 5 lbs net explosive weight (NEW) that would be capable of severing piles typically severed with 50 lbs bulk charges. The project was later modified to allow for *in-situ* measurement and the comparison of the pressure wave and acoustic energy released from the detonated engineered and bulk charges. SNC's study was a success and the data suggested that use of an engineered charge of < 5 lbs NEW can reduce the impact zone to MPS by as much as 50% over the standard 50 lbs charges. However, the amount of data generated on this contract was quite limited, and it was evident after the conclusion of this effort that similar studies should be performed to generate more *in-situ* data.

To this end, Explosive Services International (ESI) was awarded a contract (1435-01-06-CT-39658) under TAR Project No. 570 in March 2006 to perform similar testing and measurement of *in-situ* explosive detonation effects. The Scope of Work (SOW) for this new project had as a primary goal the generation of *in-situ* data, but in a much larger volume than TAR Project 429 (at least 16 shots). However, instead of making all cuts at 15 ft below mudline (BML), as was done on the SNC TEC contract, TAR Project 570 would evaluate the effect of placing charges at 15-ft, 20-ft, 25-ft, and 30-ft BML; gathering blast effect data to compare the difference that depth would make in peak pressure, impulse, and acoustic energy.

Ultimately, the project hypothesis was that by increasing the BML cut depth for the same charge size, attenuation from the additional target and sediments would increase and help reduce the pressure wave/acoustic energy; thereby, decreasing the resultant MPS impact zone. In effect, an increase in BML severance depth, if quantifiable through modeling and/or additional similitude work, could be used as an additional mitigative measure to supplement MPS monitoring and/or reduction of charge NEW.

Explosive Services International's team included Sonalysts, Inc. of Waterford, CT, who was responsible for the *in-situ* measurement work. Similar to the system they developed and deployed for TAR Project 429, Sonalysts designed an array consisting of 12 tourmaline transducers (acoustic receivers) that were prearranged in 'nearfield' and 'farfield' down lines placed at set distances from the target structure. Once deployed, MMS personnel from the Gulf of Mexico OCS Region (GOMR), verified the distances using the agency's sector-scanning sonar and a series of sonar reflectors placed on each of the downlines. The measurements would be used to extrapolate the slant distances between each of the transducers and the charges set within the targets during the analysis phase of the project. In addition to Sonalysts and MMS GOMR, assistance with the severance targets, field vessels, berthing, and barge time was provided as 'donations-in-kind' by Maritech Resources, Incorporated (Maritech) and Merit Energy Company (Merit).

The *in-situ* measurement work was conducted in two separate phases. The first mobilization took place in July/August 2007 at Maritech's Platform F-4 and bridge-connected Caisson F in the Eugene Island Area, Block 128 (EI128). During the EI128 phase, the acoustic array was deployed in three different configurations for three separate detonation events; 1) from the target to the derrick barge, 2) from the target to a liftboat (the measurement vessel), and 3) from the liftboat alone. The second measurement exercise was conducted in August 2008 at Merit's Platform A in East Cameron Area, Block 32 (EC32). A single detonation event was measured with the array configured from the platform to the liftboat. In all, acoustic data was successfully collected for 20 internal severance detonations and 2 open-water test shots; exceeding the project's primary goal. A secondary goal was not met due to obstructions within the target piles that prevented a set of engineered charges from being set properly.

A review of the collected data suggests that the technique of increasing the BML depth of charge placement has definite benefits with regards to blast effects and their impact on MPS. This contention was demonstrated during the detonation of a shot string of 50 lbs charges at Maritech's Platform F-4 in EI128. The 10 charge configuration consisted of 2 charges set at 15-ft BML, 3 charges set at 20-ft BML, 3 charges set at 25-ft BML, and 2 charges set at 30-ft BML. The charges placed 15-ft BML resulted in pressure readings nearly twice that of the 12 psi temporary threshold shift (TTS) level set by the National Marine Fisheries Service (NMFS).[3] However, the charges placed at 20-ft BML had recorded pressure very close to or below 12 psi, and pressure readings for those placed 25-ft/30-ft BML were well below the TTS limit. During the EC32 exercise on Merit's Platform A, 80 lbs charges were set at 15-ft and 20-ft BML. Although the slant ranges for the 20-ft BML charge were slightly greater for nearfield (109 feet versus 67 feet) and far-field (263 feet versus 214 feet) than those for the 15-ft BML charge, the pressure recorded for 20-ft BML detonation was significantly lower than that for the 15-ft BML charge.

Further interpretation of the data appears to indicate that the increase in BML depth introduces several variables that have the potential to reduce the coupling efficiency of the detonation energy from the charge to the water column, subsequently increasing the amount of attenuation. Some of these variables include the physical coupling between the charge and the target, the BML distance (i.e., its effect of the on the local impedance of the target), the jetting below the charge site, the amount of water/air above the charge site, and the coupling between the pile and seabed. The pile to seabed coupling efficiency could be diminished by any voids or non-homogenous elements (i.e., rocks, man-made material, etc.) around the target and even the composition of the local sediments could impact the ability of the seabed medium to conduct and transmit the detonation energy.

Ultimately, an analysis of the data collected from the *in-situ* measurement work indicates that increasing the BML depth of the severance charge works to increase attenuation of pressure wave/acoustic energy and result in subsequent reduction in the size of the MPS impact zone. The noticeable increase in energy attenuation infers that the data collected under TAR Project 570 could be used in future similitude equations/modeling efforts to provide a tool for predicting the subsurface blast effects from explosive-severance activities. These predictive tools will be a valuable aide to MMS, the oil and gas companies, and the decommissioning contractors in that it will be possible to anticipate more precisely the environmental effects of a charge of a certain design and NEW placed at a certain BML depth.

1.0. INTRODUCTION

1.1. THE USE OF EXPLOSIVES ON THE OUTER CONTINENTAL SHELF

The MMS is responsible for permitting a varied array of offshore operations and ensuring that they are conducted in a safe, effective, and environmentally-sound manner. Several of these activities rely upon

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[3] A TTS level of 12 psi was established by NMFS during Marine Mammal Protection Act (MMPA) rulemaking for the USS Winston Churchill Shock-Trails (*FR*, 2001) and used for MMS's take-regulations for decommissionings (*FR*, 2008a). The current TTS level of 23 psi was established by NMFS during MMPA rulemaking for the USS Mesa Verde Shock-Trails (*FR,* 2008b).

the underwater detonation of specialized explosive charges to perform specific functions. These functions include:

- Perforation of well casings;
- Sound sources for geophysical surveys;
- Remote-/quick-release options (i.e., via explosive bolts and pins, cable shearing devices, etc.);
- Down-hole drill pipe and casing cutting; and
- Severance of bottom-founded components (e.g., piles, caissons, conductors, and well stubs) during the decommissioning of OCS structures and wells.

Structures and equipment are secured to the seabed during oil and gas exploration and development operations. As per MMS lease agreements and OCSLA regulations (30 CFR 250.1710 – *wells* and 30 CFR 250.1725 – *platforms*), companies are required to decommission their structures/equipment and remove seafloor obstructions to at least 15 feet below-the-mudline (BML) within one year of lease termination or after a structure has been deemed obsolete or unusable. Though nearly 3,100 structures have been removed since 1973, there are currently over 3,700 structures remaining on the GOM OCS (see Figure 1.1.).[4] Presently, there are over 1,200 unproductive/unnecessary structures that are considered "idle" in the Gulf of Mexico (GOM) that could be candidates for decommissioning.[5]

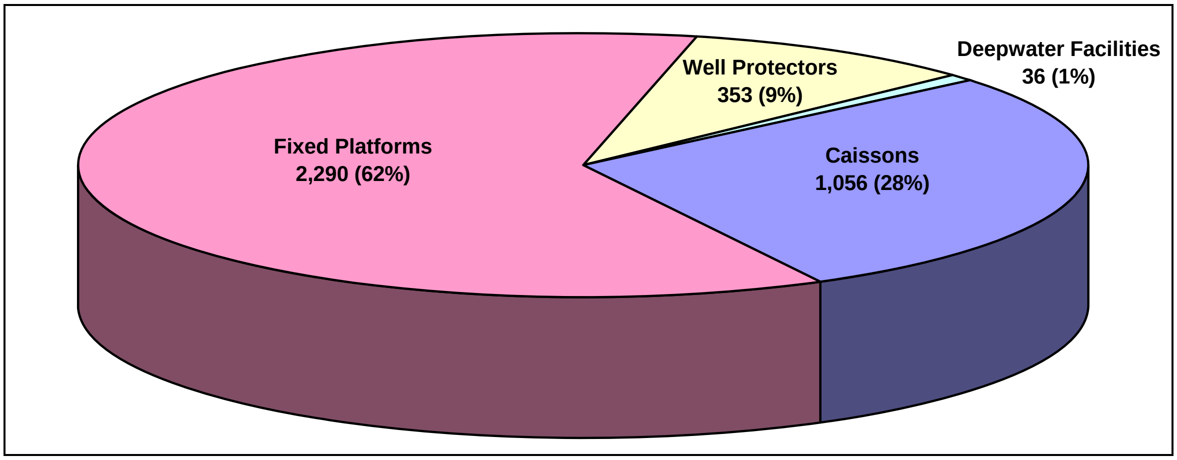

Figure 1.1. Active Structures on the Gulf of Mexico Outer Continental Shelf.

The MMS GOM OCS Regional Office (GOMR) permits an average of 175 structure decommissionings annually with over 65-percent of all approved operations proposing explosive-severance charges as either the primary and/or back-up cutting option.[6] Though several nonexplosive-severance methodologies can achieve the same goal (i.e., sand cutters, diver severance, abrasive water jet (AWJ) cutters, etc.), many operators feel that explosive-severance charges offer the most flexible, cost-effective, efficient, and safest cutting options. But despite their apparent advantages, the detonation of the explosives and the acoustic energy/shockwave released has the potential to injure or kill marine protected species (MPS); primarily sea turtles and marine mammals.

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[4] Broussard, TJ, Personal Communication, Minerals Management Service, Gulf of Mexico OCS Region, April 2009

[5] Kaiser, M.J and A.G. Pulsipher "Idle Iron in the Gulf of Mexico" Minerals Management Service, Gulf of Mexico OCS Region, May 2007

[6] Minerals Management Service, "Structure-Removal Operations on the Outer Continental Shelf of the Gulf of Mexico – Programmatic Environmental Assessment," Gulf of Mexico OCS Region, February 2005

1.2. MITIGATION APPROACHES FOR EXPLOSIVE USE DURING DECOMMISSIONINGS

1.2.1. MARINE PROTECTED SPECIES OVERSIGHT

The U.S. Department of Commerce (DOC), National Marine Fisheries Service (NMFS) is delegated under the Endangered Species Act (ESA) to provide guidance and oversight for threatened and endangered species that could be impacted by decommissioning activities. In the GOM, the ESA-related MPS include:

- Sea Turtles;
  - Loggerhead sea turtle (*Caretta caretta*);
  - Green sea turtle (*Chelonia mydas*);
  - Hawksbill sea turtle (*Eretmochelys imbricata*);
  - Kemp's Ridley sea turtle (*Lepidochelys kempi*);
  - Leatherback sea turtle (*Dermochelys coriacia*);
- Marine Mammals;
  - Sperm Whale (*Physeter macrocephalus*); and
  - West Indian Manatee (*Trichechus manatus)*

West Indian Manatees in the U.S. are protected under federal law by the Marine Mammal Protection Act of 1972, and the Endangered Species Act of 1973. Manatees are also protected by the Florida Manatee Sanctuary Act. The Florida Manatee Recovery Plan was developed as a result of the Endangered Species Act and sets forth a list of tasks geared toward recovering Manatees from their current endangered status. Similarly, the Marine Mammal Protection Act made the Secretary of Commerce responsible for all cetaceans and pinnipeds, except walruses, with authority for implementing the Act delegated to NMFS. Though up to 28 different marine mammals could be present in the GOM at any one time, the MMPA-related species most prone to take during decommissionings are the previously-mentioned sperm whale/manatee and three species of coastal dolphin:

- Bottlenose dolphin (*Turisops truncatus*);
- Atlantic spotted dolphin (*Stenella frontalis*); and
- Pantropical spotted dolphin (*Stenella attenuatus*).

The MMPA also established a moratorium on the "taking" of marine mammals in waters under U.S. jurisdiction, with the term "take" meaning to harass, hunt, capture, or kill or attempt to harass, hunt, capture, or kill any marine mammal. The MMPA defines harassment as:

> "…any act of pursuit, torment, or annoyance which (i) has the potential to injure a marine mammal or marine mammal stock in the wild; or (ii) has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to migration, breathing, nursing, breeding, feeding, or sheltering."

The terms "Level A" and "Level B" harassment correspond to definitions (i) and (ii), respectively. For the MMPA incidental-take rulemaking conducted for the U.S. Navy's Winston Churchill ship shock tests, NMFS established the criteria for nonlethal, injurious impacts (Level A harassment) as the incidence of 50-percent tympanic-membrane rupture and the onset of slight lung hemorrhage for a 12.2-kg dolphin calf.[7] Also considered a permanent threshold shift (PTS), Level A harassment take is assumed to occur:

1. at an energy flux density value of 1.17 in-lb/in^2 (which is about 205 dB re 1 µPa^2-s); and
2. if the peak pressure exceeds 100 psi for an explosive source.

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[7] *Federal Register*. "Taking and Importing Marine Mammals; Taking Marine Mammals Incidental to Naval Activities; Final Rule (50 CFR Part 216, Subpart N)" 66 FR 87, May 2001

The horizontal distance to each threshold is determined and the maximum distance at which either is exceeded is taken to be the distance at which Level A harassment would occur. The rulemaking also established the level of non-injurious impacts (Level B harassment). The criterion for Level B is defined by the onset of a temporary threshold shift (TTS), which is assumed to be induced:

1. at energies greater than 182 dB re 1 µPa^2-s within any ⅓-octave band; and
2. if the peak pressure exceeds 12 psi for an explosive source.

As with Level A, the horizontal distance to each threshold is determined and the maximum distance at which either is exceeded is to be the distance at which Level B harassment (TTS) would occur.[8] Based upon analyses and observations, Level B harassment would be the only take likely to occur incidental to decommissionings. Additionally, the results of recent modeling efforts indicate that the horizontal distance (radius around a detonation event) is always greatest for peak pressure. However, during a recent MMPA incidental-take rulemaking for shock tests of the USS Mesa Verde, NMFS established new criterion for Level B harassment.[9] The onset of a TTS is now assumed to be induced:

1. at energies greater than 183 dB re 1 µPa^2-s within any ⅓-octave band; and
2. if the peak pressure exceeds 23 psi for an explosive source.

When the SOW for this TAR project was developed, the data comparison for the collected *in-situ* measurements were designed to center on the previous 12 psi TTS criteria since it has driven mitigation development up to that point. Therefore, discussion and various charts/graphs in this report will reference the 12 psi limit. However, it should be noted that the new 23 psi TTS criteria would actually result in shorter TTS impact-zone ranges (see Figure 1.2).

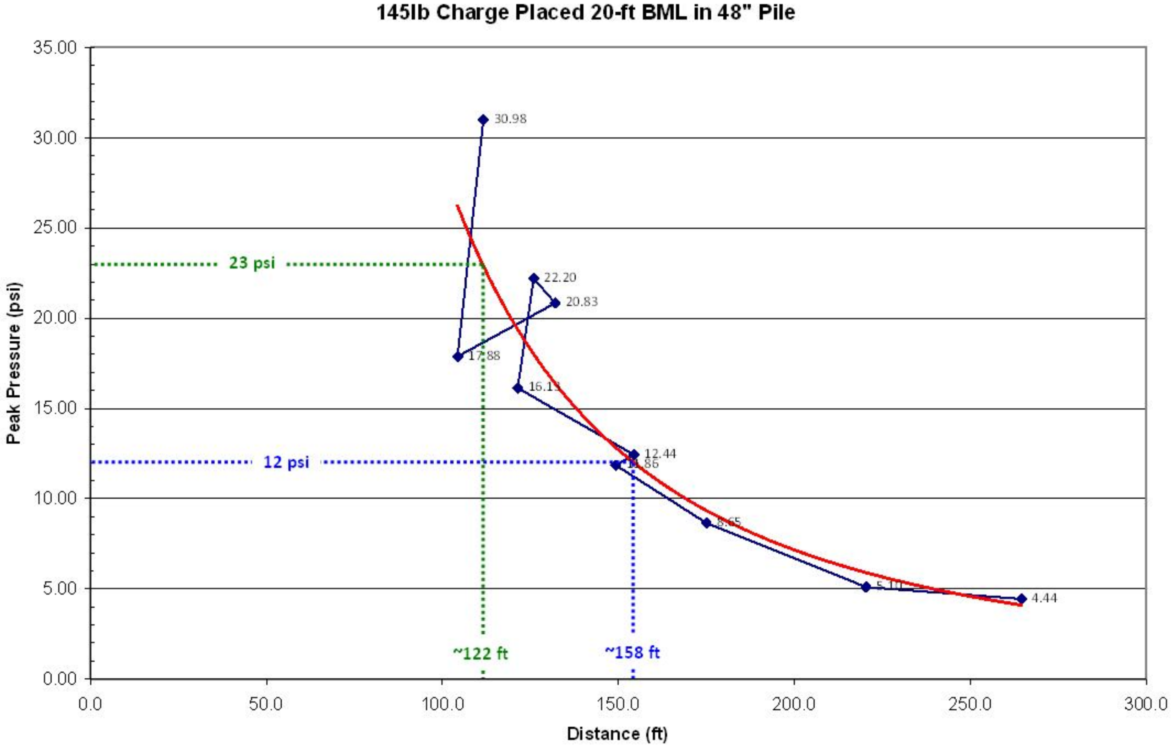

Figure 1.2. Impact-Zone Difference between a 12 psi TTS Level and a 23 psi TTS Level.

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[8] Minerals Management Service, "Structure-Removal Operations on the Outer Continental Shelf of the Gulf of Mexico – Programmatic Environmental Assessment," Gulf of Mexico OCS Region, February 2005

[9] *Federal Register*. "Taking and Importing Marine Mammals; Taking Marine Mammals Incidental to a U.S. Navy Shock Trial (50 CFR Part 216, Subpart O)" 73 FR 143, July 2008

Since NMFS has had the lead ESA/MMPA role in establishing PTS/TTS level criterion, MMS has worked with the agency for more than two decades to help develop and oversee mitigation that has been implemented during decommissionings using explosive-severance charges. Over the last ten years, the agencies' coordination and mitigation development has evolved tremendously as information on MPS impacts has improved and actual peak pressure/acoustic energy data has been collected and analyzed.

1.2.2. SITE-SPECIFIC MPS MITIGATION (UP TO 1988)

In 1986, NMFS's Galveston Laboratory informed MMS GOMR of their concern about several sea turtle stranding events wherein over 130 dead sea turtles washed ashore along the Texas and Southwestern Louisiana coasts. They suggested a correlation between the strandings and nearby state water decommissioning operations. Since details on explosive use, type, and methodologies were not submitted with removal applications at that time, the Regional Director of MMS GOMR sent a Letter to Lessees and Operators (LTL) in August 1986 requesting notification 30-days in advance of any decommissionings along with a description of their proposed targets, removal methodology, and type/weight of explosives. A similar LTL was sent in December 1986 noting MMS's decision to conduct site-specific Section 7, ESA coordination with NMFS on all removals proposing explosives.

Once a notice and the related removal information were received, MMS would prepare a site-specific environmental assessment (SEA) as per National Environmental Protection Act (NEPA) guidance. Afterwards, subsequent site-specific ESA coordination with NMFS would result in the conditioning of mitigation meant to monitor for the presence of sea turtles and avoid detonation events once detected. Though not standardized at this point, mitigation centered on limiting charge weights to less than 50 lbs, restricting detonations to daylight-only, and establishing a set of surface and aerial monitoring surveys to be performed pre- and post-detonation. Since most mitigation measures were nearly identical and a greater number of nonproductive facilities needed decommissioning, MMS and NMFS took the necessary steps to outline programmatic options that would apply to a larger number of decommissioning applicants.

1.2.3. "GENERIC" MPS MITIGATION (1988 - 2006)

Using the information gathered under the 1986 LTL requests, MMS addressed all removal operations and the potential impacts of severing methodologies (nonexplosive/explosive tools) in a 1987 programmatic environmental assessment (PEA) aimed at the removal of traditional, bottom-founded structures limited to the shallow shelf of the OCS (less than 200 meters). Though inclusive of most decommissioning operations at that time, the analyses did not address well abandonment operations and areas outside of the Western and Central GOM and the programmatic mitigation measures outlined in the PEA for monitoring requirements and impact zones were not based upon a charge's NEW or any acoustic data or criteria.[10]

Once the PEA was completed, MMS requested a "generic" Section 7 Consultation from NMFS under ESA that would be applicable to a wider array of decommissioning proposals; thereby negating the need for site-specific coordination. In 1988, NMFS issued a programmatic Biological Opinion (BO) and Incidental Take Statement (ITS) that addressed the five species of sea turtles (sperm whale populations were not known to exist in the GOM at that time) and established mitigation that would apply to all decommissioning that proposed activities that fell under the "generic" condition. The mitigation (see

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[10] Minerals Management Service. "Programmatic Environmental Assessment: Structure Removal Activities, Central and Western Gulf of Mexico Planning Areas" Gulf of Mexico OCS Region, March 1987

Table 1-1) is administered and performed by NMFS personnel from the Galveston Laboratory's Platform Removal Observer Program (PROP).

Table 1-1

"Generic" Mitigation Requirements for Explosive Severance (1987-2006)

Explosive Type, Size, and Placement	• Maximum 50 lbs Charge Size • Internal Placement no less than 15 ft BML • Maximum of 8 Charges in Single Detonation Event; Each Staggered by 900 Milliseconds
Pre-Detonation Surface Survey	• Started 48 Hours from Structure or Associated Vessel • Performed by 1 or 2 NMFS PROP Observers
Pre-Detonation Diver Survey	• If Required by PROP Lead Observer
Pre-Detonation Aerial Survey	• ½ Hour Helicopter Monitoring out to 3,000 ft Impact Zone
Post-Detonation Aerial Survey	• ½ Hour Helicopter Monitoring out to 3,000 ft Impact Zone
Post-Detonation Diver Survey	• If MPS Sighted During Pre-Det Surveys and as Required by PROP Lead Observer
Post-Post-Detonation Survey	• As Required; Within 7-Days Post Severance

A short time after the establishment of the 'generic' mitigation, NMFS's Southeast Regional Office (SERO) issued a 'verbal' waiver from the ITS for any explosive charges equal to or less than 5 lbs. Their contention was that the low NEW charges were resulting in minimal impacts; therefore, ≤5 lbs charges did not present any serious harm to sea turtles (the primary species of concern at the time). For several years, most of the explosive contractors began to develop small engineered cutters utilizing linear-shaped charges with weights at or below the 5 lbs level for use in decommissionings. Though engineered charges offer a greater "risk of failure" due to their need for precise setting and delicate placement devices and detonators, since they were waived from the 'generic' conditions, they offered industry a low cost option for certain circumstances. Additionally, they were used during for critical night-time severance work and during periods of foul weather when helicopter operations were halted.

In 2001, in part due to rising public concern over several marine mammal strandings and an increase in MMPA take-regulation petitions, NMFS chose to rescind the ≤5 lbs verbal waiver and make all charge sizes (0-50 lbs) accountable for the 'generic' conditions. With the full mitigation suite now required, operators began to disuse low NEW charges in lieu of full 50 lbs charges since they offered less 'risk of failure' during standard severance activities.

Emphasizing a continued need for an incentive to keep explosive weights low, MMS formally requested that NMFS amend the 1988 BO/ITS to establish a minimum charge size of 5 lbs. Though not identical to the previous verbal waiver, NMFS SERO ultimately addressed the request in a separate, informal BO issued in October 2003. The "de minimus" BO, as it was called, waived several mitigative measures of the 1988 BO (i.e., aerial observations, 48-hr pre-detonation observer coverage, on-site PROP personnel, etc.), reduced the potential impact zone from 3,000 ft to 700 ft based upon a MMS-funded modeling study, and gave the operators/severance contractors the opportunity to conduct their own observation work once properly trained. Following issuance of the BO, personnel from the active explosive severance companies underwent MPS monitoring training and later participated in over a dozen 'de minimus' severance decommissionings as protected species observers.

1.2.4. "DYNAMIC" MPS MITIGATION (2006-PRESENT)

Starting in 2001, MMS began to work with industry leads and decommissioning contractors to gauge the effectiveness and limitations of the explosive and nonexplosive severance tools and request input into upcoming removal targets. In January of 2002, MMS held a Decommissioning Workshop where operators, project management groups, severance contractors, and lift/service vessel companies were able to express their concerns and make recommendations for regulatory improvements. In 2003, the Offshore Operators Committee (OOC) and GOM explosive-severance contractors provided MMS with the Explosive Technology Report (ETR) that provided detailed information on logistics, explosive-cutting tools, potential targets, and their recommendations for a 'dynamic' explosive-severance program with four blasting categories based upon NEW.[11] The 'dynamic' aspect of the ETR's blasting categories was based on two critical contentions; 1) the diminished incentive for operators to reduce the NEW of their severance charges and 2) the ineffectiveness and risks associated with a single, maximum charge size.

The first rationale for the blasting program is to tie a suitable amount of mitigation to the appropriate charge size/configuration based upon the potential for similar impacts. For years, operators were given little incentive to lower the NEW of their severance charges since the mitigation was identical whether you used 10 lbs or 50 lbs. The concept accepted by MMS was if an operator had the opportunity to reduce the potential mitigation burden, they would be more likely to opt for the lower NEW charges despite the increased 'risk of failure.' The lower the NEW, the smaller the resultant impacts zone and potential for MPS takes. Building upon the 'dynamic' proposal, MMS added a category for self-monitoring and broke the 5 NEW groups into 20 explosive-severance scenarios based upon water depth (for species delineation) and BML/above mudline (AML) charge placement (see Table 1-2).

The second premise was the inefficiency of the maximum 50 lbs charges in the severance of standard sized piles and conductors. Review of PROP and contractor records indicated that it often took two or more 'backup' charges to complete a single severance. From the standpoint of the operator/contractor, this meant two or more additional charge setting and mitigation cycles that ultimately tied up barge/lift vessel time and scheduling. From the standpoint of the protected species scientists, added reshoots meant two or more additional chances for an animal to enter into the impact zone and possibly be taken. Reducing the NEW of a severance charge was a well-founded and logical mitigation option; reducing the actual number of charges required to be detonated was even more fundamental.

Working with this information, MMS began preparing a new programmatic EA that would address all water depths on the GOM OCS, new technology and MPS information, and the much expanded 'dynamic' severance program. To assist with the PEA's preparation, MMS funded several additional reports and studies to synthesize critical information on nonexplosive severance, MPS impacts and species population estimates, and detailed removal forecasting trends. A shock wave study and sound propagation model for determining impact zones for MPS was developed by Applied Research Associates (ARA), Inc. to help establish impact zone ranges and data for related marine mammal impact model runs.[12]

When the PEA was completed in February 2005, MMS petitioned NMFS for incidental-take regulations under Subpart I of the MMPA. Since the rulemaking process was considered a 'major Federal action' by

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[11] DEMEX Division of TEi Construction Services, Inc. "Explosive Technology Report for Structure Removals in the Gulf of Mexico" Picayune, MS, August 2003

[12] Dzwilewski, P.T. and G. Fenton. " Shock Wave/Sound Propagation Modeling Results for Calculating Marine Protected Species Impact Zones During Explosive Removal of Offshore Structures" Minerals Management Service, Gulf of Mexico OCS Region, September 2003

NMFS, the agency also began a Section 7, ESA Consultation between its protected species offices. As a result of these efforts, a new BO and ITS were issued in August of 2006 that superseded both the 'generic' and the 'de minimus' BO's.[13]

The final MMPA take-regulations were published in June of 2008.[14] The 2006 BO and ITS were amended shortly afterwards to address the potential takes of sperm whales covered in the take-regulations. The survey mitigation prescribed under the promulgated regulations were nearly identical to those proposed/analyzed in the 2005 PEA and the terms and conditions of the 2006 ESA BiOp and ITS (see Table 1-2).

Table 1-2
"Dynamic" Mitigation Requirements for Explosive Severance (2006- Present)

Blasting Category	Impact Zone Radius (@ 12 psi)	Scenario	Pre-Det Surface Survey (min)	Pre-Det Aerial Survey (min)	Pre-Det Acoustic Survey (min)	Post-Det Surface Survey (min)	Post-Det Aerial Survey (min)	Post-Post-Det Aerial Survey (Yes/No)
Very-Small	261 m (856 ft)	A1	60	N/A	N/A	30	N/A	No
		A2	90	N/A	N/A	30	N/A	No
	293 m (961 ft)	A3	60	N/A	N/A	30	N/A	No
		A4	90	N/A	N/A	30	N/A	No
Small	373 m (1,224 ft)	B1	90	30	N/A	N/A	30	No
		B2	90	30	N/A	N/A	30	No
	522 m (1,714 ft)	B3	90	30	N/A	N/A	30	No
		B4	90	30	N/A	N/A	30	No
Standard	631 m (2,069 ft)	C1	90	30	N/A	N/A	30	No
		C2	90	30	120	N/A	30	No
	829 m (2,721 ft)	C3	90	45	N/A	N/A	30	No
		C4	90	60	150	N/A	30	Yes
Large	941 m (3,086 ft)	D1	120	45	N/A	N/A	30	No
		D2	120	60	180	N/A	30	Yes
	1,126m (3,693ft)	D3	120	60	N/A	N/A	30	No
		D4	150	60	210	N/A	30	Yes
Specialty	1,500 m (4,916 ft)	E1	150	90	N/A	N/A	45	No
		E2	180	90	270	N/A	45	Yes
	1,528 m (5,012 ft)	E3	150	90	N/A	N/A	45	No
		E4	180	90	270	N/A	45	Yes

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[13] National Marine Fisheries Service. "Biological Opinion/Incidental Take Statement Concerning Permitting Structure Removal Operations on the Gulf of Mexico Outer Continental Shelf" ESA Division, Silver Spring, MD. August 2006

[14] *Federal Register* "Taking and Importing Marine Mammals; Taking Marine Mammals Incidental to the Explosive Removal of Offshore Structures in the Gulf of Mexico; Final Rule (50 CFR Part 216, Subpart S)" 73 FR 119, June 2008

Though greatly improved as compared to the pre-2006 mitigation requirements, the ten existing impact zone calculations are still considered highly conservative and could extend further than the actual TTS limits. At first glance, an increased survey area beyond the TTS limit would appear to provide additional protection for MPS. However, the real ability of a monitoring program to protect MPS is directly related to the likelihood that the animal is detected – not the extent of the area being covered. Therefore, if monitoring efforts are wasted on areas where the animals could not be harmed, then the chance of sighting MPS within the actual TTS impact zone is greatly reduced. Since impact zone refinement appears to have the greatest potential for improving MPS detection, MMS has focused its efforts on *in-situ* measurement work that could provide critical data necessary for refining existing predictive tools.

1.3. PRIOR ACOUSTIC/SHOCKWAVE MEASUREMENT WORK

One of the earliest studies related to explosive severance data measurement was done by John Goertner, of the Research and Technology Department of The Naval Surface Weapons Center (NSWC) Dahlgren, with results recorded in the report “Fish-Kill Ranges for Oil Well Severance Explosions” (1 April 1981). While the data generated on this study are interesting for comparison, the tests were done on ½ scale well heads with C-4 explosive charges of 7.0 pounds fired at 7 ½ feet below mudline. The pressure gages were placed at close ranges; the most remote being thirty feet away.

Another study undertaken by Mr. Goertner and reported in “Prediction of Underwater Explosion Safe Ranges for Sea Mammals” (16 August 1982), did not involve any experimental testing. Rather, scaling was done on tests done by the Lovelace Foundation and reported in “Far-field Underwater-Blast Injuries Produced by Small Charges” (Richmond, Yelverton, and Fletcher: 1973) and “Safe Distances from Underwater Explosions for Mammals and Birds” (Yelverton, et al: 1973). These earlier tests involved underwater tests on small (approximately 15 to 150 pounds) terrestrial mammals. The later Goertner study used the data generated by the Lovelace Foundation to mathematically predict possible injuries that might be caused to larger marine mammals (whales, porpoises, and manatees) based on charges of different geometries and weights at various depths.[15]

A more relevant study was performed by Joseph Connor, Jr., also of the Research and Technology Department of the Naval Surface Warfare Center (NSWC Changed its name from a “Weapons” Center to a “Warfare” Center in the intervening years) Dahlgren, with results recorded in “Underwater Blast Effects From Explosive Severance of Offshore Platform Legs and Well Conductors” (15 December 1990). This study tested charges in tubulars on an actual structure at varied depths below mudline and used a similar deployment scheme for arrays of transducers to that used for more recent work to gather peak pressure data and determine impulse and energy flux data. The gathered data was used to generate similitude equations to offer a predictive tool for future removal operations of a similar nature. As the array deployment methods and charge placement techniques of Mr. Connor’s study closely mirror the work detailed in this report, the predictions of his Similitude Equations appear on the graphs for the actual data gathered and presented in the Appendices.

Building upon Connor’s work, MMS contracted Applied Research Associates, Inc. to develop a method to determine shockwave propagation into the water column from the detonation of explosive-severance charges.[16] The study was achieved by performing numerical simulations of various explosive, target,

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[15] Goertner, John F. “Prediction of Underwater Explosion Safe Ranges for Sea Mammals” Naval Surface Weapons Center, Dahlgren, VA, Research and Technology Department, 18 August 1982

[16] Dzwilewski, P.T. and G. Fenton. “ Shock Wave/Sound Propagation Modeling Results for Calculating Marine Protected Species Impact Zones During Explosive Removal of Offshore Structures” Minerals Management Service, Gulf of Mexico OCS Region, September 2003

sediment, and marine environments and determining the level of energy coupled into the water. The numerical simulations confirmed that less energy is released into the water column for the detonation within a piling than would be coupled for open-water detonations. As previously mentioned, the resultant model, a spreadsheet application referred to as the "Underwater Calculator" (UWC), was developed to predict the shockwave, acoustic impulse, and energy flux density for both open water and within-target detonations with the results used for mitigation development in the 2005 PEA.

In 2001, SNC TEC was awarded a contract by MMS under TAR Project No. 429 (Contract No. 1435-01-01-CT-311360) to develop an explosive charge system that would require less explosive to sever offshore structures through the use of an engineered charge and to obtain data to evaluate its impact on marine life. The aim for the engineered explosive charge total system weight was to be below 10 lbs and, if possible, below 5 lbs. The project team was led by SNC TEC and comprised of Explosive Services International (ESI), Defence Research and Development Canada Suffield (DRDC Suffield), and Sonalysts, Inc. (Sonalysts). The team members were involved in different tasks related to charge development and its set-up on the ESI-developed Scorpion™ delivery system as well as the different aspects of testing, including blast measurements during final tests in the Gulf of Mexico on an *in-situ* structure, severing piles with both bulk charges and the engineered charges at 15-ft BML.

Following simulation studies, a charge system based on linear shaped charges (LSCs) was developed to sever piles of 30" and 48" diameters with wall thickness less than 1.5". The Scorpion™ system was used to hold the charges and position them in the piles. Total explosive charge weights of 4.05 and 6.58 lbs were obtained for the 30" and 48" diameter pipes respectively. In preliminary tests conducted on submerged pipes in a quarry lake, the Scorpion™ system worked well and the charges successfully severed the two different pile diameters. In the tests against actual structures in the GOM, only 30" piles were available for cutting at 15-ft BML. It is believed that the Scorpion™ system did not deploy properly leading to improper arrangement of the device in the pile resulting in a reduction of the charges effectiveness and incomplete severing. Additional work has been done since to solve the problem with the system deployment. Measurements were taken using Sonalysts' array to determine peak pressure, impulse, and energy flux density for both the engineered charge and the bulk charges used.

The general conclusions of the measurement phase of TAR Project 429 was that values of peak pressure (shockwave), impulse, and energy flux density obtained from both the engineered and the bulk charges generally follow the accepted exponential shape when presented as a function of the distance from the blast charge divided by the cube root of the charge weight. These values are also closer to those computed with the Connor Similitude Equation than those obtained using the UWC, which can be expected based on the method used to obtain the equations and the conservative assumptions used to develop ARA's model. The values for the peak pressure and energy flux density are obtained at half the distance for the 4.05 pounds engineered charge than for the 50 pounds bulk charge (see Appendix A). The data suggests that use of an engineered charge of 5 lbs NEW or less can reduce the impact zone for MPS by as much as 50% over the 50 lbs bulk charges commonly used.

1.4. TAR PROJECT NO. 570 PROPOSAL AND OBJECTIVES

1.4.1. PROJECT ASSUMPTION

The main assumption made by TAR Project No. 570 is that an increase in the BML cut depth for an explosive-severance charge would result in increased attenuation from the additional target and surrounding sediments that would work to reduce the pressure wave and acoustic energy released during detonation; thereby, decreasing the resultant MPS impact zone. In effect, this study was developed to gather in-situ measurements that would show that an increase in BML severance depth, if quantifiable through subsequent modeling and/or additional similitude work, could be used as an additional mitigative measure for decommissionings using explosives. Supporting the main assumption is the premise that current predictive-modeling tools do not represent actual TTS impact zones used in mitigation planning and additional *in-situ* data would be critical for increasing their accuracy and enhancing the overall understanding of underwater detonations.

1.4.2. PROJECT OBJECTIVES

Project No. 570 centered on two primary objectives that would support the assumptions made by the study and assist with continued data collection:

1. Evaluate the effect of placing explosive-severance charges (similar configuration and NEW) at 15-ft, 20-ft, 25-ft, and 30-ft BML and gathering the resultant blast effect data to compare the difference that depth would make in peak pressure, impulse, and energy flux density (acoustic energy), and;
2. Increase the volume of measured *in-situ* detonation data by at least 16 successful shots for interpretation in this and future acoustic studies. These 16 shots were to include engineered charges ranging from five to seven pounds alongside more commonly used bulk charges, both to be placed at different depths below mudline for the in-situ measurements covered under Primary Objective 1.

2.0. THEORETICAL BACKGROUND - SOUND PROPAGATION THROUGH WATER

2.1. SHOCK WAVE ATTENUATION

Porous materials are used extensively for shock isolation. Explosively produced shock waves move through some materials more readily than others. The shock impedance of a material and also boundaries between different materials determines how an explosive shock wave attenuates. A material of an impedance that shock waves do not move readily through such as soil causes attenuation that “whittles” down the pressure in the front more rapidly (than a material like steel or water) until the pressure reaches a region of elastic behavior and the shock deteriorates to a sound wave. Conversely, materials with impedances amenable to transmission of shock waves (steel, water) result in a slower degradation of the shock waves into the elastic region.

A basic material difference between soil and steel or water is that soil has interstitial areas that are occupied by something other than soil (water, silt, air or gasses). Close to the mudline, these interstitial areas are filled with a large percentage of water. The particles of soil are suspended in water and the shock wave moves through this material more as it would move through water than soil. At greater depths below mudline the interstitial areas are occupied with a greater percentage of material other than water. In this case the shock waves are transmitted particle to particle. Crossing boundaries between materials (water to steel to soil, or soil to soil particle through interstitial substances) creates reflective and rarefaction waves which cause faster decay of the shock front. Figure 2.1 below depicts a shock front attenuating to the elastic region (a sound wave). The shock front in front of point A is at high pressure. The velocity at the back of the wave (point B) is moving into a higher density region than the front and is encountering faster particle speed than the front, thus it is travelling faster than point A. The rear of the shock wave (rarefaction wave) eventually catches up to the front and “smears out” the back of the wave and "whittles down" the front to a sound wave (D), as the rarefaction wave in the rear continues to travel faster than the front of the shock wave.[17]

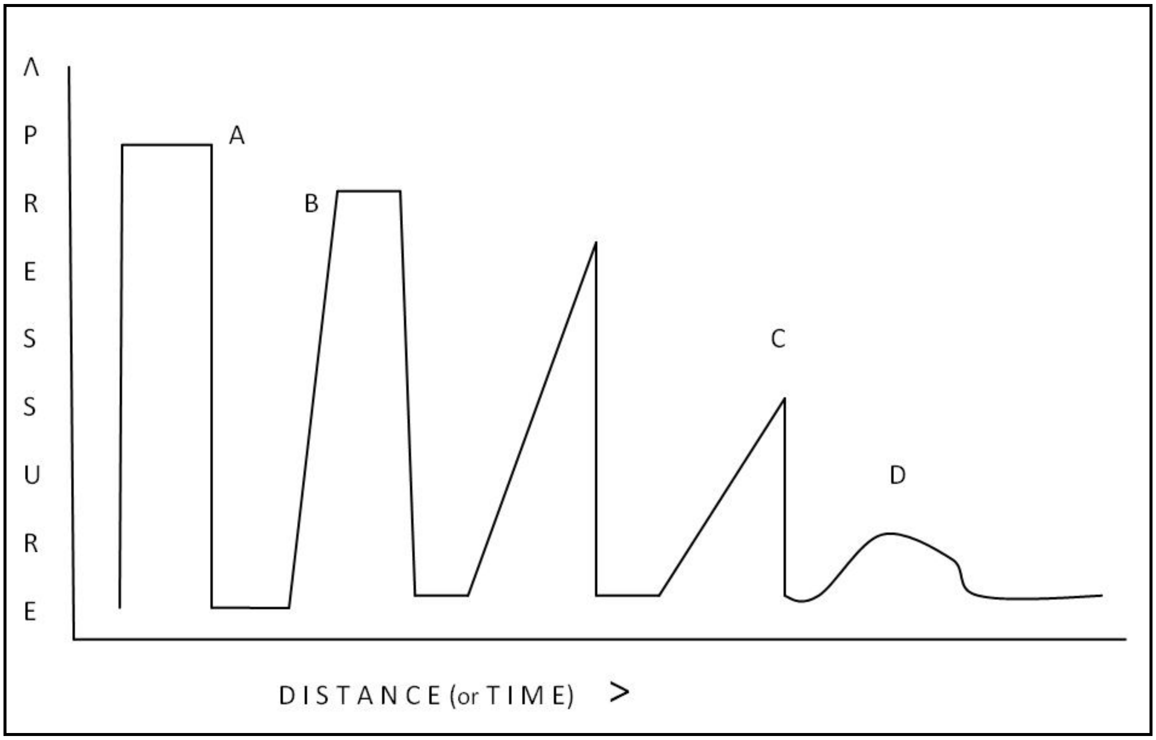

Figure 2.1. Attenuation of a Shock Wave to the Region of Elastic Behavior (i.e. a Sound Wave).

2.2. NOISE ATTENUATION AT SEA

Sound waves spread out in a fashion that relates to the source directivity and the surrounding environment. Consider a source which is infinitely small and which radiates spherically, in others words in all directions equally. This is termed a point source. Placed in open water, with no boundaries (sea surface or seabed) in close proximity (i.e. the distance from each boundary is much greater than the wavelength of the frequency radiating from the source), the sound will propagate in a spherical fashion, with the observed sound pressure value diminishing at a rate of $1/r^2$; hence, the term inverse square law or spherical spreading.

If the same source is used, but the wavelength of the frequency emitted is much larger than the distance to each of the boundaries (water surface and a "hard" seabed), the "sphere" of propagation will be truncated and the propagation will be in a cylindrical fashion, giving a pressure drop off rate of 1/r, or cylindrical spreading. If this source is placed in a duct, for example, and the radiated frequency's wavelength is much greater than the cross sectional dimensions of the duct, the waves will propagate as plane waves, and there will be no loss (or at least minimal) of the pressure amplitude throughout the duct. See Figure 2.2 for plots of these spreading laws.

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[17] Cole, Robert H. "Underwater Explosions" Princeton University Press, 1948
Cooper, Paul W. & Kurowski, Stanley R. "Introduction to the Technology of Explosives" VCH Publishers, Inc. 1996
Fedoroff, Basil T. & Sheffield, Oliver E. "The Encyclopedia of Explosives and Related Items" Picatinny Arsenal, 1975
Cooper, Paul W. "Explosives Engineering" VCH Publishers, Inc. 1996

In underwater acoustics, there is another spreading phenomenon termed hyperspherical spreading in which the sound pressure levels drop off at a rate of $1/r^3$, or inverse cube.[18] This unintuitive rate is said to be due to time stretching in a free field. As will be seen in a later discussion, the Connor similitude equations also infer inverse cube spreading, but for a different reason.

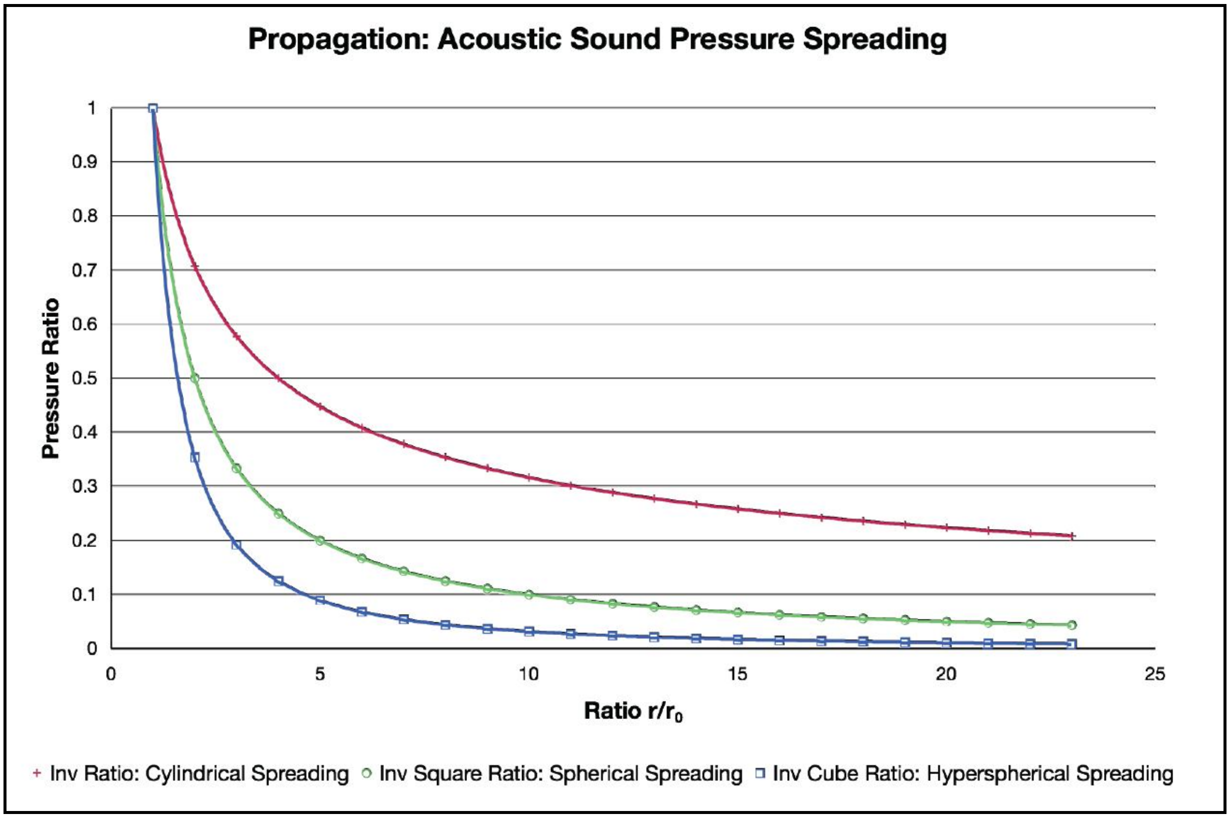

Figure 2.2. Sound Pressure Decrease versus Range Ratio for Various Spreading.

Another factor in determining the velocity of sound in the ocean is the temperature of the water. An increase of ten degrees Fahrenheit increases the sound velocity by 40 feet/second. Some variation to this may occur depending on temperature, depth, and salinity. In the ocean, different horizontal layers of water are not at the same temperature and this results in a vertical gradient of sound velocity. This can cause the sound wave front to travel at different rates which bends and distorts the wave front.[19]

3.0. EXPERIMENTAL DESIGN AND PROCEDURE

3.1. BASIC CHARGE PLACEMENT PROTOCOL

Unlike TAR Project 429, which made all cuts at 15-ft BML to center on the comparison of engineered charges versus bulk charges, TAR Project 570 was developed to evaluate the effect of placing similar charges at 15-ft, 20-ft, 25-ft, and 30-ft BML to measure the difference that depth would make in peak pressure, impulse, and acoustic energy. Since the target structures would not be selected until well after the contract was awarded, the SOW for TAR Project 570 provided allowances for in-field determinations regarding the charge size, type (i.e., engineered/bulk), and BML depth configuration to be used. The flexibility permitted ESI and the measurement team to ensure that the BML protocol was

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[18] Urick, R.J. "Principles of Underwater Sound; 3rd ED" New York: McGraw-Hill, 1975

[19] Cole, Robert H. "Underwater Explosions" Princeton University Press, 1948

met while at the same time matching the proper charge with each target so not to interrupt the operators' decommissioning requirements. This aspect was critical in overcoming several field challenges related to problems with pile jetting, obstructions and damage within the targets, and scheduling issues. The final charge size and placement information can be found in Tables 4-1 and 4-2.

3.2. BASIC ACOUSTIC ARRAY DESIGN

Based on the success of TAR Project 429 and the interest on the part of MMS in gathering similar related data, ESI chose to once again use Sonalysts to provide array expertise for TAR Project 570. Similar to the array developed for the previous measurement work, Sonalysts constructed a transducer array consisting of twelve (12) PCB W138A Underwater Blast Pressure Tourmaline Transducers. The transducers function as receivers and were used for capturing peak pressure readings. The transducers were powered by PCB ICP power supplies with the signals fed into a Yokogawa DL750 ScopeCorder where the data would be stored for later retrieval.

As represented in Figure 3.1, the nearfield downlines, 3 each, had set on them 3 transducers positioned at 5-, 20-, and 40-ft vertically above the mudline. The farfield arrays, 3 each, had set on them 1 transducer 40-ft above the mudline. Each transducer was tied back to the power supply and ScopeCorder via a dedicated coaxial cable, so once the water depth for the targets were known, the transducers and cables were attached to the rope downlines. With each set with a sonar reflector and anchor, the downlines were then supported in the water column by a float and coated steel cable that was suspended taught between the target structure and the measurement vessel (M/V) that housed the power supplies, ScopeCorder, and technicians. The cable was pre-marked for the proper standoff from the structure and each nearfield and farfield downline offset to assist with array deployment.

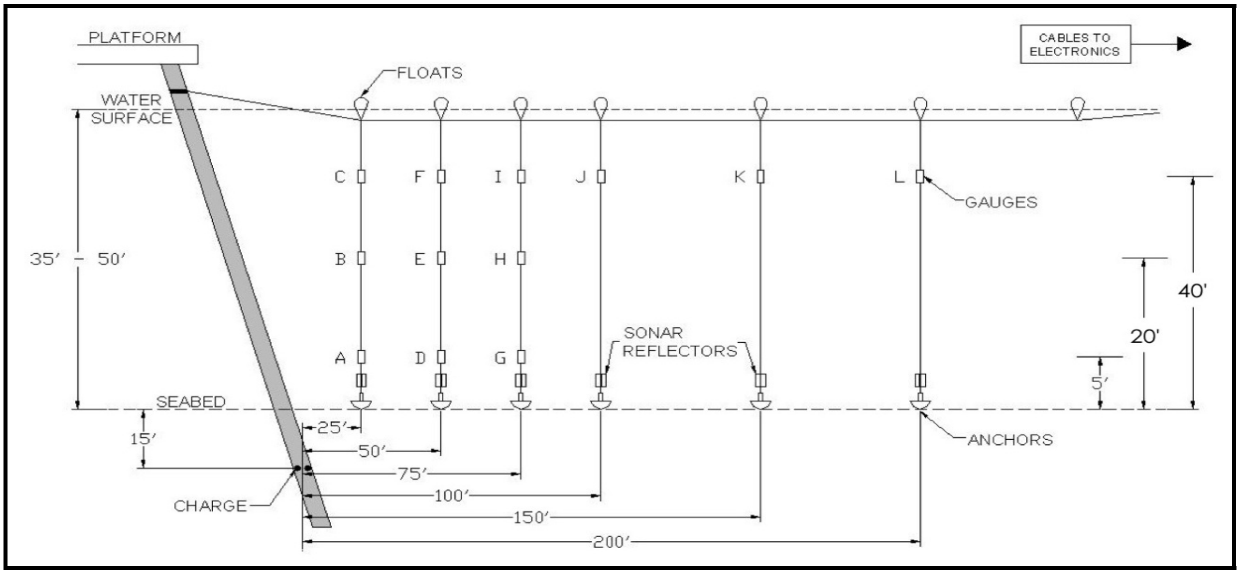

Figure 3.1. Proposed Physical Transducer Array Overview.

3.3. ARRAY DEPLOYMENT AND VERIFICATION

3.3.1. PROPOSED DEPLOYMENT METHODOLOGY

Prior to the field mobilizations, the primary deployment methodology was based upon the procedure used during the TAR Project 429 deployments, which was developed to allow the least amount of interference with the decommissioning schedule and derrick barge crew. This method required the use of a dedicated M/V that would rely upon a system of winches and anchoring to assist with deployment of the array and subsequent station keeping so to maintain a stable platform for the equipment and personnel during the detonation event. After setting a bow anchor about 500 ft from the structure, the M/V would back its stern into the target structure while paying out the forward anchor line. With the stern of the M/V at the structure, the array cable and a stern winch line could be attached to a leg of the platform. With the M/V engines out of gear (to negate problems from prop wash), the forward anchor line was taken in as the stern winch line was paid-out to allow forward movement and controlled deployment of the downlines over the stern. Once the final farfield line was set, the anchor/winch system moved the M/V forward to the fullest extent of the transducer cables (generally about 250-300 ft) and held-fast to maintain station keeping.

Once the M/V was secured, personnel from MMS GOMR would deploy their Mesotech, MS-1000 sector-scanning sonar to record the fixed positions of the structure components and each of the sonar reflectors attached to the downlines. Once the positions were verified and enough scans recorded, the sonar would be retrieved and secured just prior to the detonation event. The recorded scans would be rerun later to document the distance data using specialized MS-1000 software. In addition, the team would use a RBR XR-420 CTD logger prior to each detonation event to record the depth, speed of sound (derived from conductivity/salinity), and temperature measurements.

3.3.2. DEPLOYMENT METHODOLOGIES USED DURING THE 1ST MOBILIZATION

Once in the field on the first mobilization, it was discovered that the crewboat contracted as a M/V did not have a functioning forward anchor windlass. Additionally, since the crewboat was an aluminum-hulled vessel, portable tuggers (i.e., pneumatic-powered winches with steel bases) supplied by the derrick barge could not be welded to the deck to assist with the station keeping. Therefore, three separate field procedures were developed to deal with equipment shortfalls and overcome sea/weather conditions.

Array Deployment Using the Derrick Barge as a Measurement Vessel

When it was determined that the crewboat would not be a sufficient M/V, a liftboat was dispatched to the removal site. However, before it could enter the field, the project team was presented with an opportunity to take measurements of a well string detonated within a caisson. The operator and barge contractor agreed to allow the team to deploy the array from the derrick barge similar to the proposed methodology (Section 3.3.1); using the vessel's highly-controlled anchoring system to pull away from the target in increments. Because barge policy was to maintain at least an 800 ft standoff from an explosive detonation, the team had to attach a 500 ft leader line in front of the array to compensate for the maximum 300 ft extent of the transducer cabling. There were several disadvantages related to this methodology. In addition to tying up valuable barge time, the downlines/transducers had to be deployed and retrieved from a much higher position along side of the barge, leading to additional damage to the delicate connections and wiring. Only farfield measurements could be recorded. Lastly, additional sets of MS-1000 sonar records had to be taken along side the structure prior to the array work, during the midpoint of the array deployment, and at the final station keeping position to overcome the larger distance (see Appendix B; pg B-6 for details).

Array Deployment Using a Small Watercraft and Liftboat

Once the liftboat arrived in the field, the orientation of the barge and prevailing currents/seas did not allow for a controlled deployment from the vessel. Therefore, after the array cable was attached to the platform, the liftboat maneuvered back 300 ft from the structure and jacked-down. With the slack taken from the array cable and the liftboat set on the seabed, the vessel's small emergency watercraft (an inflatable Zodiac™ with a 20 horsepower outboard) was used to ferry each downline into position and the cabling was brought back to the liftboat for connection to the power supply and ScopeCorder. This process was repeated for the remaining five downlines and when completed, the inflatable was lifted back onto the M/V so that the MMS team could conduct the MS-1000 sonar recordings (see Appendix B; pg B-7 for details). The main advantages noted for this methodology were that:

- the liftboat provided an extremely stable measurement platform that could be jacked out of the water during the detonation events;
- the liftboat could provide berthing/galley accommodations for the measurement team, negating multiple personnel transfers;
- the deployment and subsequent retrieval work could be done quickly without interfering with critical barge operations; and
- the downlines were carefully set at the water level allowing for more precise float heights and sensitive care of the electronic components.

Array Deployment from a Measurement Vessel

The third deployment method was developed on a day when the weather conditions/sea state would not allow for safe use of the small watercraft and the array cable between the platform and M/V. Therefore, to allow for measurements to be taken, the team set all the downlines around the deck of the liftboat, running several sets of MS-1000 sonar recordings to capture the orientation of each. The primary disadvantage of this methodology is that only farfield measurements could be taken (see Appendix B; pg B-8 for details).

3.3.3. DEPLOYMENT METHODOLOGY USED DURING THE 2ND MOBILIZATION

It was determined prior to the second mobilization that array deployment using the small watercraft presented the greatest advantages. Therefore, arrangements were made early in the planning stage to have a liftboat available as the M/V and to have it set up with a small watercraft, equipment storage, and accommodations for the measurement team (see Appendix C; pg C-5 for details).

4.0. MEASUREMENT RESULTS AND ANALYSIS

4.1. PRESENTATION OF RESULTS

As previously mentioned, since donations-in-kind and available test structures were available from Maritech and Merit, removal scheduling allowed for two separate measurement series to be conducted under TAR Project 570. Three individual detonation events were measured during the first mobilization in EI128 under the methodologies presented in Section 3.3.2. A single detonation event was measured during the second mobilization in EC32 using the methodology discussed in Section 3.3.3. Details on the charge selection and placement and the related measurement results can be found below.

4.1.1. MEASUREMENT RESULTS FROM THE 1ST MOBILIZATION

The first mobilization under TAR Project 570 took place between July 26 and August 1, 2007 in EI128, about 30 miles off the Louisiana coast south of Morgan City. The measurement work was conducted in association with the decommissionings of Platform F-4, a 10-pile jacketed platform, and the bridge-connected Caisson F, both belonging to Maritech. One well conductor (F3) remained on the Platform F-4 and an internal conductor was set within Caisson F. The deck-prep, jetting, cutting, and lifting work was conducted off of the ***Cherokee***, a derrick barge from Global Industries, Inc., and the project management was overseen by TETRA Applied Technologies, Inc. The first detonation event was measured off of the ***Cherokee*** and the second and third detonation measurements were conducted from the ***Seabream***, a liftboat contracted from Hercules Offshore, Inc., for use as a stable measurement vessel.

Figure 4.1 illustrates the layout for Platform F-4's 10 piles, named A1 through A5 and B1 through B5, the well conductor within the platform (F3), and Caisson F with an internal conductor (C1). There were also open water tests using five pound charges. Their locations are recorded as OW1 and OW2. These two charges provided additional data for comparison to the predictions of the UWC and Connor Similitude Equation as well as equipment calibration.

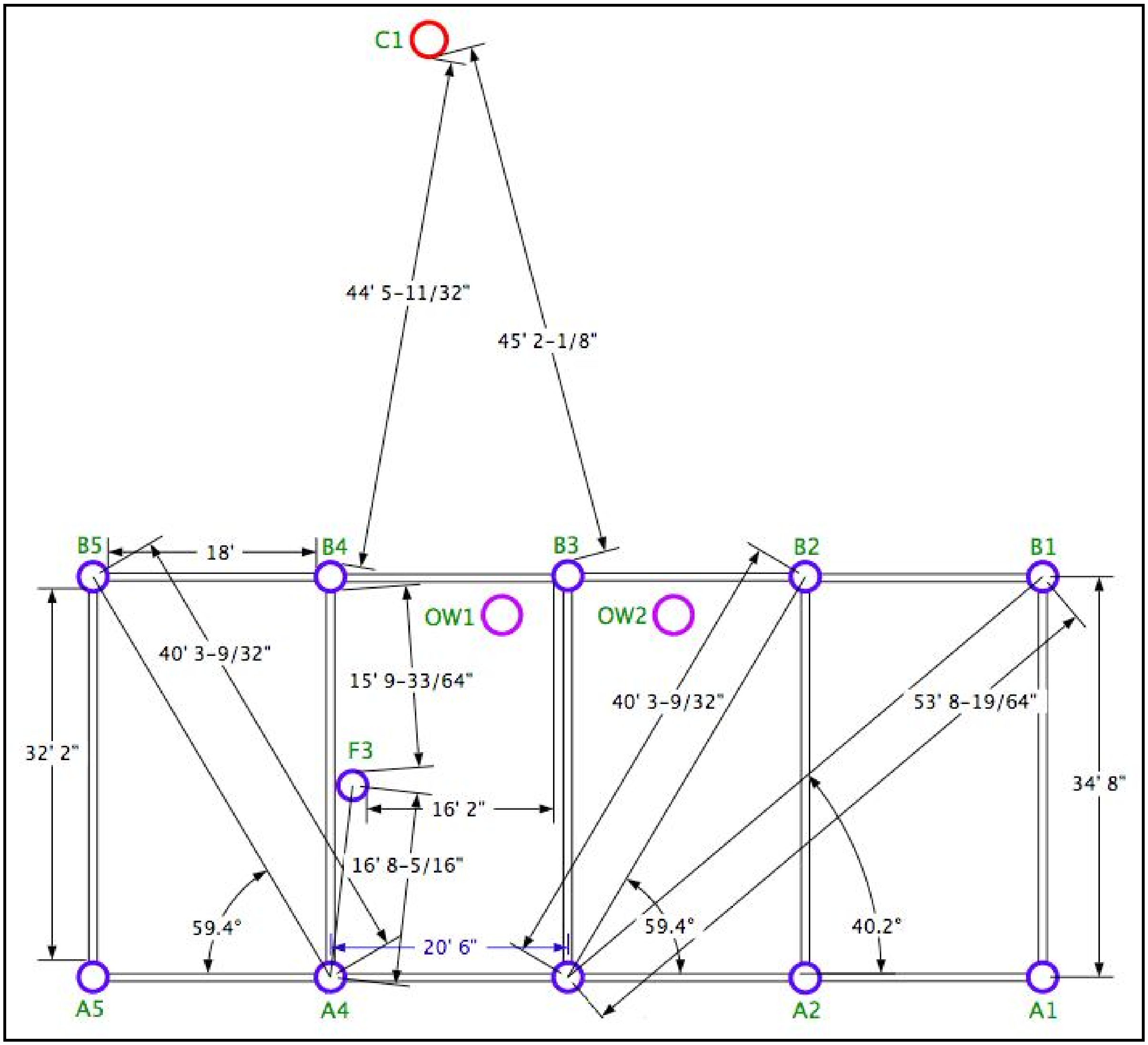

Figure 4.1. Locations of Platform F-4's Pilings and Conductor (F3) and Caisson F (C1) at the EI128 Location.

Once the topsides were removed and jetting operations complete, ESI was able to choose the charge configurations for the caisson, piles, and conductors. After gauging operations were conducted on the jetted targets, it was determined that pile damage and several obstructions within the tubulars would not allow for proper placement of the Scorpion™ engineered-charge delivery devises. Therefore, bulk charges were selected for all of the severance work to allow for the greatest number of successful detonations and so as not to disrupt Maritech's removal schedule. The final charge locations and configurations (i.e., size, BML depth) can be found in below in Table 4-1.

Table 4-1

Charge Configuration for Platform F-4 and Caisson F; Eugene Island Block 128

Final Sequence	Target	Charge Placement Relative to Mudline	Charge Weight (lbs)	Target Diameter (Inches)	Wall Thickness (Inches)	Comments
July 29, 2007						
1	Well Conductor C1	15-ft BML	25			Conductor Inside Caisson C1
July 31, 2007						
1	Caisson	20-ft BML	75	36	1.000	Caisson diver cut 4 ft above mudline
2	OW1	5-ft AML	5	N/A	N/A	Calibration and Model Comparison
3	Well Conductor F3	30-ft BML	50	30	0.625	16 Inch Inner String 26 Inch Outer Wall
4	OW2	5-ft AML	5	N/A	N/A	Calibration and Model Comparison
August 1, 2007						
1	A1	15-ft BML	50	30	0.625	
2	A2	15-ft BML	50	30	0.625	
3	A3	20-ft BML	50	30	0.625	
4	A4	30-ft BML	50	30	0.625	Was originally to be Scorpion™ @ 4.4 lbs
5	A5	20-ft BML	50	30	0.625	Was originally to be Scorpion™ @ 4.4 lbs
6	B5	25-ft BML	50	30	0.625	Was originally to be Scorpion™ @ 4.4 lbs
7	B4	30-ft BML	50	30	0.625	Was originally to be Scorpion™ @ 4.4 lbs
8	Well Conductor F3	30-ft BML	65	30	0.625	Well conductor wasn't cut on 7/31/07
9	B3	20-ft BML	50	30	0.625	
10	B2	25-ft BML	50	30	0.625	
11	B1	25-ft BML	50	30	0.625	

Information on the transducer calibration and location information for the three detonation events can be found in Table D-1 of Appendix D. The measured acoustic data for the detonations can be found in Table D-3 of Appendix D.

4.1.2. MEASUREMENT RESULTS FROM THE 2ND MOBILIZATION

The second mobilization took place on August 9, 2008 in EC32, about 9 miles off the Louisiana coast south of Grand Chenier. The measurement work was conducted in association with the decommissioning of Merit's Platform A, a 4-pile jacketed platform. Though previously plugged and abandoned (P&A), five well conductors remained on the platform for final severance and removal with the facility. The deck-prep, jetting, cutting, and lifting work was conducted off of the ***DB-1***, a derrick barge from TETRA Applied Technologies, Inc. All array deployment work and measurements were conducted from the ***Hammerhead***, a liftboat contracted from Hercules Offshore, Inc., for use as a stable measurement vessel. Figure 4.2 illustrates the layout for Platform A's four piles, named A1, A2, B1, and B2. The five well conductors were named 1, 2, 3, 4, and 5.

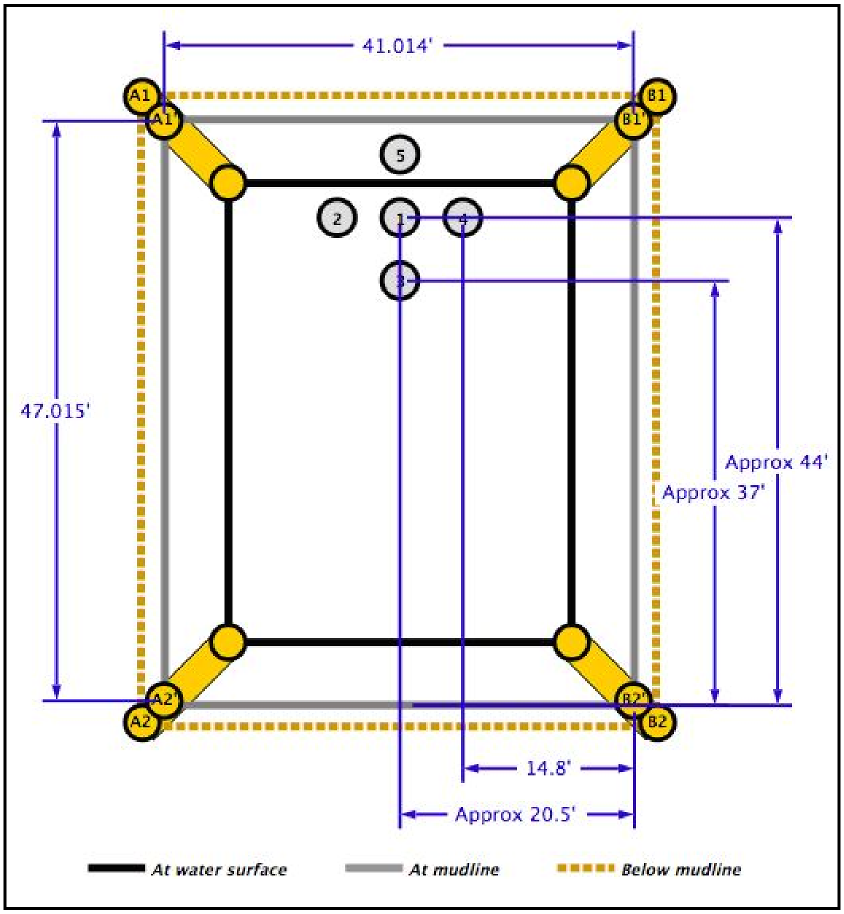

Figure 4.2. Locations of Platform A's Pilings and Conductors at the EC32 Location.

As with the EI128 platform, gauging work on Platform A's piles indicated that obstructions would not allow for proper placement of a Scorpion™, so bulk charges were selected to allow for the greatest number of successful detonations and so not to disrupt Merit's removal schedule. The final charge locations and configurations (i.e., size, BML depth) can be found in below in Table 4-2.

Table 4-2

Charge Configuration for Platform A; East Cameron Block 32

Final Sequence	Target	Charge Placement Relative to Mudline	Charge Weight (lbs)	Target Diameter (Inches)	Wall Thickness (Inches)	Comments
1	Pile B2	15' BML	80	36	1.00	Initially slated for Scorpion™
2	Pile B1	20' BML	80	36	1.00	Initially slated for Scorpion™
3	Conductor 1	25' BML	145	48	1.50	Outside tubular size*
4	Conductor 5	25' BML	145	48	1.25	Outside tubular size*
5	Conductor 3	30' BML	145	48	1.25	Outside tubular size*
6	Conductor 4	30' BML	145	48	1.25	Outside tubular size*

**The outside casing size was used for well conductor ARA model calculations as the model does not accommodate multiple inner string configurations for the well conductors*

Information on the transducer locations and the measured acoustic data for the EC32 detonation event can be found in Tables D-2 and D-4 of Appendix D.

4.2. ANALYSIS OF RESULTS

4.2.1. UNDERSTANDING THE INFLUENCE OF CHANGE IN MEDIA

If the charge energy is directly and perfectly coupled to the pile/jacket, the efficiency is maximized. If the charge is a bulk charge, much of the energy could be lost due to the coupling cavity (water, air, mud below). This is demonstrated by the example of shaped charges which require less energy (charge weight) to effectively sever piles of the same size and wall thickness. For well conductors, issues arise regarding the number and size of inner well casings, the presence (or lack of) and type of grouting, and other structural anomalies. Some of the variables which influence coupling efficiency are:

- Bulk versus shaped charge and the configuration of each;
- Physical coupling between the charge and pile/jacket;
- Distance below mudline: this changes the effective local impedance of the pile;
- Depth of jetting in pile below the charge location; and
- Amount of water/air in the pile/jacket.

The coupling between the pile and seabed also influences efficiency. Voids or non-homogenous elements (rocks, bits of scrap) will alter the expected efficiency. Furthermore, the actual composition of the local seabed will determine further the efficiency, i.e. the ability for the seabed medium to conduct and transmit sound waves.

Lastly, there is coupling between the seabed and water column above it. In some instances, they are similar enough in density that there is no impedance change, lending to the two becoming one continuous medium. For a given seabed composition, the water column weight per unit area increases with depth, adding another factor regarding a possible impedance mismatch location. The speed of sound will be different for the seabed and seawater mediums due to the differences in density and modulus. The propagation time for the explosion energy to reach the measurement transducer can be calculated knowing these speeds of sound and the slant range (see Figure 4.1). However, depending on the charge's actual coupling to the pile/jacket, it is possible that some of the sound energy arriving at the transducer is due to sound radiation from the pile/jacket, amplified by the pile's resonant modes. This would cause the observed time waveform to be smeared, either creating multiple overpressure peaks, or one wide rounded peak.

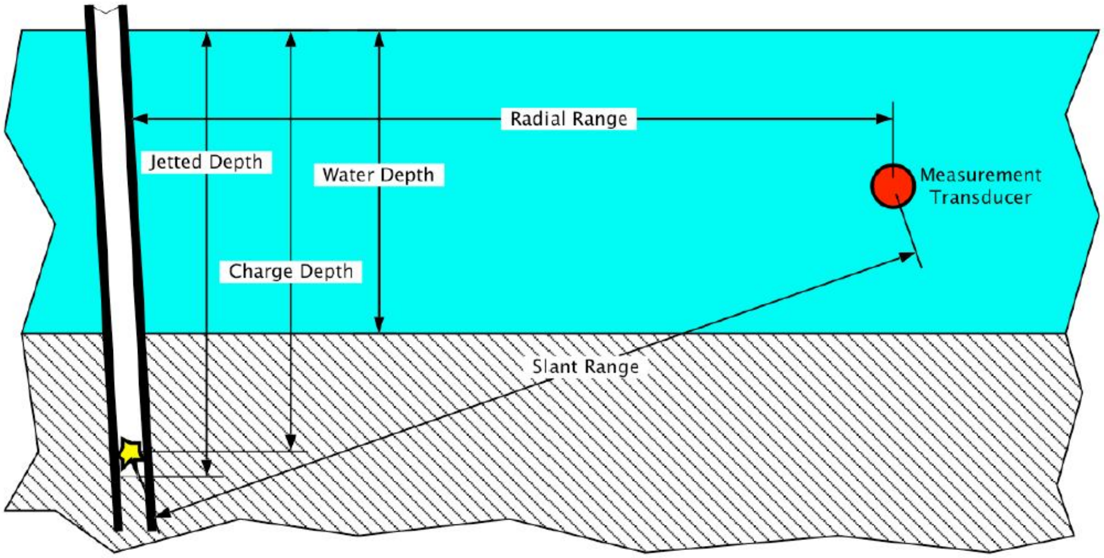

Figure 4.3. Schematic of Sound Transmission Paths.

4.2.2. DATA INTERPRETATION

Some examples are presented following which represent multiple shots for a given charge size. Within each charge size data set, various conditions are seen. These include varying BML depths, pile wall thicknesses, and a pair of open water shots. These plots include overlays of both Connor and ARA predicted values. A review of the graphs presented shows that the ARA model is very conservative for non-open-water shots. While the open-water shots correlate very well with ARA predicted values, the predictions for BML shots in piles/jackets show much higher overpressure values than measured. Apparently, the ARA model does not take into account the changing ratio of seabed/water distances (hence time spent in a given medium) for various slant ranges, transducer depths and radial ranges.[20]

Conversely, the similitude equations developed by Connor correlate very well with much of the data presented herein. In some cases, the Connor predictions, in which pressure decreases proportional to the charge weight cubed, overlay the measured data; in others, the measured data falls somewhat below the Connor predictions. Of note is the observation by Connor that shots of charges at BML depths between 8 and 26 feet yield similar overpressure values.[21] This can be seen in Figure 4.4 where, although the 15-ft BML data is in an area separate from the confluence of 20-/25-/30-ft BML data points, the data points on average fall reasonably close to one another.

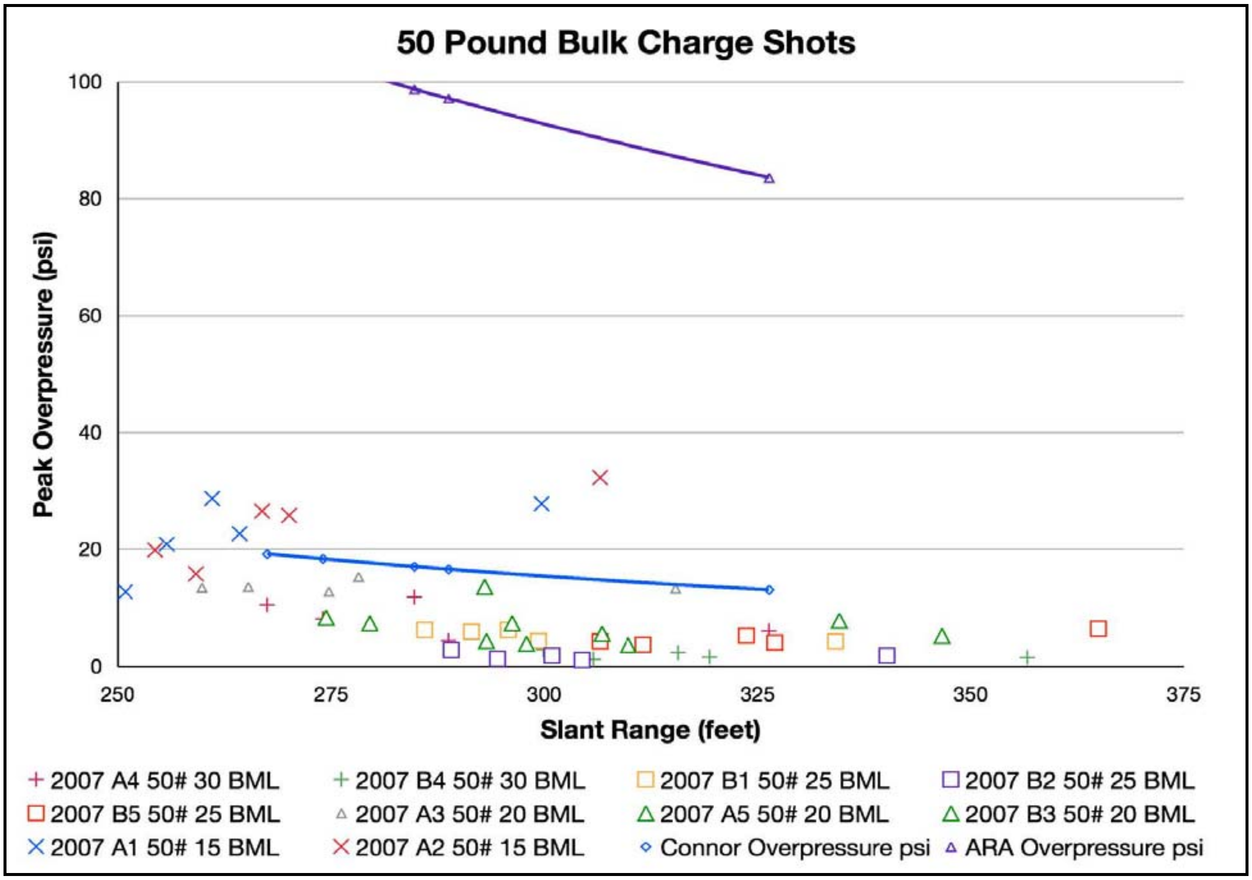

Figure 4.4. 50 Pound Bulk Charge Shots - Far.

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[20] Dzwilewski, P.T. and G. Fenton. " Shock Wave/Sound Propagation Modeling Results for Calculating Marine Protected Species Impact Zones During Explosive Removal of Offshore Structures" Minerals Management Service, Gulf of Mexico OCS Region, September 2003

[21] Connor, Joseph G., Jr. "Underwater Blast Effects From Explosive Severance of Offshore Platform Legs and Well Conductors" Naval Surface Warfare Center, Dahlgren, VA, Research and Technology Department, 15 December 1990

While an exhaustive available reference material search has not been conducted, it seems that the actual sound transmission mechanism has not been fully studied nor adequately described empirically, at least in publicly available publications. While modeling calculations are available to predict theoretical values, there appears to be little in the way of data to reinforce these equations. It is not clear as to what percentage of the sound wave incident at the transducers originates from the line-of-sight path along the slant range and what percentage originates along the radial range line-of-sight path. This may explain the precursors which Connor observed during his measurements.[22] In air acoustics, a technique termed Sound Intensity Mapping (SIM) is used to determine the energy flux of sound wave propagation, resulting in the vector quantity of sound intensity, or W/m^2. This directional flow of sound helps to illustrate and show just how the sound radiates and clearly identify noise sources. However, other than military use, underwater sound intensity measurements are unknown with current technology.

Furthermore, the time data waveforms from these measurements look considerably different than the classic open-water shock pulse (see Figure 4.5). Some of this discrepancy can be attributed to the fact that some frequency dependent filtering and delay will occur due to the impedance of the seabed and seawater. Other factors include reflections among multiple piles within a platform structure, coupling anomalies as previously stated, and transducer movement. Smeared waveforms may also be a product of the multiple sound transmission paths described above.

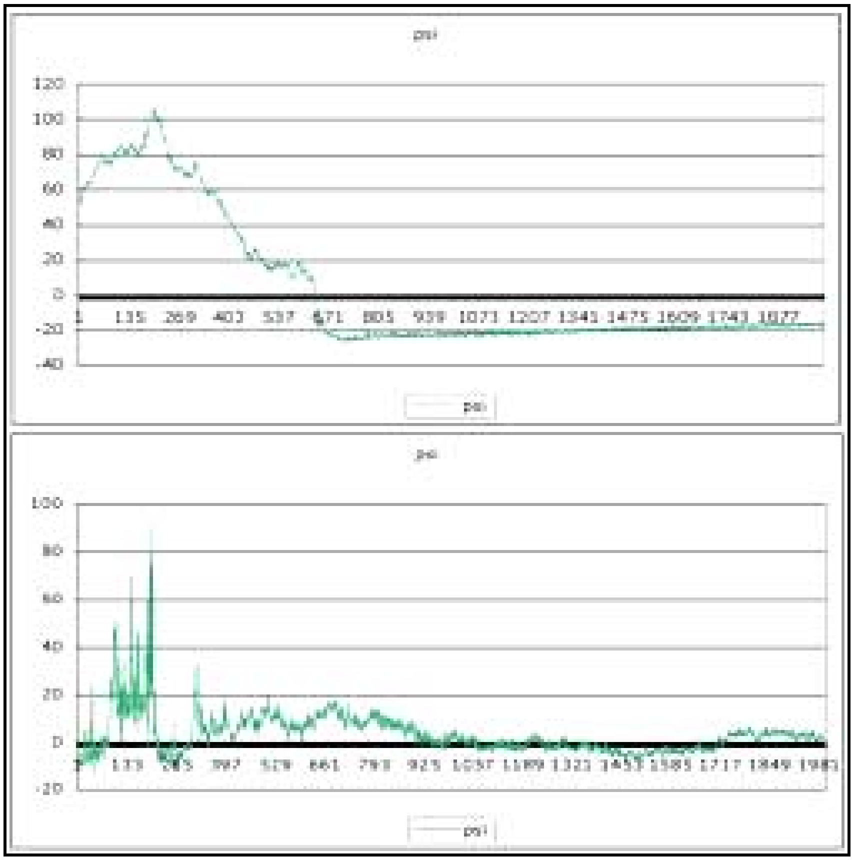

Figure 4.5. Some Example Waveforms (2008 Jacket B2, XDCRs D and G).

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[22] Connor, Joseph G., Jr. “Underwater Blast Effects From Explosive Severance of Offshore Platform Legs and Well Conductors” Naval Surface Warfare Center, Dahlgren, VA, Research and Technology Department, 15 December 1990

The four 145 pound shots taken in the well conductors of EC32 Platform A all fall below Connor values predicted for charges detonated in well conductors, and far below ARA predicted values (see Figure 4.6 and Table 4-3 below). The shots at 30-ft BML are very close in overpressure levels whereas the two 25-ft BML shots are considerably different. This difference can be attributed to the fact that one well conductor WC1 has a 1.5" wall thickness and the other, WC5, has a 1.25" wall thickness. Intuitively one might think that WC1 values should be lower due to the thicker wall. However, the construction of the well conductor as well as the grout condition and consistency along with many other variables explained in the preceding text also influence the transmission loss (efficiency) of the charge energy. Most important is the fact that levels of all of the shots fall below the Connor predictions.

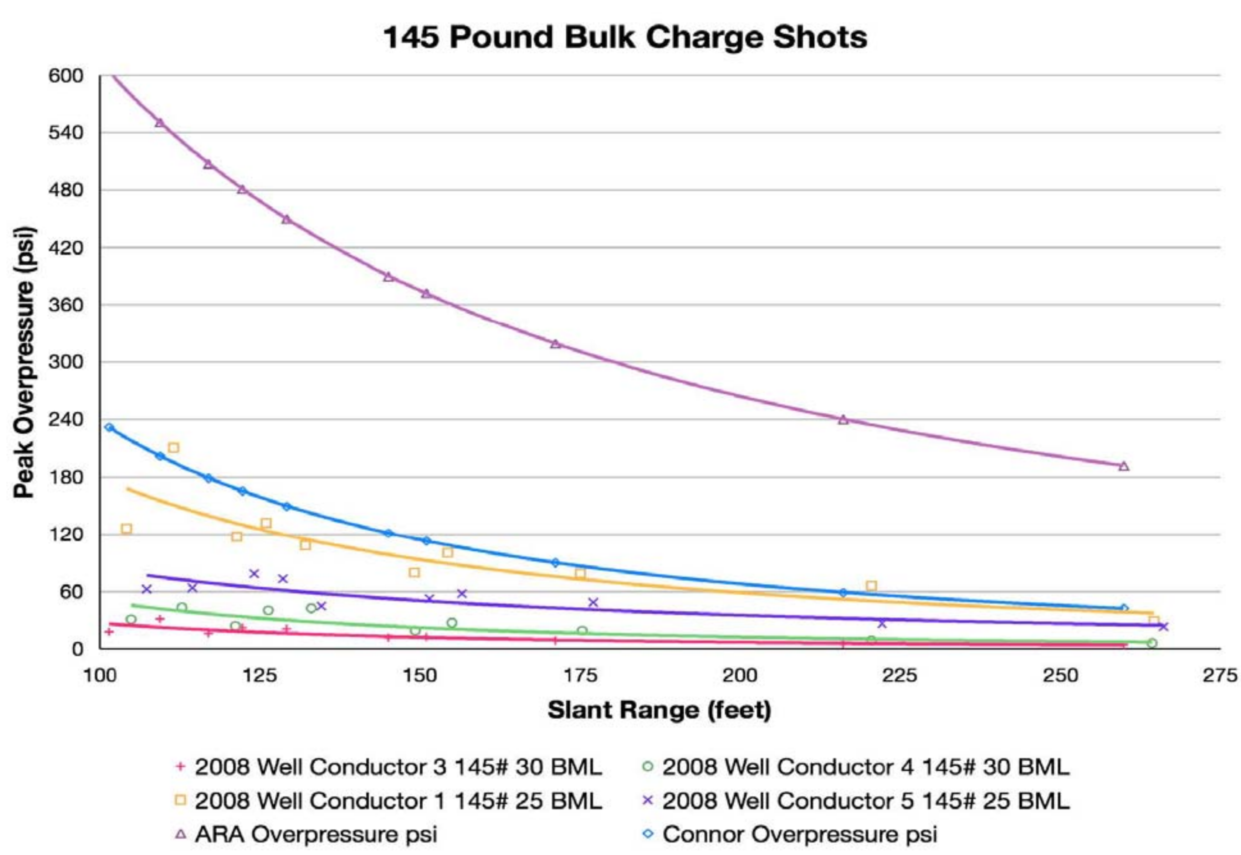

Figure 4.6. 145 Pound Bulk Charge Shots from EC32 Platform A.

Table 4-3

145 Pound Bulk Charge Shots Details for Figure 4.6

Target	Charge Placement Relative to Mudline	Charge Weight (lbs)	Target Diameter (Inches)	Wall Thickness (Inches)
Well Conductor 1	25-ft BML	145	48	1.50
Well Conductor 5	25-ft BML	145	48	1.25
Well Conductor 3	30-ft BML	145	48	1.25
Well Conductor 4	30-ft BML	145	48	1.25

The two pile shots for EC32 Platform A, 80 lbs bulk charges, yielded overpressure values that are consistent with the predictions by Connor for pile severance (see Figure 4.7 and Table 4-4 below). Again, the ARA predictions are shown to be greatly conservative.

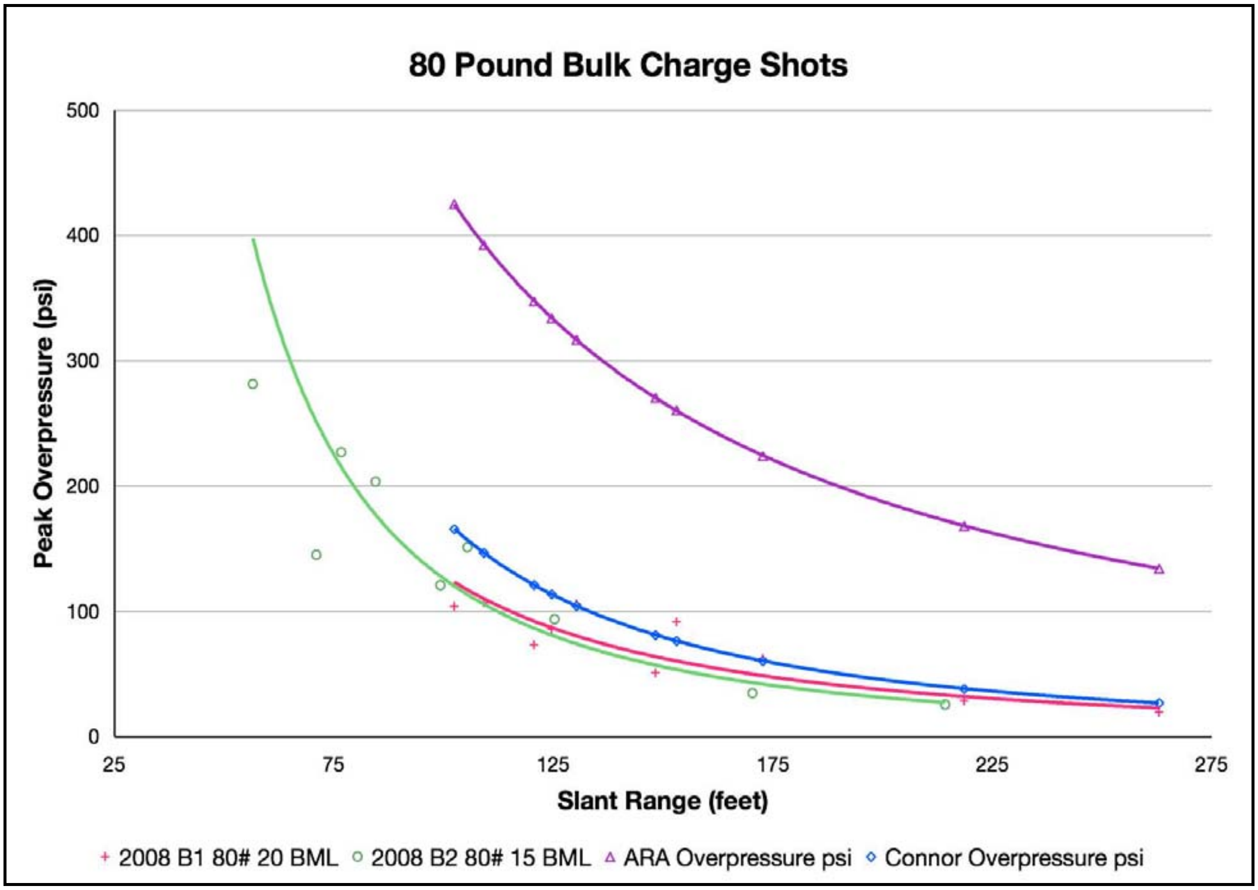

Figure 4.7. 80 Pound Bulk Charge Shots from EC32 Platform A.

Table 4-4

80 Pound Bulk Charge Shots Details for Figure 4.7

Target	Charge Placement Relative to Mudline	Charge Weight (lbs)	Target Diameter (Inches)	Wall Thickness (Inches)
Pile B-1	20-ft BML	80	36	1.00
Pile B-2	15-ft BML	80	36	1.00

Twelve different 50 pound bulk charge shots were analyzed from both TAR Project No. 429 (South Timbalier Block 21, Platform No. 97) and TAR Project No. 570 (EI128 Platform F-4) which show the measured overpressure data to be, once again, consistent with Connor predictions (see Figure 4.8 and Table 4-5 below). As with the 145 lbs and 80 lbs charges, the measured in-situ data was seen to be far below ARA predicted values.

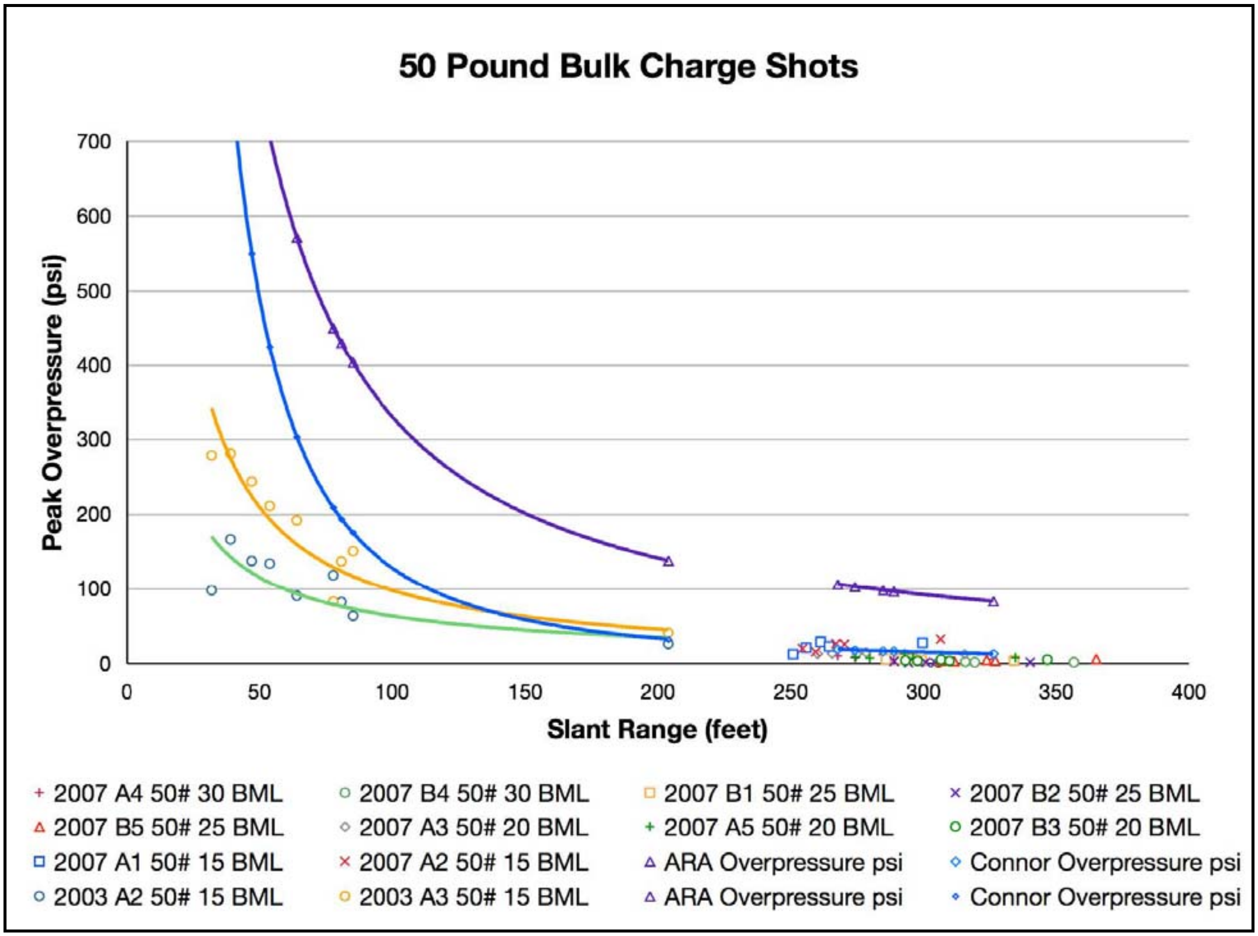

Figure 4.8. 50 Pound Bulk Charge Shots from ST21 Platform 97 (2003) and EI128 Platform F-4 (2007).

Table 4-5

50 Pound Bulk Charge Shots Details for Figures 4.8, 4.9, and 4.10

Target	Charge Placement Relative to Mudline	Charge Weight (lbs)	Target Diameter (Inches)	Wall Thickness (Inches)
Pile A4 (2007)	30-ft BML	50	30	0.625
Pile B4 (2007)	30-ft BML	50	30	0.625
Pile B1 (2007)	25-ft BML	50	30	0.625
Pile B2 (2007)	25-ft BML	50	30	0.625
Pile B5 (2007)	25-ft BML	50	30	0.625
Pile A3 (2007)	20-ft BML	50	30	0.625
Pile A5 (2007)	20-ft BML	50	30	0.625
Pile B3 (2007)	20-ft BML	50	30	0.625
Pile A2 (2003)	15-ft BML	50	24	1.000
Pile A3 (2003)	15-ft BML	50	24	1.000
Pile A1 (2007)	15-ft BML	50	30	0.625
Pile A2 (2007)	15-ft BML	50	30	0.625

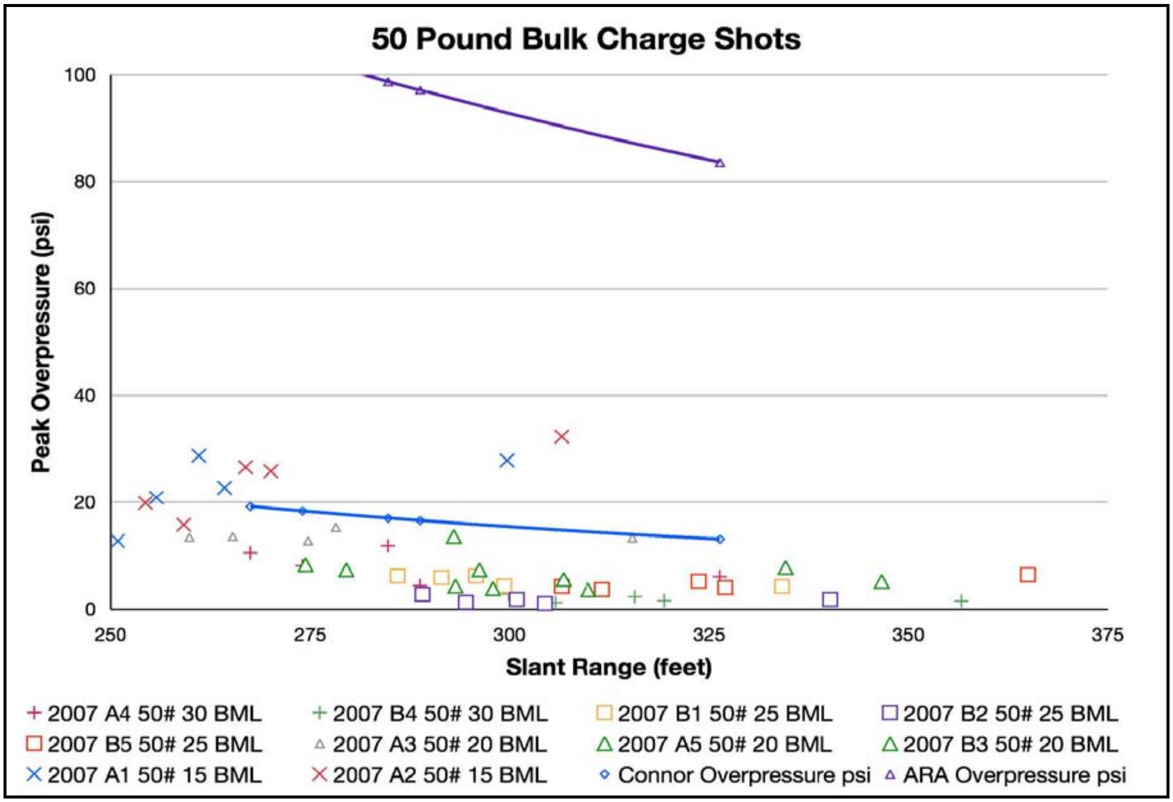

Figure 4.9. 50 Pound Bulk Charge Shots from ST21 Platform 97 (2003) and EI128 Platform F-4 (2007) - Farfield.

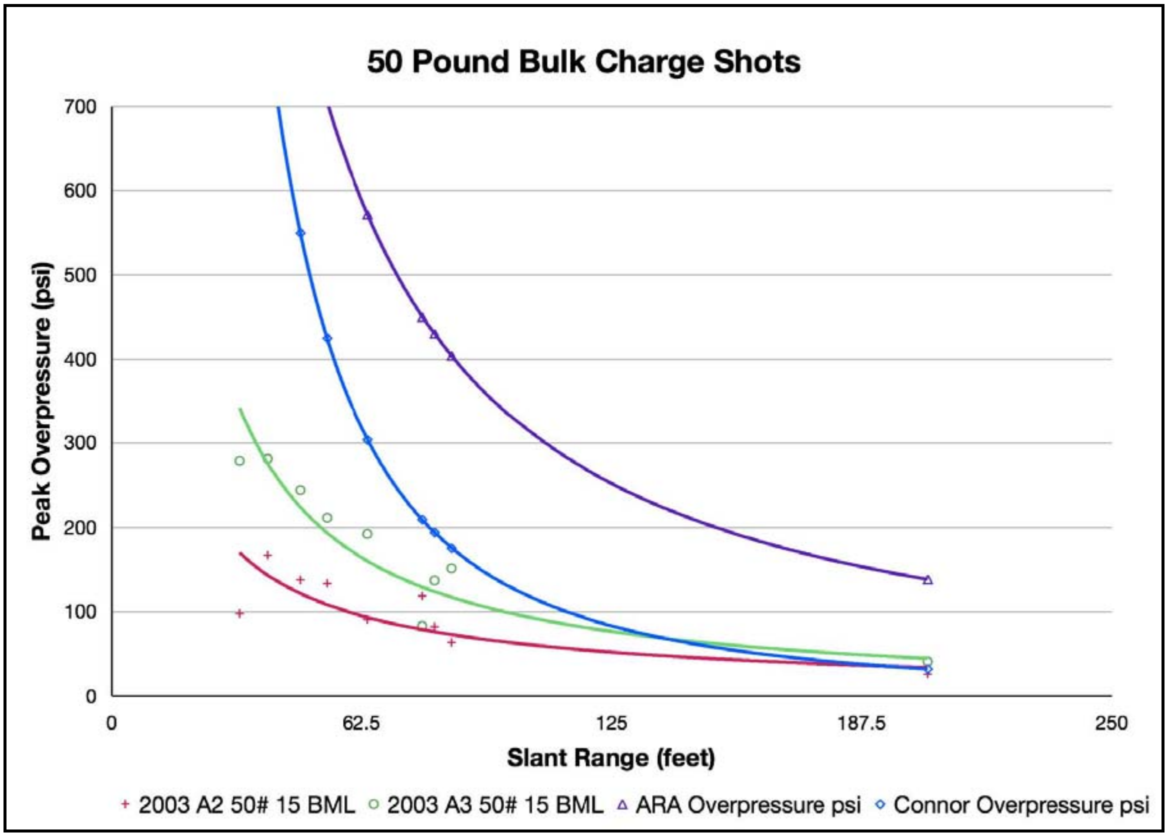

Figure 4.10. 50 Pound Bulk Charge Shots from ST21 Platform 97 (2003) and EI128 Platform F-4 (2007) - Nearfield.

Two open-water bulk charge shots were made during the second detonation event during the EI128 mobilization to provide additional data for comparison with current modeling and for calibrations. As seen in Figure 4.11 below, the 5 lbs open-water charges were shown to be consistent with the ARA model predictions.

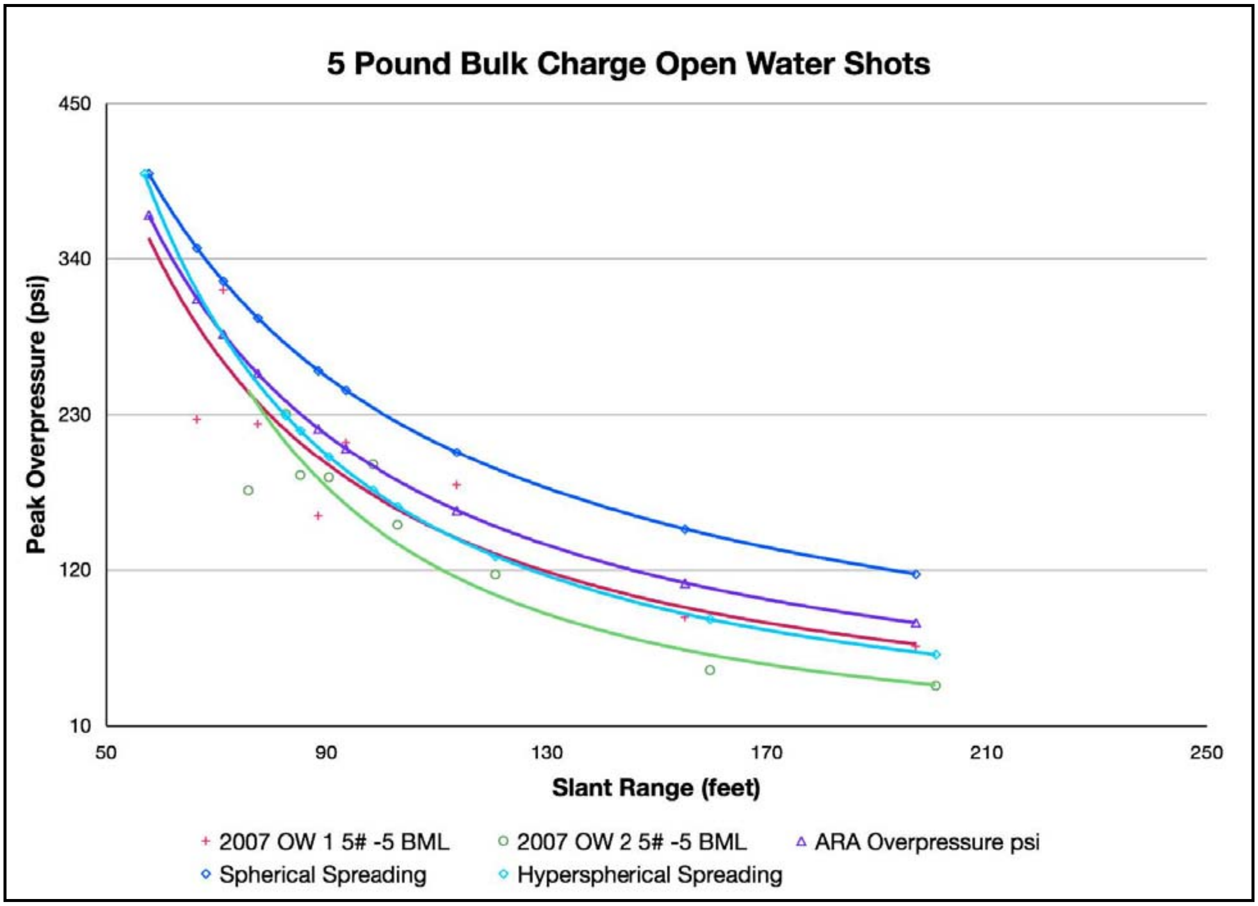

Figure 4.11. 5 Pound Open-Water Bulk Charge Shots from EI128 Measurement Work – Charges Tethered 5 ft AML.

5.0. CONCLUSIONS

Since past modeling work is based purely upon equations and incorporates theoretical attenuation for the target (pile/conductor/etc.), surrounding sediments, and hydrostatic head, the impact zones derived from their efforts have resulted in fairly-inaccurate, excessively-large estimates. An overestimated impact zone is extremely problematic in that MPS monitoring efforts are essentially wasted on areas where the animals could not be harmed and the level of effort (i.e., additional personnel, helicopter requirements, extended vessel time, etc.) could present scheduling problems and unnecessary expenses for the operators.

A review of the *in-situ* measurement data collected from TAR Project No. 570 supports the study's assumption that an increase in the BML cut depth for an explosive-severance charge would result in increased attenuation that would work to reduce the pressure/acoustic energy released during detonation; thereby, decreasing the resultant MPS impact zone. Based on the levels observed during the measurement work, it is reasonable to hypothesize that there is a BML severance depth at which a minimal explosive charge (most-likely an engineered charge) would not release enough detonation energy to surpass the sediment/target attenuation. The hypothetical small charge/BML depth combination could potentially negate any potential impacts to MPS and eliminate the need for weather/daylight restrictions, dedicated observers, helicopters, and any other mitigative measures. The charge itself and associated BML placement would become the mitigation tool.

6.0. REFERENCES

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7.0. APPENDICES

Appendix A	Measurement Data from TAR Project No. 429 – November 2003
Appendix B	1st Measurement Series: Platform "F-4" Eugene Island Block 128 - July/August 2007
Appendix C	2nd Measurement Series: Platform "A" East Cameron Block 32 - August 2008
Appendix D	Transducer Location and *In-Situ* Measurement Data
Appendix E	Lessons Learned from TAR Project No. 570

Appendix A

Measurement Data from TAR Project No. 429 – November 2003

Data Measurements from TAR Project No. 429

All of the data presented was collected during the in-situ measurement phase of TAR Project No. 429.[1]

Table A-1

TAR Project 429 Peak Overpressure (psi) Measurements

Transducer	Slant Range	4.6 lb ARA	4.6 lb Meas.	50 lb ARA	50 lb 1 Meas	50 lb 2 Meas
A_R25V5	32.0	484.00	78.79	1339.50	98.24	278.99
B_R25V15	39.0	377.19	140.29	1043.80	167.05	281.63
C_R25V25	47.1	298.90	139.16	827.20	137.86	244.14
D_R50V5	53.8	255.05	74.38	705.80	134.16	211.59
F_R50V25	64.0	206.49	86.68	571.40	90.93	192.51
G_R75V5	77.6	162.76	119.05	450.40	118.80	83.35
H_R75V15	80.7	155.52	93.22	430.40	82.73	137.67
I_R75V25	85.0	146.05	45.54	404.20	64.14	151.38
L_25R200	203.9	50.15	10.12	138.80	26.77	41.25

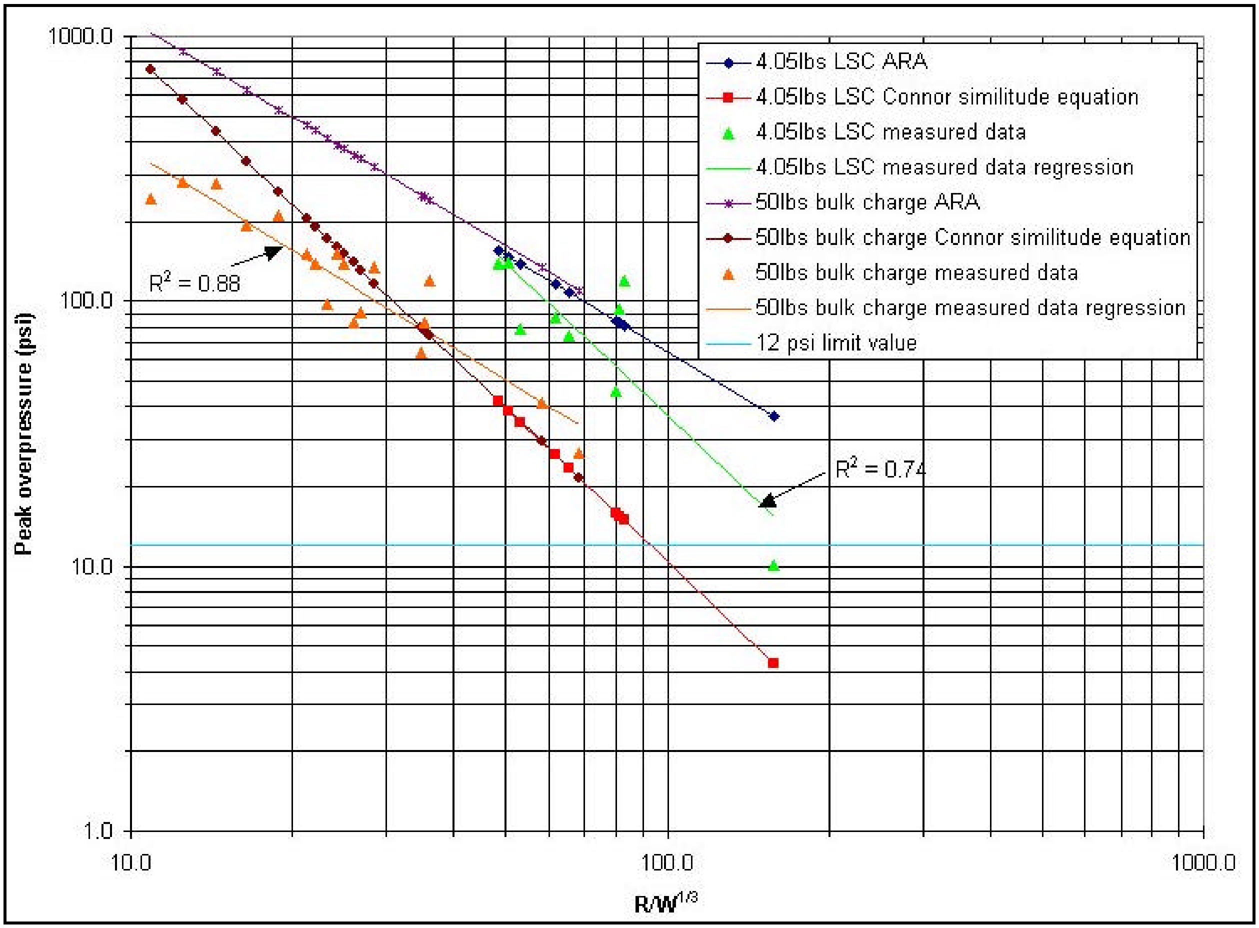

Figure A.1. Peak Pressure (shockwave) Data From Engineered and Bulk Charges

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[1] SNC Technologies Corporation "Oil Platform Removal Using Engineered Explosive Charges: In-situ Comparison of Engineered and Bulk Explosive Charges" Final Report Contract 1435-01-01-CT-31136 TAR Project # 429 April 2004

Table A-2

TAR Project 429 Impulse (psi•s) Measurements

Transducer	Slant Range	4.6 lb ARA	4.6 lb Meas.	50 lb ARA	50 lb 1 Meas.	50 lb 2 Meas.
A_R25V5	32.0	0.087	0.011	0.528	0.014	0.158
B_R25V15	39.0	0.072	0.012	0.362	0.015	0.177
C_R25V25	47.1	0.060	0.016	0.303	0.067	0.138
D_R50V5	53.8	0.053	0.012	0.268	0.018	0.016
F_R50V25	64.0	0.045	0.010	0.228	0.051	0.103
G_R75V5	77.6	0.038	0.008	0.190	0.015	0.037
H_R75V15	80.7	0.037	0.010	0.184	0.010	0.060
I_R75V25	85.0	0.035	0.006	0.175	0.050	0.075
L_25R200	203.9	0.015	0.004	0.077	0.022	0.031

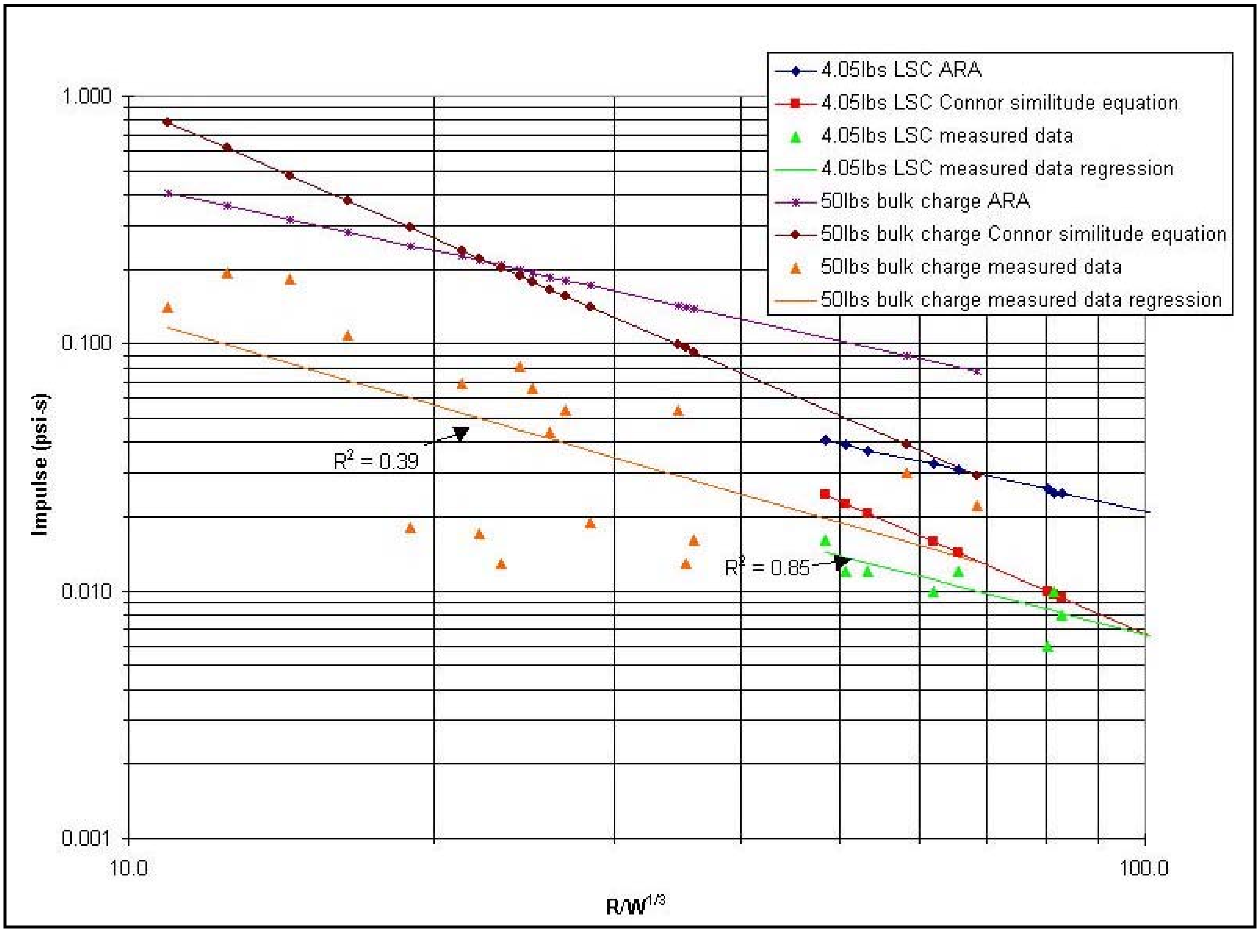

Figure A.2. Impulse Data From Engineered and Bulk Charges

Table A-3

TAR Project 429 Energy Flux Density (psi•in) Measurements

Transducer	**Slant Range**	**4.6 lb ARA**	**4.6 lb Meas.**	**50 lb ARA**	**50 lb 1 Meas**	**50 lb 2 Meas**
A_R25V5	32.0	3.113	0.055	57.600	0.076	4.149
B_R25V15	39.0	2.002	0.096	27.900	0.136	5.379
C_R25V25	47.1	1.326	0.132	18.500	0.805	3.584
D_R50V5	53.8	1.002	0.054	13.900	0.104	0.159
F_R50V25	64.0	0.689	0.038	9.620	0.409	1.741
G_R75V5	77.6	0.452	0.053	6.310	0.082	0.234
H_R75V15	80.7	0.417	0.057	5.820	0.043	0.651
I_R75V25	85.0	0.373	0.013	5.210	0.268	0.980
L_25R200	203.9	0.056	0.004	0.786	0.051	0.091

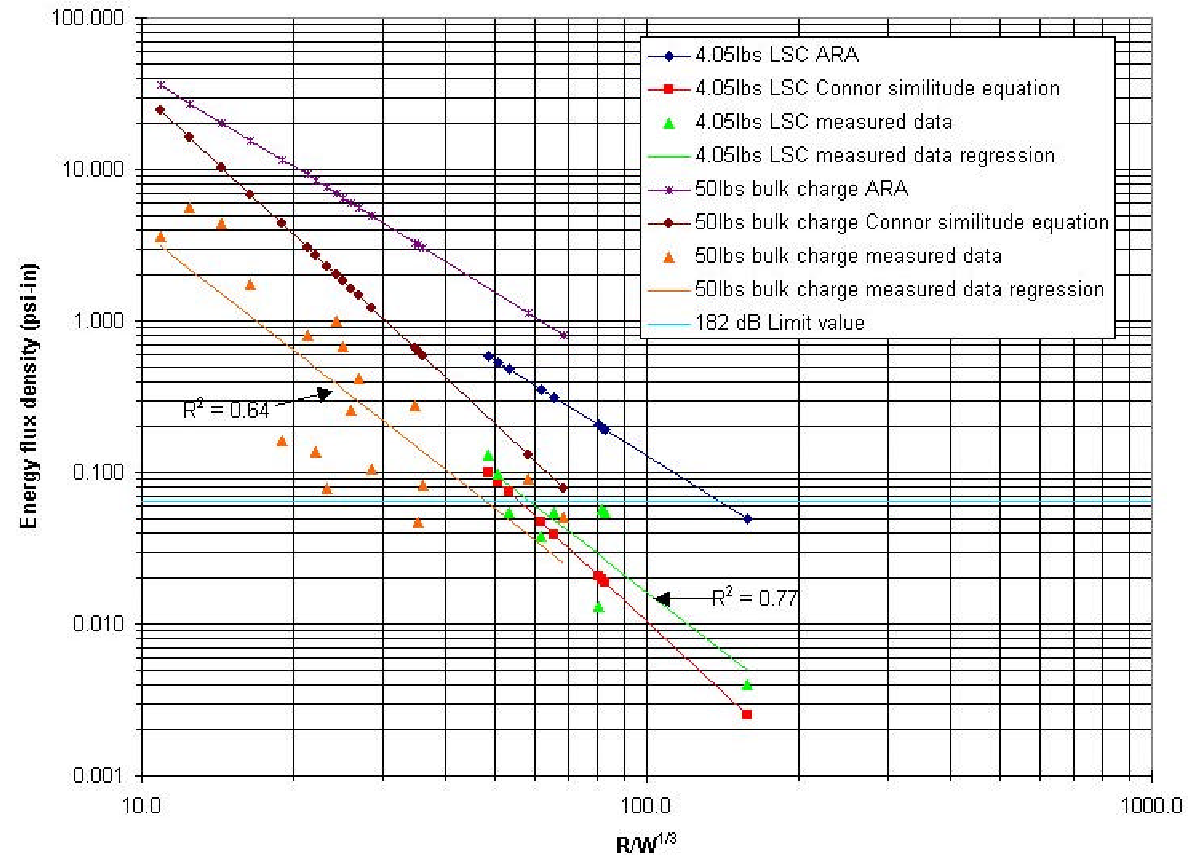

Figure A.3. Energy Flux Density (Acoustic Energy) Data From Engineered and Bulk Charges

.

Appendix B

1st Measurement Series: Platform “F-4” Eugene Island Block 128 - July/August 2007

First Measurement Series: Maritech Platform A Decommissioning in Eugene Island Block 128

July and August, 2007 saw the commencement of testing activity on the contract with the removal of platform MRI E.I. 128-F OCS-G-00053 with an associated free-standing caisson and conductor along with underwater acoustic shock wave measurements of the decommissioning process. This removal took place between July 26th and August 1st, 2007.

These structures (Maritech Platform F-4, Complex ID 20887-1, and Caisson F, Complex ID 20887-2) were installed in the 1950's. The actual removal took place on July 29th, July 31st , and August 1st ,2007 with measurements taken to determine the underwater shock pressure pulse parameters of peak overpressure, impulse and energy flux density at various pressure transducer positions resulting from the explosive cutting of the piles, conductor and the separate free-standing caisson and conductor. In the diagram below (figure #2 prepared by Sonalysts), the ten piles are A1 through A5 and B1 through B5, the conductor within the platform F3, and the freestanding caisson with an internal conductor C1. There were also open water tests using five pound charges. Their locations are recorded as OW1 and OW2. These two charges provided additional data for comparison to the predictions of the ARA Model and Connor Similitude Equation as well as equipment calibration. The orange dot at the bottom of figure #2 represents the position of the A, B, C, array downline for the July 31, 2007 deployment.

Photo#1: Structure Maritech F4 Complex ID 20887-1 at Right with Diver-Cut Caisson F (Complex ID 20887-2) Being Pulled

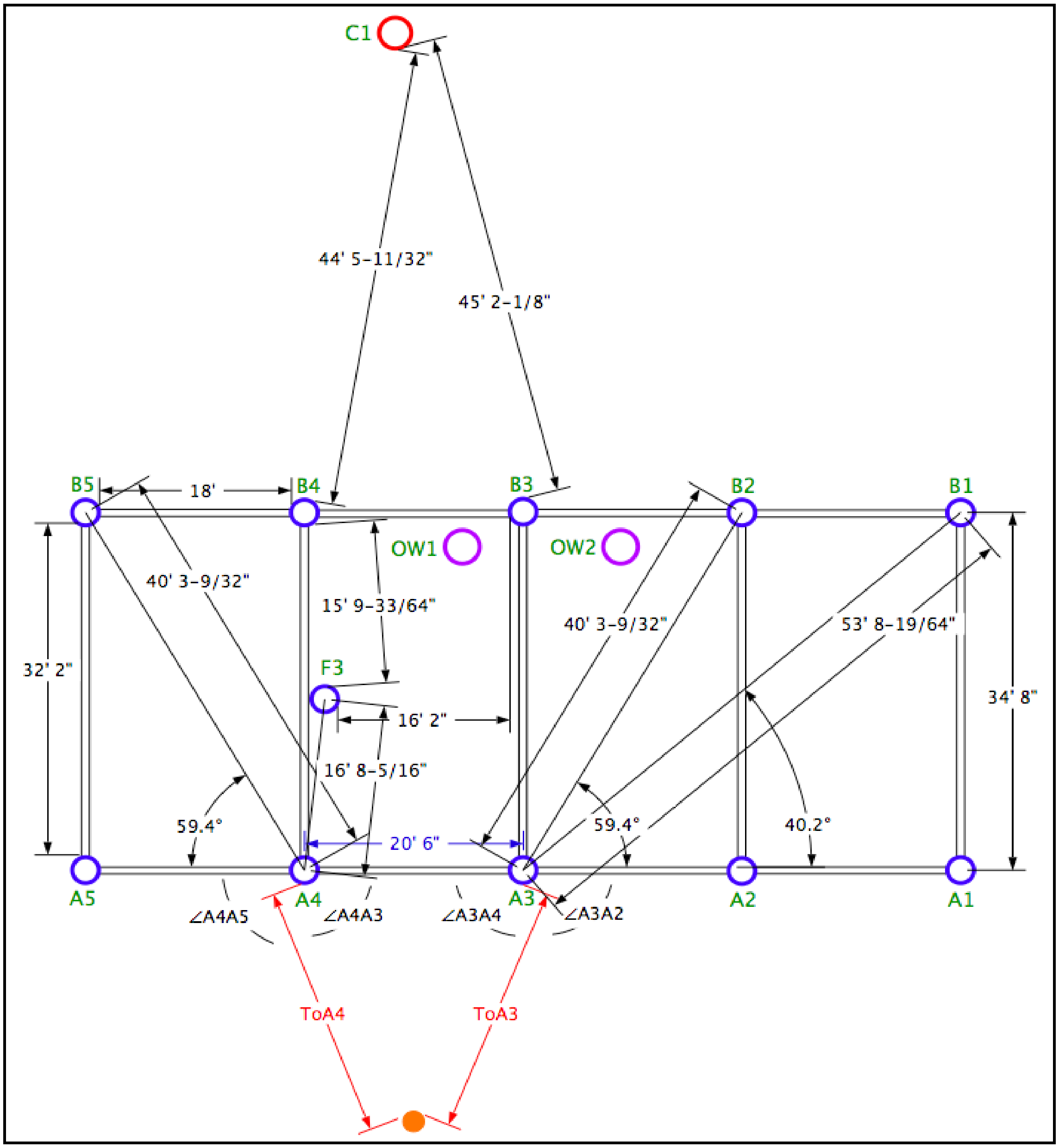

Figure2: Locations of the piles and conductors on the F-4 platform

Twelve PCB W138A Underwater Blast Pressure Tourmaline Transducers were used for capturing peak pressure readings. These transducers were powered by PCB ICP power supplies with the signals fed into a Yokogawa DL750 ScopeCorder where the data was stored for later retrieval. The nearfield downlines, three (3) each, had three transducers positioned at five, twenty, and forty feet vertically above mudline. The farfield arrays, three (3) each, had one transducer forty feet above mudline. Distance of each array from the structures varied for the three series of blasts. These distances are recorded with Sonalysts' data below in table #1. Transducer array positions were verified by MMS personnel using a Mesotech MS-1000 Sector Scanning Sonar prior to each group of detonation events.

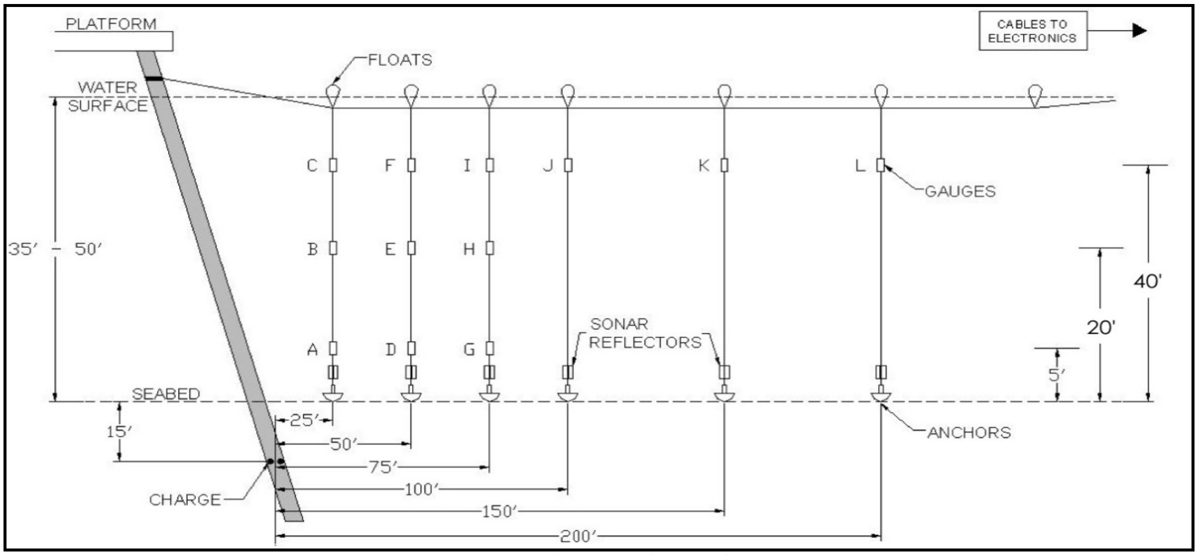

Figure 3. Proposed physical transducer array overview.

Actual Ranges of Transducers for Three Array Deployments: Table #1

Transducer Array Location	7/29 Downline Range to Ref Caisson C1 (ft) With Internal Conductor	7/31 Downline Range to Ref Piling A4 (ft)	8/1/07 Location	8/1 Downline Range to Ref Piling A4 (ft)
A	534	19	Port Stern	319
B*	534	19	Port Stern	319
C	534	19	Port Stern	319
D	563	50	Starboard Midship	281
E	563	50	Starboard Midship	281
F*	563	50	Starboard Midship	281
G	582	73	Starboard Bow	265
H*	582	73	Starboard Bow	265
I*	582	73	Starboard Bow	265
J	605	97	NA	NA
K	647	142	NA	NA
L	679	186	NA	NA

*Inoperative for 7/29, 7/31, & 8/1 deployments   *Inoperative for 8/1 deployment only

For depth, speed of sound (derived from salinity and conductivity) and temperature measurements, a RBR XR-420 CTD logger was used. Additional measurements were taken of open water detonations of five (5) pound explosive charges. On Sunday, July 29th, the internal conductor (C1) inside of the free standing caisson was severed with a twenty-five pound bulk charge and pulled from the caisson. On Tuesday, July 31st, the caisson (diver cut at four feet above mudline) was severed with a seventy-five pound bulk charge. Also on July 31st, two five pound bulk charges were detonated at five feet above mudline to provide additional data points for comparison to the predictions of the ARA Model and Connor Similitude Equation and check measurement equipment function, and an attempt was made to sever the platform's conductor (F3), with a fifty pound bulk charge. On Wednesday morning, August 1st, the platform's ten piles were severed, each with a fifty pound bulk charge, and the platform's conductor

(F3) was shot a second time, this time with a sixty-five pound bulk charge. All bulk charges were filled with Composition-B explosive, with the exception of the two five pound open water shots which were Pentolite explosive. National Marine Fisheries Service (NMFS) had a Turtle Watch Helicopter in the air for pre-blast and post-blast surveillance. On each series of blasts, they stopped operations during the countdown due to reported sightings resulting in delay and necessitating restart(s) of the countdown procedure.

Explosive Services International (ESI) had intended to sever some of the targets on this structure with the Scorpion™ Pile Severing Device, and these engineered charges of ~five pounds Net Explosive Weight (NEW) were prepared on site, but half were damaged somehow in the transfer from the Cherokee derrick barge to the structure by derrick. When an attempt was made to deploy the remaining devices, it was found that even though the piles on the structure gauged well, the Scorpions could not be delivered to the target zone. As a result, all targets on this structure were severed with bulk charges, and the data gathered reflects this. The Scorpion Pile Severing Devices (engineered charges) are pictured below on the deck of the Cherokee (photo #2). They have already been loaded at this point with the Linear Shaped Charge (LSC) segments. It was expected that they would be used on future tests on this contract, but on the second test series, the ESI team ran into the same difficulties in trying to deliver the Scorpion™ engineered charges to the target zones.

Photo#2: Scorpion™ Pile Severing Device with installed Engineered Charges (LSC's)

On July 29th the conductor inside the freestanding caisson was to be severed. For this test, the measurement arrays were deployed off the deck of the Cherokee (Global Industries, Inc's derrick barge) which was provided by the operator (Maritech) and the removal contractor (Tetra). This was not an optimum platform to deploy and work from (as the arrays were farther back from the structure than was intended and proposed in the SOW). However, the 135' crew boat, Raider which was supplied as a work platform and means to deploy the arrays had an inoperable windlass (its only one) and would not have been able to maneuver or hold position adequately. The service of a 105' jack-up boat, the

Seabream (Hercules Offshore) was secured, but the Seabream would not arrive in time for the severing of the C1 conductor. As the captain of the Cherokee did not want to have the derrick barge closer than 800' to the detonation, a 500' leader line was attached to the caisson and the aircraft cable with the attached arrays secured to the distal end of the leader rope. Thus, the first array was roughly 535' from the caisson containing the conductor-C1.

A small calibration charge was detonated alongside the hull of the Cherokee and it was found after the arrays were deployed that three of the twelve transducers (B, F, & I) were non-functional. They could not be repaired in the field and remained inoperative throughout the removal operation and related measurements. A twenty-five pound bulk charge was used to sever the internal conductor in the free-standing caisson. The charge was made of a melt pour Composition-B (approximately 60/40% RDX & TNT) cast into a sheet metal housing. The charge was positioned fifteen feet below mudline (BML). The Charge was initiated by a SMS (Salt Mine Series) Primaline® Primadet®[24] in the top of the charge. From the Primaline extending approximately four feet out of the booster in the charge, 50gn/ft detonating cord was tied in and extended to the surface. An electric detonator was attached to the distal end of the detonating cord and the detonator connected to the receiving unit of a Radio Controlled Firing Unit the transmitter of which was used to initiate the blast from the deck of the Cherokee. A photo of the severed conductor appears below.

Photo #3: Conductor Severed with 50 Pound Bulk Charge (Shot Sequence #1, but Typical of Bulk Charge Cut)

On Tuesday, July 31st, a second group of tests were conducted. The caisson from which the conductor had been removed on the 29th, had been diver-cut at four feet above mudline. The detonations for the 31st were to be the subsea stub of the caisson, the conductor inside the structure of the platform and two open water five pound detonations. The intent was to deploy the arrays using the jack-up boat Seabream, by first attaching the aircraft cable to the structure, and then backing off from the structure deploying the arrays in sequence. However, the good weather enjoyed prior to the 31st had deteriorated and the currents were too strong on the windward side of the structure for the Seabream to be able to hold position. The aircraft cable was secured to the structure and the Seabream backed off

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[24] Primadet® is a registered trademark of Dyno Nobel

to the length of the cable, the distal end of which was secured to the Seabream's bow. Then, the decision was made to use the Seabream's inflatable boat to deploy the array downlines. This was done with some difficulty, by taking one downline at a time out to the buoy it was to be connected to, deploying the downline and reeling the communications cable and connector back to the Seabream. This had to be done separately for each of the six arrays in 3-4 foot seas.

The arrays were successfully set and the detonations carried out as planned. The sub-sea caisson stub diver-cut at four feet above mudline had a seventy-five pound Composition B charge placed at twenty feet BML. The caisson was 36" in diameter with a 1" wall. The conductor inside the platform structure was shot with a fifty pound Composition B charge placed thirty feet BML. Also, two five pound Pentolite (approximately 50/50% PETN & TNT) open water charges were fired at five feet above mudline. One (OW2) was placed between pile B3 and B2 and the second (OW1) between pile B3 and B4. All charges were top-primed with SMS Primaline Primadets. Approximately four feet from each charge, 50gn/ft detonating cord was tied in to the Primaline and the detonating cord extended to the surface. At the surface, the shots were sequenced with 1,000ms delay shock tube detonators. This is done by connecting the shock tube with a plastic connector at right angles to the 50gn/ft detonating cord leading below surface. The shock tube is extended to the next charge in the sequence and the delay detonator connected to the free end of that charge's 50gn/ft detonating cord. The detonating cord from the first charge in the sequence was tied in to 18 gn/ft Zap®[25] Cord detonating cord. The Zap cord was connected to an electric detonator wired to the Radio Controlled Firing Unit. The first photo below (#4) shows the detonation of the seventy-five pound charges in the four foot sub-sea caisson stub. The second (#5) shows the detonation of the fifty pound charge placed in the conductor within the platform structure. The buoys for arrays may be seen in the foreground of these pictures.

Photo #4: 75 Pound Bulk Charge Shot on Caisson Sub-sea Stub Diver Cut 4ft ABL (shot Sequence #2)

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[25] Zap® Cord is a registered trademark of Dyno Nobel

Photo #5: 50 Pound Bulk Charge Shot on Conductor Internal to Structure--
Array Buoys in Foreground (First Shot Unsuccessful). Shot Sequence #3.

By August the 1st, the reinforcements of the platform had been completed and the topsides removed. (It was discovered that the topsides of the structure were deteriorated due to corrosion and reinforcing members had to be added prior to attempting a lift.) The piles were discovered to be empty to beyond the target zones. Sea water was pumped into the piles to remove the variable of firing the charges to sever the platform legs in an empty pile. The piles were all loaded with fifty pound Composition B bulk charges. Piles A1 and A2 had the charges placed at fifteen feet BML. Piles A3, A5, and B3 had the charges set at twenty feet BML. Piles B1, B2 and B5 had the charges placed at twenty-five feet BML. And piles A4 and B4 had the charges placed at thirty feet BML. The piles were all 30 inches in diameter with a .625" wall thickness. Additionally, the conductor within the platform structure which was unsuccessfully shot on July 31st was re-shot with a sixty-five pound Composition B charge placed at thirty feet BML. All charges were top-primed with SMS Primaline Primadets with 50gn/ft detonating cord extending from the Primaline to the surface. A 1,000ms delay was introduced into the sequence between each detonation by using shock tube delay detonators tied in as described above. The 50gn/ft detonating cord leading to the first charge in the sequence had Zap Cord tied into the distal end which led to an electric detonator connected to the receiving unit of the Radio Remote Firing Unit. The blast was fired from the deck of the Cherokee using the Radio Remote transmitter.

The weather had deteriorated since the 31st, and the seas had swells of four feet plus with strong currents on the windward side of the structure. It was decided that it was too hazardous to attempt to deploy the arrays as was done on the 31st (using the Seabream's small inflatable). Rather, the decision was made to gather data with what arrays could be deployed directly off the deck of the Seabream. The anchors were doubled on the first three arrays, each with three transducers, to counter the effects of the strong currents. The transducers on each array were at five, twenty and forty feet above mudline. The ABC array was set off the port stern, the DEF array was positioned over the starboard midships and the GHI array off the starboard bow. The Mesotech Sector Scanning Sonar was again lowered over the bow of the Seabream to obtain accurate positioning data on the transducer arrays in relation to the structure prior to the detonation of the charges, as was done on the 29th and 31st. MMS personnel are shown in the photo below gathering data with the Mesotech Sonar.

Photo #6: MMS personnel Mr. T. J. Broussard and Mr. Tre Glenn
Setting up Mesotech Sector Scanning Sonar on Deck of the Seabream.

After deployment of the arrays, it was found that in addition to the B, F and I transducers, transducer H had also become inoperative. The photos below (T.J. Broussard photo credit) show some of the detonations in the sequence of eleven shots on the piles and conductor.

Photo #7: Delay shot sequence on piles A1 through A5 and B1 through B5 and conductor F3

Photo #8: Delay shot sequence on piles A1 through A5 and B1 through B5 and conductor F3

The tables from the Sonalysts report appear below and in Appendix #2. Not included in these tables is the data from the RBR XR-420 logger. Measurements taken 7/31/07 @ 18:33:00 were as follows:

Table #2: RBR XR-420 CTD Logger Data

Date	Time	Cond (mS/cm)	Temp (°C)	Pressure (deciBars)	Depth (m)	Speed of Sound (m/sec)
7/31/07	18:33:00	51.0	28.2	24.9	14.6	1,538.2

Appendix C

2nd Measurement Series: Platform “A” East Cameron Block 32 - August 2008

Second Measurement Series: Merit Platform A Decommissioning in East Cameron Block 32

Introduction

Measurements were made on August 9, 2008 on Merit Platform EC32A to determine the underwater shock pressure pulse parameters of Peak Overpressure, Specific Impulse, and Energy Flux Density at each of twelve transducer positions resulting from explosive cutting of the piling legs and well conductors on the subject structure. On August 9, two of the four structure pilings were cut using eighty pound bulk charges. In addition, the four well conductors were cut using one hundred forty-five pound bulk charges. All cuts were successful. Locations of all of the pilings and conductors are shown in Figure B-1, and charge depths and other details are delineated at the end of this section.

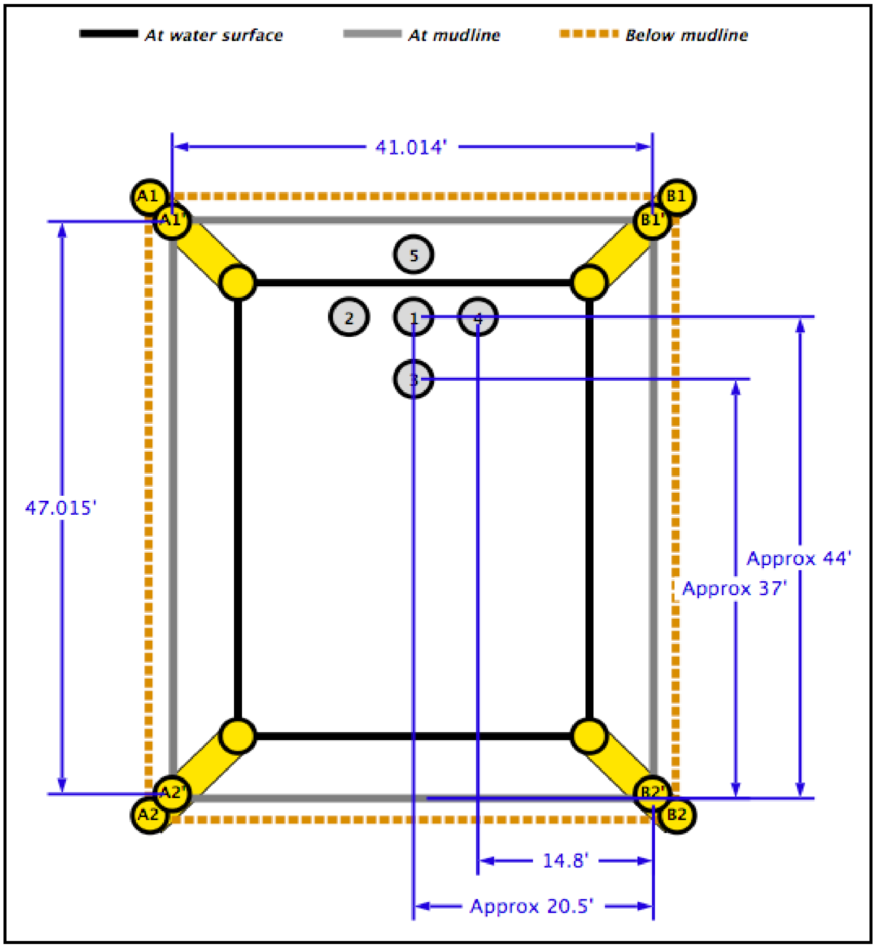

Figure 1. Locations of Various Pilings and Conductors on the EC-32A Structure

Collected data was compared to ARA model projected levels.[1] Transducer location data was measured by Minerals Management Service (MMS) staff using a Mesotech MS-1000 sector-scanning sonar in order to confirm the actual position of the array.

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[1] Dzwilewski, Peter T. and Fenton, Gregg, Shock Wave / Sound Propagation Modeling Results for Calculating Marine Protected Species Impact Zone During Explosive Removal of Offshore Structures, Applied Research Associates, Inc., January 20, 2003.

Photo #9: Merit EC-32 A Platform Structure

Photo #10: Merit EC-32A platform structure showing acoustic shock measurement array deployment.

Measurement Execution

With previous deployment difficulties in mind, a jack-up barge, the M/V Hammerhead (145' Liftboat; Hercules Offshore) out of Intercoastal City, was utilized as the base from which to deploy the measurement array system and the Mesotech sidescan sonar. The measurement team boarded the Hammerhead on Sunday afternoon August 3rd but, due to tropical storm/hurricane Edouard, both the team and Hammerhead remained docked at Intracoastal City until Wednesday August 6 when the Hammerhead was able to travel to the worksite, Merit EC-32A platform, arriving at approximately 22:00 hours on the same evening.

Photo #11: 145' Jack-up Boat M/V Hammerhead (Hercules Offshore)

Once allowed to approach the platform area on Thursday morning, the liftboat captain was able to get the boat maneuvered, with minimum difficulty, to a location within close range of the platform and the array tether cable was attached to the B2 piling. The liftboat backed away while the aircraft cable tether was played out and floats attached at their intended locations. Once the last float was placed, the liftboat continued to back off until it was approximately 300 feet from the B2 piling. The jacks were set and this location remained as the deployment position for the two array deployments. The actual slant ranges are shown for the array deployment in the data section below.

Three "calibration" charges of a small weight were detonated (two on Friday and one on Saturday) near the Merit DB1 derrick barge in order to ascertain that the instrumentation was operating properly.

The acoustic measurement array was deployed twice: once on Friday evening and then on Saturday late afternoon. On Friday evening, the detonations could not be carried out due to a time restriction as dusk approached. On Saturday at approximately 5:30 PM local time, the B2 and B1 pilings along with well conductors 1, 3, 4 and 5 were cut using bulk charges. Charge weights, cut depths below mudline, and firing sequence are shown in the data section below. The original intention was to cut all four pilings (A1, A2, B1, B2) and the well conductors (1, 2, 3, 4, 5), but problems with jetting precluded the desired goal from being reached and the A1 and A2 pilings, and conductor 2, were left to be cut on Sunday. These last three were not measured as the measurement team left the site on late Saturday evening. Also, piles B1 and B2, were originally slated for severance with an engineered charge delivered on a Scorpion™ Pile Severing Device. However, as experienced on the removal of platform 128-F OCS-G-00053 in 2007, unexpected diametric restrictions or damage inside piles B1 and B2 prevented delivery of the Scorpions to the target zone so all tubular were severed with bulk charges.

All bulk charges were loaded with Composition B. The charges were top-primed with SMS Primaline Primadets. About four feet from the bulk charge, 50gn/ft detonating cord was connected to the Primaline. The detonating cord lead to the surface where a delay pattern was incorporated into the sequence using 1,000ms delay shock tube detonators connected as described previously. The detonating cord for the first blast in the sequence was tied into 18gn/ft Zap cord, which was connected to an electric detonator wired to the receiving unit of a Radio Remote Firing Unit. The blast sequence was initiated from the deck of the Merit DB1 derrick barge using the transmitting unit of the Radio Remote Firing Unit.

The array was deployed using the Hammerhead's Narwhal smallboat by making multiple trips with the cable/transducer reels to attach the downlines and cabling along the tether aircraft cable. Deployment was carried out by T. J. Broussard, Tre Glenn, and Herb Leedy of MMS.

Photo #12: Tre Glenn (left) and T. J. Broussard of MMS Deploying Shock Measurement Arrays

After the first deployment, it was found that three of the twelve transducers were not functioning: B (B_R25D22), C (C_R25D37), and E (E_R50D22). Field repairs were made and the transducers reconnected to the broken cables. After the second deployment, it was determined that transducers C (C_R25D37) and I (I_R75D37) were not functioning. Also, data from transducer E (E_R50D22) became noisy after the first detonation (B2) and should be considered suspect.

Instrumentation Used

Measurements were made using a transducer array consisting of twelve PCB W138A Underwater Blast Pressure Transducers (tourmaline) that were configured with the first three downlines having transducers , three (3) at five, twenty and thirty-five feet vertically above the mudline. These nearfield downlines were positioned at horizontal distances of twenty-five, fifty, and seventy-five feet from the charge position. The last three transducers were positioned at horizontal distances of one hundred, one hundred fifty, and two hundred feet (farfield), with each one at thirty-five feet vertically above mudline. The blast transducers were powered by PCB ICP power supplies, and then fed into a Yokogawa DL750 ScopeCorder where data was measured and stored for later retrieval.

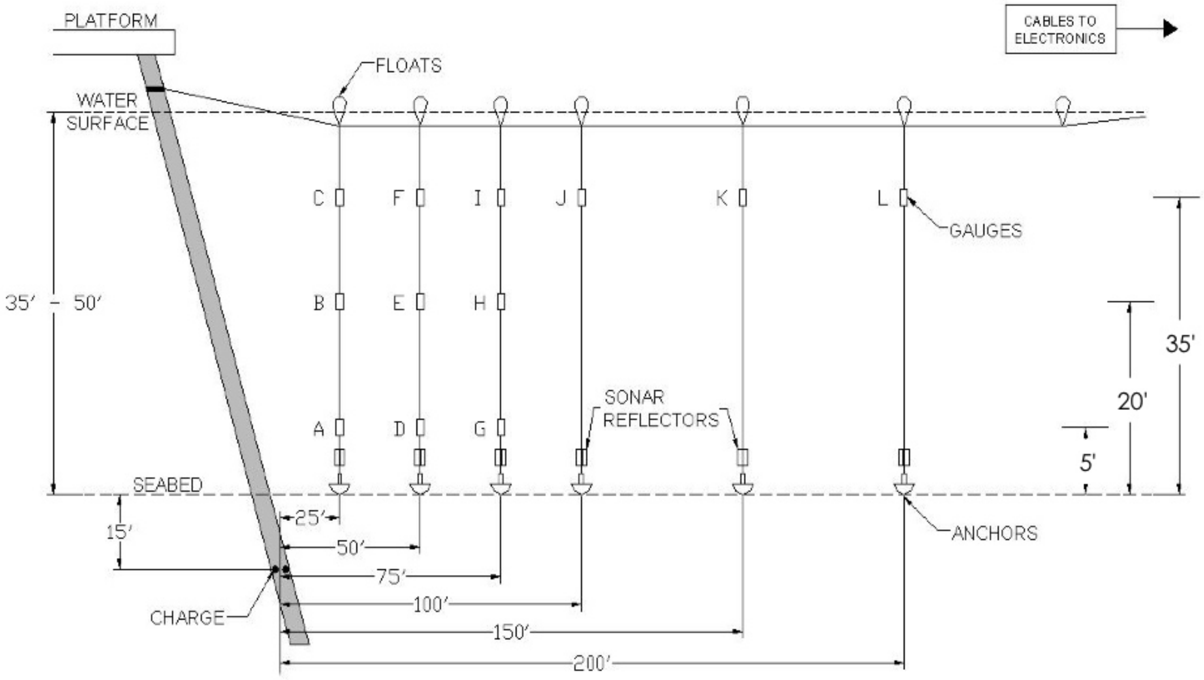

Figure 2. Physical transducer array overview (Note: 1st array deployment transducers B, C, and E non-functional, 2nd deployment, transducers C and I non-functional and E noisy).

For depth, speed of sound (derived from conductivity/salinity), and temperature measurements, a RBR XR-420 CTD logger was used. A depth of 39 feet was reported by the CTD. Following is the CTD data collected on Friday August 8th:

Table #5: RBR XR-420 CTD Logger Data

Date	Time	Cond (mS/cm)	Temp (°C)	Pressure (deciBars)	Depth (m)	Speed of Sound (m/sec)
8/8/08	14:46:40	32.8	28.1	22.0	11.8	1525.3

Appendix D

Transducer Location and *In-Situ* Measurement Data

Table D-1

Array Transducer Information for the 1st Mobilization at Platform F-4 and Caisson F; Eugene Island Block 128

Yokagawa DL750 Channel	DL750 Signal Name	XDCR Array Location	7/29/2007 Range to Reference Caisson F (ft)	7/31/2007 Range to Reference Pile A4 (ft)	8/1/2007 M/V Orientation & Range to Reference Pile A4 (ft)	Distance AML (ft)	Cable Length (ft)	PCB XDCR	Serial Number	Sensitivity mV/psi	A Factor for Y=AX+B on Yokogawa
1	A_R25D10	A	534	19	Port Stern (319)	5	325	138A01	6992	5.251	1.904E+02
2	B_R25D25	B	534	19	Port Stern (319)	20	350	138A01	6982	5.124	1.952E+02
3	C_R25D45	C	534	19	Port Stern (319)	40	400	138A01	6986	5.007	1.997E+02
4	D_R50D10	D	563	50	Starboard Midship (281)	5	300	138A01	6991	5.127	1.950E+02
5	E_R50D25	E	563	50	Starboard Midship (281)	20	325	138A01	6996	5.181	1.930E+02
6	F_R50D45	F	563	50	Starboard Midship (281)	40	375	138A01	6988	5.132	1.949E+02
7	G_R75D10	G	582	73	Starboard Bow (265)	5	275	138A01	6989	5.201	1.923E+02
8	H_R75D25	H	582	73	Starboard Bow (265)	20	300	138A01	6984	5.153	1.941E+02
9	I_R75D45	I	582	73	Starboard Bow (265)	40	350	138A01	6987	4.980	2.008E+02
10	J_R100D10	J	605	97	NA	40	250	138A01	6983	5.010	1.996E+02
11	K_R150D10	K	647	142	NA	40	200	138A01	6985	5.199	1.923E+02
12	L_R200D10	L	679	186	NA	40	150	138A01	6993	5.106	1.958E+02

Table D-2

Array Transducer Information for the 2nd Mobilization at Platform A; East Cameron Block 32

Yokagawa DL750 Channel	DL750 Signal Name	XDCR Array Location	Range to Reference Piling B2 (ft)	Exp'd XDCR Depth (ft)	Actual XDCR Depth (ft)	Distance AML (ft)	Cable Length (ft)	PCB XDCR	Serial Number	Sensitivity mV/psi	A Factor for Y=AX+B on Yokogawa
1	A_R25D07	A	46	7	4	5	325	138A01	6984	5.153	1.941E+02
2	B_R25D22	B	46	22	19	20	350	138A01	6991	5.127	1.950E+02
3	C_R25D37	C	46	37	34	35	400	138A01	6985	5.199	1.923E+02
4	D_R50D07	D	70	7	4	5	300	138A01	6989	5.201	1.923E+02
5	E_R50D22	E	70	22	19	20	325	138A01	6996	5.181	1.930E+02
6	F_R50D37	F	70	37	34	35	375	138A01	6983	5.010	1.996E+02
7	G_R75D07	G	94	7	4	5	275	138A01	6982	5.124	1.952E+02
8	H_R75D22	H	94	22	19	20	300	138A01	6988	5.132	1.949E+02
9	I_R75D37	I	94	37	34	35	350	138A01	6993	5.106	1.958E+02
10	J_R100D07	J	117	7	4	35	250	138A01	6986	5.007	1.997E+02
11	K_R150D07	K	164	7	4	35	200	138A01	6987	4.980	2.008E+02
12	L_R200D07	L	210	7	4	35	150	138A01	6992	5.251	1.904E+02

Table D-3

Measured and Predicted Data for the 1st Mobilization at Platform F-4; Eugene Island Block 128

Xducer and Charge Data					Measured Data						ARA UWC Data					
Xducer Number	Xducer Depth (ft)	Depth BML (ft)	Radial Distance To Charge (ft)	Slant Range (ft)	Mpa	I (kPa•s)	E (kPa•m)	psi	I (psi•s)	E (psi•in)	psi	Integrated I (psi•s)	Integrated E (psi•in)	Pile DIA inches	Pile Wall Thickness (in)	Time constant (6.7 x ⍰) (msec)
Open Water Shot 1 – 5 lbs																
A_R25D10	10	-5	57.8	66.5	1.562	0.357	0.130	226.6	0.056	0.758	311.6	0.091	2.082	0	1	1.45
C_R25D45	45	-5	57.8	57.8	2.760	0.415	0.189	400.3	0.065	1.106	370.9	0.104	2.834	0	1	1.40
D_R50D10	10	-5	70.1	77.5	1.540	0.321	0.111	223.4	0.050	0.649	259.3	0.079	1.504	0	1	1.51
E_R50D25	30	-5	70.1	71.3	2.193	0.367	0.159	318.0	0.059	0.936	287.3	0.085	1.803	0	1	1.48
G_R75D10	10	-5	87.5	93.5	1.449	0.335	0.111	210.2	0.052	0.648	206.0	0.066	1.001	0	1	1.60
H_R75D25	30	-5	87.5	88.5	1.090	1.118	0.595	158.0	0.174	3.523	220.0	0.070	1.125	0	1	1.57
J_R100D10	10	-5	108.8	113.7	1.240	0.297	0.080	179.9	0.046	0.465	162.0	0.054	0.654	0	1	1.69
K_R150D10	10	-5	151.7	155.2	0.599	0.169	0.022	86.9	0.026	0.125	111.0	0.036	0.327	0	1	1.84
L_R200D10	10	-5	194.4	197.1	0.458	0.131	0.011	66.4	0.021	0.064	197.2	0.025	0.187	0	1	1.97
Open Water Shot 2 – 5 lbs																
A_R25D10	10	-5	75.8	82.6	1.589	0.328	0.156	230.5	0.049	0.893	239.4	0.074	1.305	0	1	1.54
C_R25D45	45	-5	75.8	75.8	1.215	0.269	0.080	176.2	0.040	0.461	266.2	0.081	1.575	0	1	1.51
D_R50D10	10	-5	84.2	90.4	1.278	0.239	0.087	185.3	0.038	0.510	214.2	0.068	1.073	0	1	1.58
E_R50D25	30	-5	84.2	85.2	1.289	0.210	0.053	187.0	0.032	0.304	230.4	0.072	1.220	0	1	1.56
G_R75D10	10	-5	97.6	103.0	1.048	0.174	0.037	152.0	0.027	0.216	183.0	0.060	0.812	0	1	1.64
H_R75D25	30	-5	97.6	98.4	1.343	1.167	0.624	194.7	0.184	3.751	193.5	0.063	0.896	0	1	1.62
J_R100D10	10	-5	116.2	120.7	0.805	0.159	0.024	116.8	0.026	0.145	150.8	0.051	0.575	0	1	1.72
K_R150D10	10	-5	156.3	159.7	0.341	0.123	0.011	49.4	0.021	0.072	107.1	0.035	0.306	0	1	1.86
L_R200D10	10	-5	198.0	200.7	0.265	0.119	0.008	38.4	0.018	0.046	81.1	0.025	0.180	0	1	1.98
A1 50 lbs																
A_R25D10	10	15	250.3	255.8	0.144	0.171	0.009	20.9	0.025	0.049	112.6	0.046	0.511	30	0.625	3.06
C_R25D45	45	15	250.3	250.9	0.119	0.054	0.001	12.7	0.009	0.009	115.3	0.071	0.597	30	0.625	3.04
D_R50D10	10	15	259.0	264.3	0.157	0.161	0.008	22.8	0.024	0.048	108.1	0.044	0.473	30	0.625	3.09
E_R50D25	30	15	259.0	261.1	0.199	0.154	0.008	28.8	0.023	0.047	109.8	0.068	0.548	30	0.625	3.08
G_R75D10	10	15	295.0	299.7	0.192	0.184	0.011	27.9	0.027	0.061	92.8	0.036	0.351	30	0.625	3.20

Table D-3

Measured and Predicted Data for the 1st Mobilization at Platform F-4; Eugene Island Block 128

Xducer and Charge Data					Measured Data						ARA UWC Data					
Xducer Number	Xducer Depth (ft)	Depth BML (ft)	Radial Distance To Charge (ft)	Slant Range (ft)	Mpa	I (kPa•s)	E (kPa•m)	psi	I (psi•s)	E (psi•in)	psi	Integrated I (psi•s)	Integrated E (psi•in)	Pile DIA inches	Pile Wall Thickness (in)	Time constant (6.7 x ⍰) (msec)
A2 50 lbs																
A_R25D10	10	15	253.8	259.2	0.109	0.080	0.003	15.8	0.012	0.015	110.8	0.045	0.496	30	0.625	3.07
C_R25D45	45	15	253.8	254.4	0.137	0.169	0.009	19.9	0.025	0.051	113.3	0.070	0.579	30	0.625	3.05
D_R50D10	10	15	264.8	270.1	0.178	0.178	0.010	25.9	0.027	0.061	105.4	0.043	0.450	30	0.625	3.10
E_R50D25	30	15	264.8	266.9	0.184	0.149	0.007	26.6	0.023	0.042	106.8	0.066	0.522	30	0.625	3.09
G_R75D10	10	15	301.9	306.5	0.223	0.155	0.009	32.3	0.023	0.049	90.3	0.035	0.333	30	0.625	3.22
A3 50 lbs																
A_R25D10	10	20	258.9	265.3	0.094	0.105	0.004	13.6	0.015	0.021	107.7	0.045	0.474	30	0.625	3.09
C_R25D45	45	20	258.9	259.9	0.093	0.068	0.002	13.5	0.010	0.010	110.5	0.068	0.554	30	0.625	3.07
D_R50D10	10	20	272.1	278.2	0.106	0.105	0.004	15.3	0.016	0.020	101.6	0.042	0.424	30	0.625	3.13
E_R50D25	30	20	272.1	274.7	0.089	0.092	0.002	12.9	0.014	0.014	103.1	0.065	0.490	30	0.625	3.12
G_R75D10	10	20	310.0	315.4	0.092	0.146	0.005	13.3	0.021	0.029	87.3	0.035	0.315	30	0.625	3.24
A4 50 lbs																
A_R25D10	10	30	265.5	274.0	0.056	0.039	0.001	8.2	0.006	0.004	103.6	0.046	0.450	30	0.625	3.12
C_R25D45	45	30	265.5	267.5	0.073	0.043	0.001	10.5	0.006	0.005	106.7	0.067	0.521	30	0.625	3.10
D_R50D10	10	30	280.7	288.8	0.031	0.033	0.000	4.5	0.005	0.002	97.2	0.042	0.397	30	0.625	3.16
E_R50D25	30	30	280.7	284.8	0.083	0.047	0.001	11.9	0.007	0.007	98.8	0.063	0.455	30	0.625	3.15
G_R75D10	10	30	319.2	326.3	0.042	0.041	0.001	6.1	0.006	0.003	83.6	0.035	0.297	30	0.625	3.27
A5 50 lbs																
A_R25D10	10	20	273.4	279.5	0.051	0.031	0.000	7.4	0.005	0.002	101.1	0.042	0.419	30	0.625	3.13
C_R25D45	45	20	273.4	274.4	0.058	0.033	0.000	8.4	0.005	0.003	103.4	0.065	0.493	30	0.625	3.12
D_R50D10	10	20	290.5	296.2	0.051	0.043	0.001	7.4	0.006	0.004	94.1	0.038	0.366	30	0.625	3.19
E_R50D25	30	20	290.5	293.0	0.094	0.048	0.001	13.6	0.008	0.007	95.4	0.060	0.427	30	0.625	3.18
G_R75D10	10	20	329.4	334.5	0.054	0.051	0.001	7.9	0.008	0.004	81.1	0.032	0.274	30	0.625	3.30

Table D-3

Measured and Predicted Data for the 1st Mobilization at Platform F-4; Eugene Island Block 128

Xducer and Charge Data					Measured Data						ARA UWC Data					
Xducer Number	Xducer Depth (ft)	Depth BML (ft)	Radial Distance To Charge (ft)	Slant Range (ft)	Mpa	I (kPa•s)	E (kPa•m)	psi	I (psi•s)	E (psi•in)	psi	Integrated I (psi•s)	Integrated E (psi•in)	Pile DIA inches	Pile Wall Thickness (in)	Time constant (6.7 x ⍰) (msec)
B1 50 lbs																
A_R25D10	10	25	284.6	291.5	0.041	0.027	0.000	6.0	0.004	0.002	96.0	0.041	0.384	30	0.625	3.17
C_R25D45	45	25	284.6	286.0	0.043	0.041	0.001	6.2	0.006	0.004	98.2	0.063	0.450	30	0.625	3.16
D_R50D10	10	25	292.7	299.3	0.030	0.032	0.000	4.3	0.005	0.002	92.9	0.039	0.360	30	0.625	3.20
E_R50D25	30	25	292.7	295.8	0.043	0.023	0.000	6.2	0.003	0.001	94.3	0.060	0.418	30	0.625	3.19
G_R75D10	10	25	328.2	334.1	0.040	0.037	0.000	4.3	0.006	0.002	81.2	0.033	0.278	30	0.625	3.30
B2 50 lbs																
A_R25D10	10	25	287.7	294.5	0.010	0.012	0.000	1.4	0.002	0.000	94.8	0.040	0.375	30	0.625	3.18
C_R25D45	45	25	287.7	289.1	0.020	0.023	0.000	2.9	0.003	0.001	97.0	0.062	0.440	30	0.625	3.16
D_R50D10	10	25	297.9	304.4	0.008	0.010	0.000	1.1	0.002	0.000	91.1	0.038	0.347	30	0.625	3.21
E_R50D25	30	25	297.9	300.9	0.020	0.025	0.000	1.9	0.004	0.001	92.4	0.059	0.404	30	0.625	3.20
G_R75D10	10	25	334.4	340.2	0.013	0.015	0.000	1.8	0.002	0.000	79.5	0.032	0.267	30	0.625	3.31
B3 50 lbs																
A_R25D10	10	20	292.3	297.9	0.035	0.018	0.000	3.9	0.003	0.001	93.5	0.038	0.361	30	0.625	3.19
C_R25D45	45	20	292.3	293.2	0.030	0.029	0.000	4.4	0.004	0.002	95.3	0.061	0.426	30	0.625	3.18
D_R50D10	10	20	304.4	309.8	0.025	0.017	0.000	3.7	0.003	0.001	89.1	0.036	0.328	30	0.625	3.23
E_R50D25	30	20	304.4	306.7	0.042	0.023	0.000	5.6	0.003	0.001	90.2	0.057	0.386	30	0.625	3.22
G_R75D10	10	20	341.7	346.6	0.036	0.010	0.000	5.2	0.000	0.000	77.7	0.030	0.252	30	0.625	3.33
B4 50 lbs																
A_R25D10	10	30	298.1	305.7	0.009	0.013	0.000	1.2	0.002	0.000	90.6	0.039	0.347	30	0.625	3.21
C_R25D45	45	30	298.1	299.9	0.020	0.033	0.000	2.9	0.005	0.001	92.8	0.060	0.407	30	0.625	3.20
D_R50D10	10	30	312.1	319.4	0.011	0.014	0.000	1.6	0.002	0.000	85.8	0.036	0.313	30	0.625	3.25
E_R50D25	30	30	312.1	315.7	0.016	0.024	0.000	2.4	0.004	0.001	87.0	0.057	0.363	30	0.625	3.24
G_R75D10	10	30	350.1	356.6	0.011	0.014	0.000	1.6	0.002	0.000	75.1	0.031	0.241	30	0.625	3.36

Table D-3

Measured and Predicted Data for the 1st Mobilization at Platform F-4; Eugene Island Block 128

Xducer and Charge Data					Measured Data						ARA UWC Data					
Xducer Number	Xducer Depth (ft)	Depth BML (ft)	Radial Distance To Charge (ft)	Slant Range (ft)	Mpa	I (kPa•s)	E (kPa•m)	psi	I (psi•s)	E (psi•in)	psi	Integrated I (psi•s)	Integrated E (psi•in)	Pile DIA inches	Pile Wall Thickness (in)	Time constant (6.7 x ⍰) (msec)
B5 50 lbs																
A_R25D10	10	25	305.2	311.6	0.026	0.030	0.000	3.7	0.004	0.001	88.5	0.037	0.328	30	0.625	3.23
C_R25D45	45	25	305.2	306.5	0.034	0.036	0.000	4.3	0.005	0.002	90.3	0.059	0.388	30	0.625	3.22
D_R50D10	10	25	320.9	327.0	0.028	0.030	0.000	4.0	0.005	0.002	83.4	0.034	0.293	30	0.625	3.28
E_R50D25	30	25	320.9	323.7	0.036	0.041	0.001	5.2	0.006	0.003	84.5	0.054	0.344	30	0.625	3.27
G_R75D10	10	25	359.4	364.9	0.045	0.050	0.001	6.5	0.007	0.004	73.0	0.029	0.226	30	0.625	3.38
Conductor In Caisson 25 lbs																
A_R25D10	10	15	533.6	536.2	0.018	0.017	0.000	2.6	0.002	0.000	47.0	0.015	0.089	16	1	3.83
C_R25D45	45	15	533.6	533.8	0.020	0.024	0.000	3.0	0.004	0.001	47.3	0.031	0.122	16	1	3.83
G_R75D10	10	15	582.3	584.7	0.014	0.015	0.000	2.1	0.002	0.000	42.3	0.013	0.070	16	1	3.92
H_R75D25	30	15	582.3	583.2	0.014	0.015	0.000	1.7	0.002	0.000	42.5	0.023	0.094	16	1	3.92
J_R100D10	10	15	604.7	607.0	0.016	0.017	0.000	2.4	0.003	0.000	40.4	0.012	0.063	16	1	3.97
K_R150D10	10	15	647.3	649.5	0.019	0.021	0.000	2.7	0.003	0.001	37.2	0.010	0.053	16	1	4.04
L_R200D10	10	15	678.8	680.9	0.014	0.013	0.000	2.0	0.002	0.000	35.2	0.010	0.046	16	1	4.10
Open Caisson 75 lbs																
A_R25D10	10	20	98.0	113.8	0.331	0.369	0.044	48.1	0.057	0.268	361.2	0.194	5.211	36	1	2.71
C_R25D45	45	20	98.0	100.6	0.188	0.192	0.012	27.2	0.029	0.066	419.4	0.220	6.799	36	1	2.62
D_R50D10	10	20	124.6	137.3	0.237	0.273	0.024	34.4	0.043	0.153	287.0	0.152	3.426	36	1	2.85
E_R50D25	30	20	124.6	130.2	0.242	0.382	0.037	35.1	0.059	0.225	306.5	0.173	3.902	36	1	2.81
G_R75D10	10	20	144.9	156.1	0.218	0.264	0.021	31.6	0.042	0.135	245.6	0.127	2.563	36	1	2.96
J_R100D10	10	20	167.0	176.8	0.173	0.237	0.015	25.1	0.035	0.085	211.1	0.106	1.922	36	1	3.06
K_R150D10	10	20	210.4	218.3	0.116	0.148	0.007	16.5	0.022	0.041	163.3	0.077	1.174	36	1	3.25
L_R200D10	10	20	254.0	260.5	0.091	0.107	0.004	12.4	0.016	0.020	131.6	0.059	0.772	36	1	3.41

Table D-3

Measured and Predicted Data for the 1st Mobilization at Platform F-4; Eugene Island Block 128

Xducer and Charge Data					Measured Data						ARA UWC Data					
Xducer Number	Xducer Depth (ft)	Depth BML (ft)	Radial Distance To Charge (ft)	Slant Range (ft)	Mpa	I (kPa•s)	E (kPa•m)	psi	I (psi•s)	E (psi•in)	psi	Integrated I (psi•s)	Integrated E (psi•in)	Pile DIA inches	Pile Wall Thickness (in)	Time constant (6.7 x ⍰) (msec)
Well Conductor 1 50 lbs																
A_R25D10	10	30	44.4	81.1	0.095	0.161	0.007	13.8	0.025	0.045	457.7	0.203	6.860	30	0.625	2.22
C_R25D45	45	30	44.4	55.2	0.250	0.035	0.002	36.3	0.005	0.009	732.6	0.291	15.768	30	0.625	1.99
D_R50D10	10	30	60.5	91.0	0.058	0.103	0.003	8.4	0.016	0.017	398.0	0.183	5.356	30	0.625	2.29
E_R50D25	30	30	60.5	77.2	0.136	0.027	0.001	19.7	0.004	0.003	486.4	0.213	7.639	30	0.625	2.19
G_R75D10	10	30	80.0	104.9	0.064	0.106	0.003	9.2	0.016	0.018	333.8	0.160	3.922	30	0.625	2.38
H_R75D25	30	30	80.0	93.2	0.009	0.006	0.000	1.4	0.001	0.000	386.1	0.179	5.075	30	0.625	2.30
J_R100D10	10	30	102.5	122.9	0.032	0.039	0.000	4.7	0.006	0.003	275.0	0.138	2.785	30	0.625	2.49
K_R150D10	10	30	146.4	161.4	0.035	0.040	0.001	5.0	0.006	0.003	197.5	0.100	1.533	30	0.625	2.69
L_R200D10	10	30	190.4	202.1	0.024	0.031	0.000	3.2	0.005	0.002	150.1	0.073	0.918	30	0.625	2.86
Well Conductor 2 65 lbs																
A_R25D10	10	30	280.4	288.5	0.022	0.019	0.000	3.2	0.003	0.001	97.3	0.043	0.399	30	0.625	3.16
C_R25D45	45	30	280.4	282.3	0.040	0.031	0.000	4.7	0.005	0.002	99.8	0.063	0.463	30	0.625	3.14
D_R50D10	10	30	294.8	302.5	0.028	0.025	0.000	4.0	0.004	0.001	91.8	0.040	0.356	30	0.625	3.20
E_R50D25	30	30	294.8	298.7	0.058	0.026	0.000	7.4	0.004	0.002	93.1	0.060	0.409	30	0.625	3.19
G_R75D10	10	30	333.0	339.9	0.033	0.054	0.001	4.8	0.008	0.004	79.6	0.033	0.270	30	0.625	3.31

Table D-4

Measured and Predicted Data for the 1st Mobilization at Platform F-4; Eugene Island Block 128

Xducer and Charge Data				Measured Data						ARA UWC Predicted Data						
Xducer Number	Xducer Depth (ft)	Depth BML (ft)	Slant Range (ft)	Mpa	I (kPa•s)	E (kPa•m)	psi	I (psi•s)	E (psi•in)	Mpa	I (kPa•s)	E (kPa•m)	psi	Integrated I (psi•s)	Integrated E (psi•in)	Time constant (6.7 x ⍰) (msec)
B2 (36 in DIA/1 in WT) – 80 lbs																
A_R25D07	4	15	66.9	3.538	1.944	1.341	513.15	0.282	7.654	4.93	1.961	3.017	714.3	0.284	17.228	2.380
B_R25D22	19	15	56.5	1.942	1.853	1.169	281.69	0.269	6.675	6.06	2.749	4.541	879.6	0.399	25.928	2.269
D_R50D07	4	15	84.5	1.405	0.517	0.125	203.76	0.075	0.715	3.70	1.383	1.743	536.4	0.201	9.954	2.542
E_R50D22	19	15	76.6	1.565	1.435	0.653	227.02	0.208	3.728	4.19	2.071	2.358	607.4	0.300	13.462	2.470
F_R50D37	34	15	71.0	1.002	1.249	0.508	145.29	0.181	2.899	4.59	2.223	2.777	666.2	0.322	15.855	2.419
G_R75D07	4	15	105.4	1.043	1.081	0.339	151.20	0.157	1.933	2.83	0.995	1.041	410.9	0.144	5.944	2.702
H_R75D22	19	15	99.2	0.833	0.733	0.185	120.84	0.106	1.059	3.05	1.626	1.347	442.6	0.236	7.689	2.657
J_R100D7	4	15	125.3	0.648	0.758	0.167	93.94	0.110	0.954	2.29	0.767	0.690	332.3	0.111	3.940	2.837
K_R150D7	4	15	170.3	0.254	0.419	0.042	34.64	0.061	0.238	1.58	0.475	0.328	228.6	0.069	1.870	3.092
L_R200D7	4	15	214.3	0.178	0.318	0.021	25.78	0.046	0.121	1.19	0.321	0.180	172.8	0.046	1.029	3.297
B1 (36 in DIA/1 in WT) – 80 lbs																
A_R25D07	4	20	109.1	0.738	0.879	0.215	107.00	0.128	1.225	2.71	0.979	0.968	392.9	0.142	5.527	2.730
B_R25D22	19	20	102.4	0.719	0.891	0.222	104.24	0.129	1.270	2.93	1.577	1.255	425.4	0.229	7.166	2.681
D_R50D07	4	20	130.2	0.732	0.771	0.173	106.17	0.112	0.990	2.19	0.752	0.639	317.0	0.109	3.648	2.868
E_R50D22	19	20	124.6	0.592	0.542	0.113	85.80	0.079	0.648	2.31	1.312	0.820	334.4	0.190	4.682	2.833
F_R50D37	34	20	120.6	0.506	0.571	0.095	73.35	0.083	0.541	2.40	1.352	0.879	347.8	0.196	5.017	2.808
G_R75D07	4	20	153.0	0.632	0.154	0.010	91.66	0.022	0.058	1.80	0.591	0.437	260.7	0.086	2.493	3.000
H_R75D22	19	20	148.2	0.352	0.419	0.058	51.08	0.061	0.331	1.87	1.116	0.564	270.6	0.162	3.219	2.974
J_R100D7	4	20	172.7	0.433	0.578	0.076	62.74	0.084	0.435	1.55	0.486	0.323	224.4	0.071	1.844	3.105
K_R150D7	4	20	218.6	0.198	0.354	0.027	28.70	0.051	0.155	1.16	0.327	0.176	168.3	0.047	1.006	3.316
L_R200D7	4	20	263.0	0.160	0.298	0.018	19.60	0.043	0.102	0.93	0.235	0.107	134.4	0.034	0.611	3.492

Table D-4

Measured and Predicted Data for the 1st Mobilization at Platform F-4; Eugene Island Block 128

Xducer and Charge Data				Measured Data						ARA UWC Predicted Data						
Xducer Number	Xducer Depth (ft)	Depth BML (ft)	Slant Range (ft)	Mpa	I (kPa•s)	E (kPa•m)	psi	I (psi•s)	E (psi•in)	Mpa	I (kPa•s)	E (kPa•m)	psi	Integrated I (psi•s)	Integrated E (psi•in)	Time constant (6.7 x ⍰) (msec)
Well Conductor 3 (48 in DIA/1.25 in WT) – 145 lbs																
A_R25D07	4	30	109.5	0.214	0.344	0.026	30.98	0.050	0.149	3.80	1.639	2.305	550.4	0.238	13.163	3.342
B_R25D22	19	30	101.4	0.123	0.203	0.009	17.88	0.029	0.052	4.17	2.731	3.098	605.3	0.396	17.691	3.270
D_R50D07	4	30	129.2	0.144	0.224	0.011	20.83	0.033	0.064	3.10	1.280	1.560	450.0	0.186	8.910	3.500
E_R50D22	19	30	122.3	0.160	0.282	0.016	22.20	0.041	0.090	3.32	2.291	2.063	481.1	0.332	11.782	3.446
F_R50D37	34	30	117.0	0.160	0.193	0.008	16.13	0.028	0.047	3.50	2.387	2.268	507.5	0.346	12.952	3.404
G_R75D07	4	30	151.0	0.086	0.177	0.006	12.44	0.026	0.034	2.57	1.013	1.078	372.5	0.147	6.158	3.655
H_R75D22	19	30	145.1	0.100	0.173	0.006	11.86	0.025	0.034	2.69	1.952	1.423	390.0	0.283	8.127	3.616
J_R100D7	4	30	171.1	0.072	0.133	0.003	8.65	0.019	0.020	2.20	0.827	0.789	319.2	0.120	4.507	3.787
K_R150D7	4	30	216.0	0.047	0.077	0.001	5.10	0.011	0.007	1.66	0.557	0.432	240.2	0.081	2.467	4.042
L_R200D7	4	30	259.8	0.057	0.074	0.001	4.44	0.011	0.007	1.32	0.400	0.262	192.0	0.058	1.495	4.255
Well Conductor 4 (48 in DIA/1.25 in WT) – 145 lbs																
A_R25D07	4	30	112.9	0.299	0.483	0.053	43.43	0.070	0.304	3.66	1.567	2.150	531.0	0.227	12.277	3.369
B_R25D22	19	30	105.0	0.213	0.383	0.030	30.96	0.056	0.174	4.00	2.643	2.873	580.0	0.383	16.404	3.302
D_R50D07	4	30	133.0	0.294	0.415	0.037	42.63	0.060	0.209	3.00	1.229	1.462	435.1	0.178	8.350	3.527
E_R50D22	19	30	126.3	0.278	0.591	0.062	40.37	0.086	0.356	3.19	2.225	1.927	462.8	0.323	11.003	3.477
F_R50D37	34	30	121.2	0.163	0.276	0.017	23.62	0.040	0.096	3.36	2.315	2.112	487.4	0.336	12.060	3.436
G_R75D07	4	30	155.0	0.187	0.318	0.021	27.08	0.046	0.117	2.49	0.973	1.013	361.0	0.141	5.784	3.681
H_R75D22	19	30	149.3	0.143	0.181	0.008	18.92	0.026	0.046	2.60	1.904	1.343	377.5	0.276	7.671	3.644
J_R100D7	4	30	175.3	0.131	0.263	0.012	18.97	0.038	0.071	2.14	0.797	0.745	310.5	0.116	4.257	3.811
K_R150D7	4	30	220.4	0.106	0.136	0.004	8.70	0.020	0.024	1.62	0.538	0.410	234.6	0.078	2.341	4.064
L_R200D7	4	30	264.3	0.072	0.092	0.002	6.19	0.013	0.011	1.30	0.387	0.249	187.9	0.056	1.424	4.276

Table D-4

Measured and Predicted Data for the 1^{st} Mobilization at Platform F-4; Eugene Island Block 128

Xducer and Charge Data				Measured Data						ARA UWC Predicted Data						
Xducer Number	Xducer Depth (ft)	Depth BML (ft)	Slant Range (ft)	Mpa	I (kPa•s)	E (kPa•m)	psi	I (psi•s)	E (psi•in)	Mpa	I (kPa•s)	E (kPa•m)	psi	Integrated I (psi•s)	Integrated E (psi•in)	Time constant (6.7 x ⍰) (msec)
Well Conductor 1 (48 in DIA/1.50 in WT) – 145 lbs																
A_R25D07	4	25	111.6	1.450	1.629	0.684	210.36	0.236	3.904	3.60	1.480	2.019	521.9	0.215	11.528	3.296
B_R25D22	19	25	104.3	0.869	1.467	0.489	126.10	0.213	2.791	3.90	2.529	2.684	566.3	0.367	15.323	3.235
D_R50D07	4	25	132.1	0.746	1.238	0.324	108.25	0.180	1.851	2.92	1.149	1.351	424.1	0.167	7.716	3.457
E_R50D22	19	25	126.0	0.909	1.239	0.336	131.88	0.180	1.921	3.10	2.121	1.786	449.9	0.308	10.198	3.411
F_R50D37	34	25	121.4	0.810	1.228	0.395	117.43	0.178	2.253	3.25	2.196	1.935	470.7	0.319	11.049	3.375
G_R75D07	4	25	154.4	0.694	1.060	0.239	100.61	0.154	1.363	2.42	0.902	0.926	350.7	0.131	5.289	3.611
H_R75D22	19	25	149.2	0.550	0.782	0.162	79.75	0.113	0.927	2.52	1.801	1.237	365.8	0.261	7.066	3.576
J_R100D7	4	25	175.0	0.545	0.905	0.165	79.05	0.131	0.942	2.07	0.735	0.676	300.9	0.107	3.859	3.740
K_R150D7	4	25	220.4	0.453	0.164	0.007	65.76	0.024	0.042	1.57	0.493	0.369	227.3	0.072	2.108	3.989
L_R200D7	4	25	264.6	0.207	0.489	0.043	28.88	0.071	0.248	1.25	0.353	0.223	181.8	0.051	1.271	4.199
Well Conductor 5 (48 in DIA/1.25 in WT) – 145 lbs																
A_R25D07	4	25	114.5	0.439	0.715	0.128	63.65	0.104	0.731	3.60	1.484	2.053	521.7	0.215	11.725	3.383
B_R25D22	19	25	107.4	0.430	0.687	0.098	62.32	0.100	0.562	3.89	2.591	2.742	564.9	0.376	15.655	3.322
D_R50D07	4	25	134.6	0.307	0.573	0.063	44.47	0.083	0.359	2.96	1.167	1.403	428.6	0.169	8.009	3.539
E_R50D22	19	25	128.6	0.505	0.425	0.062	73.26	0.062	0.355	3.12	2.188	1.853	452.8	0.317	10.584	3.495
F_R50D37	34	25	124.1	0.541	0.595	0.116	78.43	0.086	0.662	3.26	2.263	2.005	473.3	0.328	11.448	3.459
G_R75D07	4	25	156.6	0.397	0.547	0.070	57.58	0.079	0.399	2.45	0.917	0.964	355.5	0.133	5.506	3.694
H_R75D22	19	25	151.5	0.363	0.373	0.050	52.62	0.054	0.287	2.55	1.853	1.298	370.5	0.269	7.413	3.659
J_R100D7	4	25	177.0	0.334	0.452	0.052	48.51	0.066	0.298	2.11	0.750	0.708	306.3	0.109	4.045	3.823
K_R150D7	4	25	222.1	0.183	0.429	0.032	26.61	0.062	0.185	1.60	0.505	0.389	232.5	0.073	2.224	4.072
L_R200D7	4	25	266.1	0.157	0.214	0.010	22.77	0.031	0.055	1.29	0.362	0.236	186.5	0.053	1.347	4.284

Appendix E

Lessons Learned from TAR Project No. 570

Lessons Learned:

There were many valuable lessons learned in the previous studies (November 2003 and August 2007) that will not be repeated verbatim here for brevity. However, the reader should note that earlier lessons learned were integrated into the deployment methodology for the 2008 study as much as possible for the given conditions and resources available. This included the use of a liftboat and small boat to deploy the array. This allowed the deployment team to have better control over the array handling as it was deployed. For the 2008 study, the sea conditions were very calm, aiding in an easier and less damaging array deployment. This was not the case in the 2007 study.

Following is a list of some of the issues, which may have been noted in previous deployments but will be listed due to the importance of finding ways to overcome the problems they pose. While not exhaustive, the listed items, if implemented for any follow up or similar studies, will help to insure better array deployment and data gathering.

- Although all the data was captured for the 2008 and the 2007 studies, the loss of data in the earlier study (2003) and the difficulty in obtaining proper test targets themselves shows the need for a redundant system. This could be a second DL750 in parallel, or another less expensive and lower bandwidth backup storage system. This should be considered seriously for future deployments.

- Instrumentation was protected from the environment through the use of an equipment shelter borrowed from Tetra for the 2007 measurements. Not only did the shelter keep the instrumentation dry and clean, it allowed the setup to remain for the duration of the testing dates without the need for internal re-cabling. For the 2008 study, a tool cabinet (large, but simply a rack of enclosed shelves) was provided: it worked marginally for the task and a proper "shelter" should be used for subsequent deployments. It leaked even when the doors were properly shut and it provided no shade, making the reading of the instrumentation LCD screens difficult at best.

- Once again, three transducer/RG58 splice points were found to have failed when the array downlines were recovered at the end of the first array deployment on August 8th. These were repaired with some difficulty. Additionally, array downline ropes were made this time from nylon rope, and the downlines did not stretch. In addition, the PCB Tourmaline transducers used were retrofitted with heavier leader cabling prior to the subject deployments. It is very desirable at this point to fabricate a more robust array system utilizing watertight connectors and junction boxes so that these sorts of issues can be further minimized. Of note is the fact that data was successfully collected from ten of the twelve deployed transducers on the 2008 mobilization versus three that failed on the 2007 mobilization, so improvement is occurring.

- While this second deployment study added a half dozen more data sets to the ongoing study and the first deployment added fourteen, more data points would be desirable before similitude equations can be formulated with confidence. Also, more relevant parameters should be documented just in case they have an influence on the resultant levels observed. These include depth of charge in relation to mudline, actual depth of mudline within a piling or caisson, condition of the pilings at the cut location, quality of cut, number of "sub-charges" used in bulk charges, and any other data which may be considered pertinent. Furthermore, since the time waveforms vary considerably, it will be important to try to establish theories or demonstrable causes for the variances.

- One could make the assumption, for the subject data, that the energy source (point of explosive cut) can be thought of as a point source. In reality, not only is there acoustic energy radiating from the below mudline cut location, but also from all along the piling/conductor surface. It is not known just how much of a contribution the structural resonances, excited from the shock impulse, make to the overall resultant impulse energy. The shock time waveforms show this as a smearing, which could also be a Lloyd's mirror effect due to the shallow water. Another possibility is the lack of exact time alignment between individual charges of a multiple component bulk charge. Unless this is studied more carefully, it will be hard to determine which of the various parameters (as mentioned in the previous point) influence the measured data significantly. It is recommended that a set of pilings be outfitted with accelerometers that can be used to correlate data gathered from a linear array of in-water shock sensors. This set of measurements would take place in parallel with the "normal" data gathering effort.

- Anchoring of the transducer array was not optimal. The original plan in 2003 on the SNC TEC contract had been to use a large clump anchor with a large float at the far end of the array and a direct attachment to a piling at the originating end with a heavy aircraft cable strung in between from which down lines would be hung. This plan was changed and the array executed from the stern deck of the 150' M/V Bisso Jr. workboat in 2003. The M/V Bisso Jr. was unable to keep its winches in check, even under the smoother seas at #97, and required a tug on both #97 and #120 to hold her position. This, plus the severe vibration on board the M/V Bisso Jr., proved very detrimental to array deployment and subsequent measurements. For the 2007 set of measurements, a dedicated, more modern crew boat, the M/V Raider, was to be used. The M/V Raider, while more modern, had no air tuggers or winches fore or aft. The M/V Raider was outfitted with an anchor windlass, but it was not in working order. A jack-up barge was used to deploy the aircraft cable from which the array downlines hung, but since it could not hold position or aspect in the windward currents, it could not be used for the deployment of the downlines. It did, however, make for a stable base from which to make the measurements once the array was deployed using a smallboat. For the 2008 deployment the Jack-up boat M/V Hammerhead was used to fix the aircraft cable to the test platform and then the Hammerhead backed off paying out the cable as she went. Again, the Jack-up boat's small inflatable was used to bring the array downlines to their respective floats, one at a time, and lower them in place. This worked well, but the seas were reasonably calm. The boat and method used to deploy the array has proven to be one of the most critical aspects of these studies and, ***for any subsequent studies, the original (or alternative reasonably feasible) method needs to be strictly adhered to for a successful deployment***.

- Communications systems were much better for these deployments than for the 2003 mobilization on the SNC TEC project. This was, in part, due to the lack of the very noisy air tuggers that were used in 2003 on the M/V Bisso Jr. Also, the fact that the jack-up barge was not running at the time also contributed to a quieter environment where communications benefited.