Lawler, Matusky & Skelly Engineers LLP
Environmental Science & Engineering Consultants

Impact Assessment and Mitigation Plan
for Blasting on the Millennium Pipeline
Haverstraw Bay Crossing

Prepared for:

Millennium Pipeline Company

Prepared by:

Lawler, Matusky & Skelly Engineers LLP
One Blue Hill Plaza
Pearl River, N.Y. 10965

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Introduction

The eastern end of the Millennium Pipeline crossing of Haverstraw Bay will encounter rock in the transition from shallow water to adjacent upland. In the water, the rock is beneath a layer of unconsolidated sediment, but the rock may be resistant to removal with a conventional dredge bucket, in which case blasting would be needed to fracture the rock before it is excavated. Blasting would be undertaken following Vibra-Tech's April 15, 2002 plan (attached), which is the basis for this assessment and the mitigation planning. In addition, the technical literature on blasting effects was reviewed to develop this state-of-the-art mitigation plan. The potential effects of blasting on this small portion of the trench are expected to be minimal because of the limited blasting program (blasting will be designed as one shot), the site-specific factors which limit the abundance of fish and invertebrates in the blast area and by the use of mitigation measures.

Proposed Project

The proposed route for the Millennium Pipeline Project (Millennium) would cross the Hudson River at Haverstraw Bay between Rockland and Westchester Counties, following a 2.1-mile route from Bowline Point on the western side of the Bay to the Veterans Administration hospital property on the eastern shore (Figure 1, Vibra-Tech April 15, 2002 plan). The extensive mitigation techniques that are planned for this river crossing are detailed in the Millennium Pipeline Project Coastal Zone Consistency Determination dated March 2001, which was incorporated into the Final Environmental Impact Statement ("FEIS") issued by the Federal Energy Regulatory Commission and other cooperating federal agencies in October 2001. FEIS, Appendix J. They are also discussed in the Supplemental Draft Environmental Impact Statement at pp. 2-35 to 2-44.

As part of that crossing, Millennium has confirmed that consolidated rock would be encountered for approximately 185 feet of the easternmost portion of the crossing. The anticipated location for this rock is shown on Millennium's drawings 8525-CAD-5534 and 8525-CAD-5535, a copy of which is attached as Figures 2 and 3 to the Vibra-Tech April 15, 2002 plan for convenience. As shown on those drawings, the total expected quantity of rock in this excavation is estimated at a maximum of 260 cubic yards.

As the first step in the dredging process near the eastern shoreline, Millennium will remove sediment with the same methods proposed for the shallow water areas of the Hudson River Crossing by using an environmental bucket and other mitigation measures to ensure that turbidity is kept to a minimum and that the conditions of the Water Quality Certificate issued by the New York Department of Environmental Conservation ("NYSDEC"), dated December 8, 1999 are met. If rock is encountered, it is likely that the environmental bucket will remove at least some of the rock, particularly the fractured rock that is likely to exist at the interface between the rock and the overburden. At this point, a determination will be made as to whether the rest of the rock is susceptible to removal via mechanical means. If the rock integrity is such that it can be removed with mechanical techniques, the environmental bucket or a barge mounted excavator will be used to remove the rock. If a barge mounted excavator is used, it will only be used after the sediment and at least some rock has been removed with the environmental bucket. In addition, the environmental bucket will be used to remove sediment to an appropriate setback distance to prevent the rock removal operations from disturbing nearby sediments with resulting turbidity. The setback distance will be established in the field based upon the depth of the sediment and the rock, and sound engineering judgment. In no event will the construction work area be greater than that originally proposed for this crossing. Since the excavator will be working in rock, turbidity is not expected to be a problem, which will be confirmed in accordance with the monitoring conditions of the Water Quality Certificate. Although Millennium has agreed to attempt rock removal using the environmental bucket, it is possible that blasting will be required to fracture the rock to facilitate its removal. As part of its planning efforts, Millennium has contracted with Vibra-Tech Engineers, Inc. to prepare a blasting and mitigation plan (plan attached).

Whether the rock is fractured by blasting or mechanical means, the fractured rock will be excavated and stored in shallow draft barges. No rock will be side cast on the bottom of the Hudson River. Following installation of the pipe, the pipe will be covered with the fractured rock and then the excavated bottom sediments, which will also be stored in shallow draft barges, to restore the work area to its approximate original contours. Tidal and wave action will facilitate the restoration of this area to its original contours. Since native sediments will be used, it is anticipated that the area will recolonize with benthos promptly following construction.

Impact assessment

The potential impact of underwater blasting on aquatic life is site-specific, but the potential for effects can be reasonably estimated using various models based on controlled testing and experience at blasting operations. Site specific information on aquatic life in Haverstraw Bay was used in combination with the blasting plan to assess the potential for adverse effects. Modeling was used to estimate the area of the affected zone around the blast site for an unmitigated blast. Mitigation was then applied to minimize potential effects.

Site-specific Factors. The potential adverse effects on aquatic life are very small because the blasting area is a small portion of the available aquatic habitat. Of the designated significant habitat in Haverstraw Bay, only 0.002% would be involved in the blasting. When the contiguous functional habitat is considered, the blasting area is only 0.0008% of the total area. As shown below, the pressure effects of the blast extend a short distance from detonation point, but that distance is minimized by the use of an air bubble curtain, which effectively confines all impacts to the area within the bubble curtain.

Prior to preparation for blasting, the sediments overlying the rock in the blast area will be removed. Thus, the bottom area in the vicinity of the blast will be rendered unsuitable for invertebrates before blasting takes place. This change in habitat conditions would minimize the abundance of invertebrates in the area affected by the blast and decrease fish abundance because a potential food resource is no longer present. Crab abundance would be reduced because the blue crab prefers soft sediments. The density of fish in the area of blasting will be low due to this disturbance.

Dredging operations are known to attract fish and crabs to the periphery of the turbidity plume to feed on invertebrates dislodged by the dredging. If this occurs near the blasting site, the turbidity plume, the mechanism which attracts fish, would dissipate long before blasting would occur. Turbidity plumes are transient conditions which dissipate to background levels within minutes to hours after dredging ceases. The removal of fine-grained sediments, the source of a turbidity plume, would be completed before there is an attempt to remove rock with mechanical equipment. If mechanical equipment is unsuccessful, there will be a period of time (days) to prepare the rock for blasting. Because of these factors, the dredging will not create an artificial concentration of aquatic life which could be susceptible to blast effects. To the extent that any fish remain on the periphery of the blast area just prior to blasting, they would be isolated from blast effects by the air bubble curtain.

Blasting would take place in shallow water which minimizes the volume of water potentially affected by the blast, thereby minimizing the number of fish which could occupy the area in the vicinity of the blast. The older and larger individuals of many fish species, including the shortnose and Atlantic sturgeon, shad and striped bass, do not occur in substantial numbers in the shallow, near-shore zone of Haverstraw Bay, which tends to isolate them from blast effects.

The effects of blasting on fish which are unprotected from pressure effects have been described in the literature. Various injuries to internal organs and hemorrhaging have been reported for a variety of species, including shortnose sturgeon (Moser, 1999). These injuries are avoided by isolating fish from blast pressure effects. The site-specific factors discussed above, the embedded nature of the proposed blasting and the mitigation measures discussed below will effectively isolate fish from blasting effects in Haverstraw Bay.

Disturbance of the substrate to prepare a trench for the pipeline in the area where blasting may occur represents a temporary physical effect which is similar to the remainder of the Haverstraw Bay crossing where conventional excavation is used. After placement of the pipeline in the trench, the trench will be filled with shot rock and capped with the original sediment to the approximate original elevation. The substrate will be rapidly recolonized by invertebrates from adjacent undisturbed substrate and fish will return to the area and use it for living space just as they did before the disturbance.

<u>Blast Modeling.</u> Predictive mortality models give an approximation of the mortality radius of a given explosive charge (Hempen and Keevin 1995). These models are useful for bounding the mortality radius and are good first-order tools to make assessments of environmental impacts due to submerged explosions. Based on the quality of the aquatic resource(s) in the blasting area and predicted impacts, it is possible to make rational

decisions concerning appropriate techniques to mitigate impacts (Keevin 1998; Keevin and Hempen 1995).

There is considerable published information concerning fish mortality resulting from explosive charges detonated in open water to develop open-water blasting models (Anonymous 1948; Ferguson 1962; Hubbs & Rechnitzer 1952; Teleki and Chamberlain 1978), while there is little documentation concerning embedded charges (charges placed in drilled holes that are confined by stemming material). This becomes extremely important in evaluating the effects of blasting operations on aquatic life. The use of existing mortality data will overestimate mortality for shots confined within solid material such as the blasting potentially required in Haverstraw Bay for the Millennium Pipeline Project. Explosives in open water, which are not contained completely within rigid structures (i.e., rock), will produce both higher amplitude and higher frequency shock waves, than contained detonations. The energy consumed by rock displacement and the bedrock's radiational damping will result in lower energy reaching the water column. The use of blasting in rock removal projects will result in lower fish mortality than the same explosive charge size detonated in open water (Keevin 1998).

The mathematical mortality model, I-Blast, developed by COASTLINE Environmental Services Ltd. (1986), was used to predict the LD(50%), LD(1%), and LD(0%) lethal ranges for open water explosions. The I-Blast model was chosen because it gives a good approximation of the mortality radius resulting from open water blasting and it is a good mitigation planning tool (Hempen and Keevin 1995; Keevin 1998). I-Blast uses impulse strength modeling (Yelverton et al. 1975; Hill 1978; Baxter et al. 1982; Wright 1982; Munday et al. 1986) to predict the mortality radius from underwater explosions. The model utilizes the "specific impulse" as the portion of the pressure waveform responsible for mortality.

The routine used in I-Blast calculates the lethal range for open water explosions. The lethal range values obtained from the I-Blast model were reduced by a factor to obtain the mortality radius (50%, 1%, and 0% fish mortality) for a contained charge weight of 35 pounds (the largest charge per delay proposed for the rock removal project, reference Vibra-Tech's April 15, 2002 report) and fish weights [1/4, 1/2, 1, 15 lbs. (the latter representing the weight of a sturgeon captured during pre-blast surveys)]. The reduction factor was based on work conducted by Nedwell and Thandavamoorthy (1992). They compared the pressure time histories from the detonation of small explosive charges in both free water and embedded explosions. They found that the impulse of the water-borne shock wave following the detonation of an explosive charge embedded in a borehole was reduced from that occurring for a charge freely suspended in water at the same distance. The peak pressure value resulting from the confined charge was significantly reduced from the same size charge detonated in open water. The reduction factor has been accepted by the international blasting industry and was used in the development of their "Guidelines for the Safe Use of Explosives Under Water (Marine Technology Directorate Ltd. 1996).

The lethal range and survivability calculations are presented in 'able The values are for charge weights of double 17.5 pounds per delay (35 pounds).

Table 1. Fish and Crab Mortality - Lethal Range and Survivability Calculations For Embedded High Explosives.

I-Blast Fish Mortality Modeling Results

35 Pound (16 Kg) High Explosive Charge

Fish Weight		Lethal Range Calculation (Feet)		
Lbs.	Kg.	50% Mortality	1% Mortality	0% Mortality
0.25	0.1125	50	69	113
0.50	0.225	45	62	101
1.00	0.450	40	55	91
15.00	6.750	25	34	59

Results of field tests show that the open water mortality predictions of I-Blast more closely approximate actual mortality (Hempen and Keevin 1995). Model outputs do not account for pressure reductions that would result from the use of mitigation techniques. For example, the proposed use of a bubble curtain has the potential to significantly reduce the mortality of aquatic organisms (Keevin et al. 1997).

Swimbladder fish (1/4 to 1 pound) will survive beyond 55 to 70 feet from the unmitigated blast area, based on the results of a modified version of I-Blast. The single large sturgeon captured (15 pounds) would have a 99% survivability at a distance of 35 feet, based on I-Blast modeling and no mitigation.

Based on existing invertebrate mortality data (Keevin and Hempen 1997), the 90% survivability for blue crabs is expected at 40 to 50 ft, again without mitigation.

Mitigation

Vibra-Tech's Blasting and Mitigation Plan proposes to use the following mitigation techniques:

1. stemming of boreholes;
2. delays;
3. side scan sonar of the blasting zone to ensure that no concentrations of fish are present in the immediate vicinity of the blast;
4. use of noise generating devices to scare fish away, if needed; and
5. an air bubble curtain to reduce mortality.

These techniques represent the best techniques available to minimize blasting effects on aquatic life. Each technique is discussed below.

1. Stemming. Stemming is the use of a selected material, usually angular (crushed rock) gravel, to fill a drill hole above the explosive. Stemming is commonly used by the blasting industry to contain the explosive force and increase the amount of work done to the surrounding strata (Konya and Davis 1978; Moxon et al. 1993). This technique decreases the amount of blast energy that is lost out of the drill hole and thus reduces the impact to the aquatic environment. Brinkman (1990) has shown that approximately 50% of the explosive energy is lost if unrestricted venting is allowed to occur through the blasthole collar. Susznszky (1977) found, in a series of tests in the Danube River, that absolute values of pressure were decreased by an order of magnitude by using soil for stemming.

Gordon and Nies (1990) recommended that the optimum crushed rock particle size should be approximately 1/12 of the borehole diameter. Vibra-Tech plans to use 3/8" or ¼" crushed stone, which is roughly the size suggested by Gordon and Nies (i.e. 3.5 inch borehole /12 = 0.29 inch stone; 4 in borehole /12 = 0.33 in stone). All available information suggest that stemming will reduce the effects of explosive removal on aquatic life.

2. Delays. Large explosive charges can be divided into a series of smaller charges by use of blasting caps with delays, detonating cord with delays, or with specialized blast machines that supply the electrical charge to detonate the charge. Shot holes can be detonated simultaneously or shot in succession with a time interval between detonation of each shot hole or groups of shot holes. The use of delays effectively reduces each detonation into a series of small explosions. The greater the weight of explosives shot instantaneously, the greater the intensity of the shock wave and the greater the area of effects (Tansey 1980). The use of delays effectively reduces each shot series into a series of small explosions. Resulting blast overpressure levels are directly related to the size of the charge in each delay, rather than the summation of charges detonated in all holes. When using fish mortality models, it is appropriate to use the mortality values for the largest single charge per delay to calculate the area of mortality, rather than the combined weight of all drill holes being fired (Munday et al. 1986). For the proposed blasting 35 lbs. was used for the model analysis.

3. Pre-Blast Side Scan Sonar Survey. The NYSDEC Water Quality Certificate requires a pre-blast side scan sonar survey of the area to ensure that no concentrations of fish are present in the immediate vicinity of the blast. The acoustic study will be conducted up to the time immediately prior to the blast, keeping boat personnel and equipment safety as a priority. Pre-blast surveys have been shown to be of limited value. For example, Munday et al. (1986) showed that fish kill number could not be predicted consistently from pre-blast sonar surveys. However, the use of side scan sonar just prior to explosive detonation will give a good indication of the presence of any large schools of fish passing through the blast zone. If the side scan sonar confirms the presence of fish in the immediate vicinity of the blasting zone, noise-generating devices will be utilized to scare fish away. Alternatively, should a fish school be observed, blasting will be delayed until the fish move from the blasting zone.

4. Scaring Fish Using Noise. The use of small explosive charges (repelling charges) to scare fish away from the blasting zone prior to detonation of the main blast have not been found to be very effective (Keevin et al. 1997). Some fish were found to move, but in most instances the distances were small. Some natural resource agencies forbid the use of repelling charges because they can kill fish (Keevin1998).

The use of a continuous noise source has been found to be effective in repelling clupeids (Dunning et al. 1992; Haymes and Patrick 1986) and salmonids (Knudsen et al. 1994). The effectiveness of noise in repelling other species is not known and it is not known how far fish can be driven from the sound source. However, the use of noise could potentially reduce impacts. Noise devices have generally been effective for repelling fish for a short time followed by ineffectiveness because fish acclimate to sound rapidly. In this case, noise is thought to be effective because the noise generator will be used just prior to initiating the air bubble curtain which will have the effect of keeping fish outside of the bubble curtain and the immediate blast area. Fish need only to be scared once, because the detonation will occur shortly after the air bubble curtain is operating

*5. **Air Bubble Curtains.*** An air bubble curtain was found to be extremely effective in reducing fish mortality during explosive demolition of Locks and Dam 26 on the Mississippi River. The curtain was deployed with large explosive charges (1,970 lbs. total weight of 9.5 to 120 pound charges/delay), deep water (33 to 38 feet at the bubble curtain), and high water velocities (approximately 2 feet/second) (Keevin et al. 1997). A significant reduction ($P < 0.05$) in mortality at 120 hours for all distances tested was found for bluegill (Lepomis macrochirus) with the bubble curtain in operation when compared to the no bubble-curtain condition. Total mortality (100%) was observed to 265 feet from the blast without the bubble curtain. Mortality was observed at all nine distances tested and was still 58% at 385 feet, the farthest distance tested. With the bubble curtain in operation, 19% mortality was observed at 65 feet from the explosion. There was no explosion related mortality past 65 feet, comparing the mortality at each distance with control mortality when the bubble curtain was operating. Bubble curtains are extremely effective in reducing mortality to fish. Since the area identified for potential blasting in the Hudson River is shallow (0 to approximately 3 meters), this data is of limited relevance.

Keevin and Hempen (1997) reported that an air bubble curtain was very effective at reducing fish mortality in shallow water. It is common to note a 10 times or greater reduction in pressure with an effective air curtain. Typically, the greater the number of air bubbles, the greater the reduction in water pressure. Research from Keevin and Hempen (1997) evaluated the effectiveness of air bubble curtains in shallow water for reducing explosive pressures and associated fish kill. Test results from the detonation of a 2 kg (4.4 lbs) explosive charge in 1.25 meters (4.1 feet) of water with the use of an air curtain showed considerable reductions in peak pressure, impulse, and energy flux density plus significant reductions in fish mortality. Based on actual recorded levels, significant peak pressure reductions were realized. At 6.5 meters (21.3 feet), levels were reduced from 3147 psi to 44 psi, a 98.6% reduction, and at 14 meters (45.9 feet) from

315 psi to 39 psi, an 87.5% reduction. Mortality for bluegill fell from 100 percent without the bubble curtain to 0 percent with the bubble curtain.

Table 2.- Bluegill mortality based on live/dead counts (n=50 at each distance tested) resulting from underwater detonation of a 2 kg charge of T-100 at 1.25 m depth without and with the use of a bubble curtain. Independent duplicate trials are reported.

	Without Air Bubble Curtain				With Air Bubble Curtain				Control
	DISTANCE (Meters) FROM EXPLOSION								
	6.5	9.0	11.5	14.0	6.5	9.0	11.5	14.0	
SHOT 1									
Number Tested	50	50	50	50	50	50	50	50	50
96 hr Mortality	50	50	50	50	0	0	0	0	0
96 hour+Internal Damage Mortality	50	50	50	50	0	0	0	0	0
SHOT 2									
Number Tested	50	50	50	50	50	50	50	50	50
96 hr Mortality	50	50	50	50	0	0	0	0	0
96 hour+Internal Damage Mortality	50	50	50	50	0	0	0	0	0

The proposed blasting for the Millennium Pipeline is confined to shallow water near shore which will isolate the air curtain from the strong currents and deep water of the channel. As such, the air bubble curtain is expected to be very effective in reducing potential mortality from the proposed blasting. Given this effectiveness, the use of gill nets that could harm individual fish is not required nor recommended. Similarly, pressure wave monitoring would not be effective due to attenuation expected from the bubble curtain. Further, since the blast will be attempted as a single series, pressure wave data from this specific location will not assist in minimizing further blasting affects.

Typically the bubble curtain would consist of small diameter plastic or steel pipe with sufficient holes drilled in the top to permit release of a continuos bubble stream. The piping is connected to an air compressor of sufficient capacity to effectuate the air bubble curtain. The air bubble curtain will be installed well before the blast and tested to ensure that it provides a continuous air bubble curtain around the site. The curtain will be installed within the 1 % mortality distance based on the I-Blast model results. This will ensure that the area where fish mortality could occur is reduced to the smallest practical area.

Summary

The potential effects of blasting of a very small portion of the trench for the Millennium Pipeline in Haverstraw Bay are minimal because of the limited blasting program (blasting will be designed as one shot), the site-specific factors which limit the abundance of fish and invertebrates in the blast area and by the use of mitigation measures. These mitigation measures represent a comprehensive approach which includes all available techniques to minimize effects. During the pipeline installation the work will be monitored by resource agency staff to ensure that all mitigation measures are in place prior to the blasting.

References

Anonymous. 1948. Effects of underwater explosions on oysters, crabs and fish Chesapeake Biological Laboratory, Publication No. 70, pp. 1-43.

Baxter, L. II, E. E. Hays, G. R. Hampson, and R. H. Bachus. 1982. Mortality of fish subjected to explosive shock as applied to oil well severance on Georges Bank. Woods Hole Oceanographic Institution Technical Report WHOI-82-54.

Brinkmann, J. R. 1990. An experimental study of the effects of shock and gas penetration in blasting. Pp. 55-66. In: Third International Symposium on Rock Fragmentation by Blasting, Brisbane, Australia

Dunning, D. J., Q. E. Ross, P. Geoghegan, J. J. Reichle, J. K. Menezes, and J. K. Watson. 1992. Alewives avoid high-frequency sound. North American Journal of Fisheries Management 12:407-416.

Ferguson, R. G. 1962. The effects of underwater explosions on yellow perch (Perca flavescens) Canada Fish Culturist 29:31-39.

Gordon, G., and D. Nies. 1990. Small borehole blasting in high liability locations. Pp. 459-473. In: Proceedings of the Sixth Conference on Explosives and Blasting Techniques, Orlando, FL. Society of Explosives Engineers, Cleveland, OH.

Haymes, G. T., and P. H. Patrick. 1986. Exclusion of adult alewife, Alosa pseudoharengus, using low-frequency sound for application at water intakes. Canadian Journal of Fisheries and Aquatic Science 43:855-862.

Hempen, G.L. and T. M. Keevin. 1995. Underwater blasting effects models: A critical evaluation of I-Blast. Pp. 236-247. In: Proceedings of the Twenty-first Annual Conference on Explosives and Blasting Technique (Volume 1), Nashville, Tennessee. International Society of Explosive Engineers, Cleveland, OH.

Hill, S. H. 1978. A guide to the effects of underwater shock waves on Arctic marine mammals and fish. Pacific Marine Science Report 78-26. Institute of Ocean Sciences, Patricia Bay, Sidney, B.C. 50 p.

Hubbs, C. L., and A. B. Rechnitzer. 1952. Report on experiments designed to determine effects of underwater explosions on fish life. California Fish and Game 38:333-366.

Keevin, T. M. 1998. A review of natural resource agency recommendations for mitigating the impacts of underwater blasting. Reviews in Fisheries Science 6:281-313.

Keevin, T. M., G. L. Hempen, and D. J. Schaeffer. 1997. Use of a bubble curtain to reduce fish mortality during explosive demolition of Locks and Dam 26, Mississippi River. Pp. 197-206. In: Proceedings of the Twenty-third Annual Conference on Explosives and Blasting Technique, Las Vegas, Nevada. International Society of Explosive Engineers, Cleveland, OH.

Keevin, T. M., and G. L. Hempen. 1995. A tiered approach to mitigating the environmental effects of underwater blasting. Journal of Explosives Engineering 13: 20-25.

Keevin, T. M., G. L. Hempen, J. M. Pitlo, Jr., and D. J. Schaeffer. 1997. Are repelling charges effective in mitigating the impacts of underwater explosions? Pp. 185-195. In: Proceedings of the Twenty-third Annual Conference on Explosives and Blasting Technique, Las Vegas, Nevada. International Society of Explosive Engineers, Cleveland, OH.

Knudsen, F. R., P.S. Enger, and O. Sand. 1994. Avoidance responses to low frequency sound in downstream migrating Atlantic salmon smolt, Salmo salar. Journal of Fish Biology 45:227-233.

Konya, C. J., and J. Davis. 1978. The effects of stemming on retention in blastholes. Pp. 102-112. In: Proceedings of the Fourth Conference on Explosives and Blasting Techniques, New Orleans, LA. Society of Explosives Engineers, Cleveland, OH.

Marine Technology Directorate Ltd. 1996. Guidelines for the safe use of explosives under water. MTD Publication 96/101. London, England. 74 pp.

Moser, M. 1999. Cape Fear River Blast Mitigation Tests: Results of Caged Fish Necropsies. Final Report to CZR Inc.

Moxon, N. T., S. B. Richardson, and L. W. Armstrong. 1993. The effects of confinement on fragmentation and movement. Pp. 119-128. In: Proceedings of the Ninth Annual Symposium on Explosives and Blasting Research, San Diego, CA. International Society of Explosives Engineers, Cleveland, OH.

Munday, D. R., G. L. Ennis, D. G. Wright, D. C. Jeffries, E. R. McGreer, and J. S. Mathers. 1986. Development and evaluation of a model to predict effects of buried underwater blasting charges on fish populations in shallow water areas. Canadian Technical Report of Fisheries and Aquatic Sciences 1418.

Nedwell, J. R., and T. S. Thandavamoorthy. 1992. The waterborne pressure wave from buried explosive charges: An experimental investigation. Applied Acoustics 37:1-14.

Susanszky, A. 1977. Environmental effects of blasting operations in subfluvial strata. Pp. 206-215. In: Proceeding of the Third Conference on Explosives and Blasting Techniques, Pittsburgh, PA. Society of Explosives Engineers, Cleveland, OH.

Tansey, D. O. 1980. A delay sequencing blasting system. Pp. 345-375. In: Proceedings of the Sixth Conference on Explosives and Blasting Techniques, Tampa, FL. Society of Explosives Engineers, Cleveland, OH.

Teleki, G. C., and A. J. Chamberlain. 1978. Acute effects of underwater construction blasting on fishes in Long Point Bay, Lake Erie. Journal of the Fisheries Research Board of Canada 35:1191-1198.

Wright, D. G. 1982. A discussion paper on the effects of explosives on fish and marine mammals in the waters of the Northwest Territories. Canadian Technical Report of Fisheries and Aquatic Science 1052:v + 16 p.

Yelverton, J. T., D. R. Richmond, W. Hicks, K. Sanders, and E. R. Fletcher. 1975. The relationship between fish size and their response to underwater blast. Topical Report DNA 3677T. Defense Nuclear Agency, Department of Defense, Washington, D.C.