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POTENTIAL IMPACTS OF BLASTING RELATED ACTIVITIES ON WATER RESOURCES AND MEASURES THAT CAN BE IMPLEMENTED TO PREVENT OR MITIGATE THESE IMPACTS

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DOCUMENT SUMMARY - WHY THE DEPARTMENT OF ENVIRONMENTAL SERVICES CREATED THIS DOCUMENT

Over the past several years we have received concerns, anecdotal information and data regarding potential impacts from rock blasting related activities on water supply wells. The purpose of this document is to:

1. Describe the potential effects on wells (both quantity and quality impacts) blasting related activities could have.

2. Describe a broad range of methods that could be employed to prevent or mitigate effects from blasting related activities.

3. Describe approaches to monitor for potential for impacts associated with blasting related activities.

4. Describe the legal authorities municipalities and the State have to prevent or mitigate impacts from blasting.

The Department of Environmental Services (DES) has also provided suggested minimum language that municipalities can consider incorporating into their blasting ordinance to protect water resources. In general, existing municipal blasting ordinances do not address impacts to water resources. <u>The proposed language for the blasting ordinance should be applied to all blasting activities in municipalities.</u> The blasting company, site owner and/or developer will be responsible for complying with the requirements of the municipal blasting ordinance. The model ordinance language suggested by DES was intended to establish minimum performance standards that these entities must comply with to protect water resources. The model ordinance language does not include all of the blasting best management practices described in this document. A municipality may determine if additional best management practices should be incorporated into their blasting ordinance.

DES has also developed model language that municipalities can consider incorporating into local site plan review regulations and excavation regulations to address impacts that may occur to groundwater as a result of blasting rock and the removal and handling of blasted rock (see Attachment A). The model language also provides municipalities with a mechanism for requiring studies and water resource monitoring programs for commercial blasting projects. Attachment B provides guidance on how to conduct a water resource monitoring program. Additionally, the model site plan review and excavation language provides municipalities with a mechanism for retaining experts to verify that blasting at projects occurs in accordance with plans approved by the local governing authority and other applicable regulations such as a municipal ordinance.

The proposed language for the site plan review regulations and excavation regulations may apply whenever planning board is concerned about potential blasting impacts. The potential for blasting related impacts depends on very specific site specific conditions. Nitrate contamination in excess of three to nine times the drinking water standard of 10 milligrams per liter has occurred at blasting sites that have excavated 150,000-200,000 cubic yards of rock. Contamination associated with blasting sites has been detected in groundwater over 1500 feet from the location of blasting. Based on this limited information and providing for a margin of safety, DES recommends that when 5,000 cubic yards of rock will be excavated at a single property or place of business and there are private or public water supply wells within 2000 feet, that a municipality consider implementing the water monitoring program and third party oversight allowed by the site plan review and excavation regulations if the municipalities include the provisions suggested in Attachment A of this document. This threshold may be too high or low based on site specific conditions and is subject to revision as more data becomes available. The project owner will be responsible for complying with the requirements of the site plan review and excavation regulations.

1.0 BACKGROUND

In New England, there is very little published peer reviewed information documenting if and how the blasting of crystalline bedrock affects water levels and water quality. However, based on: 1) Six blasting sites studied by the DES[1]; 2) Limited published research at blasting sites in other hydrogeologic settings in the United States; 3) Anecdotal reports from wells owners in New Hampshire; and 4) A basic understanding of hydrogeology, it is apparent that blasting and activities associated with blasting, in some instances can adversely impact water quality and water quantity. Conversely, it is apparent that blasting has occurred frequently in New Hampshire with no noticeable problems in nearby water supply wells being reported.

Although blasting may adversely impact bedrock water supply wells, it is important to note that there are no data available that demonstrates negative effects on wells from blasting is either common or infrequent. Factors such as local hydrogeology, proximity of wells to a blasting site, the amount of blasting, intensity of the blasting, blasting procedures, duration of the blasting project and best management practices associated with the storage and handling of substances used for blasting need to be considered in determining if water supply wells may be impacted by blasting activities.

Some blasting projects have utilized the services of structural engineers to survey and document the pre- and post-blast condition of structures near a blasting site. In some instances the engineers have used instruments to measure the vibration the blasting causes near structures to determine if structures may or may not be impacted by blasting. In some cases, structural experts have cited their expertise relative to blasting and structural engineering and/or vibration monitoring data to make determinations about potential impacts to groundwater quality or quantity. Assessments by these experts or use of the vibration monitoring data relative to making statements about impacts to groundwater are not appropriate. The mechanism(s) in which groundwater may be adversely impacted by rock blasting is different then the mechanism in which damage to structures occur. Damage to structures occurs due to excessive levels of vibration. Impacts associated with rock blasting to groundwater derived from water supply wells occur due to the direct or indirect release of contaminants into groundwater that flows to and is extracted from water supply wells. These impacts can only be assessed by a licensed professional engineer or geologist who by education and experience is qualified to complete groundwater investigations and assessments.

[1] Home Deport - Merrimack; I-89 Rest Stop in Springfield; Ledge Road in Windham; Windham High School; I-93 at Exit 3 in Windham; Commercial Shopping Development in Bedford.

2.0 POTENTIAL EFFECTS OF BEDROCK BLASTING ON GROUNDWATER DERIVED FROM NEARBY WATER SUPPLY WELLS

Bedrock in New Hampshire consists of igneous and metamorphic rocks. Within these rock types, spaces between the individual mineral crystals of crystalline rocks are microscopically small, few, and generally unconnected; therefore, this primary porosity is insignificant. Igneous and metamorphic rocks are permeable only where they are fractured. The volume of water in storage in the fracture system of these rocks generally is small, and drawdown is large in pumped wells that produce only small quantities of water. Water that is stored in overlying glacial deposits or water in nearby streams or other surface-water bodies, however, commonly is hydraulically connected with the bedrock fracture system and might provide large quantities of water as recharge induced by pumping the wells completed in the crystalline rocks.

Water in the crystalline-rock aquifers generally flows in a concentrated network of fractures. Water movement through joints and fractures is often rapid. The horizontal and vertical orientation and interconnectiveness of fractures determine where released contaminants or impacts to aquifer water levels may occur

2.1 Water Levels

Blasting of crystalline bedrock may change the water level in nearby water supply wells by three different mechanisms. These are summarized as follows:

1) Bedrock wells installed topographically upgradient of a blasting area may be partially or entirely drained if bedrock is removed from a hillside and groundwater discharges to the ground surface from fractures that are now exposed at the newly formed surface of the blasted bedrock. The alteration of the water level in wells constructed in bedrock under this scenario may occur immediately or over several weeks before the lowering water level trend stabilizes.

2) Water levels in bedrock wells installed topographically downgradient or side-gradient of a blasting area may be lowered as a result of blasting, depending on the depth and influence of the blasting excavation. The removal of bedrock in a direction uphill of a bedrock well may cause a subtle lowering of the water level in these wells, as groundwater stored in the bedrock upgradient of the well may be drained at the newly formed face of the bedrock or precipitation that would normally infiltrate and recharge the bedrock aquifer is redirected as a result of changes in the ground surface topography. Measurable impacts to water levels in wells side-gradient or downgradient of a blasting site may occur immediately or over a several year period depending on how fast the water table equilibrates to the newly formed aquifer boundary condition formed by blasting. Although measurable impacts may occur, these impacts are not as likely to significantly impact the viability of a water supply. Other types of land alteration activities such as land clearing or earth excavation can have the same type of impacts.

3) Water levels in bedrock wells may be impacted where blasting operations create a depression (pit) in the ground surface and dewatering of the pit is occurring. Pumping of groundwater entering a pit created by blasting could cause partial dewatering of the bedrock aquifer. Depending on the proximity of the well and well/pump construction details, dewatering may impact the production capacity of water supply wells.

If blasting potentially could adversely impact water levels, then a water level monitoring program should be implemented. The program should consist of the use of pressure transducers and data loggers to measure water levels in a sufficient number of monitoring wells and/or drinking water supply wells that are representative of the existing water supply wells that are most susceptible to being impacted by blasting of bedrock or groundwater dewatering activities. Manual or automated measuring devices may be used at locations that are less susceptible to being impacted by blasting. A municipality can incorporate the language suggested for site plan review regulations and excavation regulations presented in Attachment A in order for it to enable itself to hire experts to develop and implement water level monitoring programs. Attachment B provides guidelines for developing and implementing a water monitoring program.

2.2 Water Quality

Blasting of crystalline bedrock may change the quality of groundwater derived from nearby bedrock wells. There are four methods by which the quality of groundwater could be changed by blasting crystalline rock. These are summarized as follows:

1) Contamination of Groundwater Resulting from a Release of a Regulated or Unregulated Substance to the Groundwater – In some instances, materials such as blasting caps and explosives are not entirely combusted during blasting and result in the release of soluble substances into the groundwater. The mechanisms in which the substances may not be destroyed during the blasting process include: a) Incomplete combustion within the blasting borehole; b) The injection of substances used for blasting into blasting boreholes that intersect a fracture network resulting in the release of substances beyond the influence of blasting area; c) Poor storage, transfer and handling procedures of substances associated with blasting; and d) Residual substances associated with blasting occurring on the face of blasted rock materials located at the blasting site, or when a stockpile of waste rock comes into contact with precipitation which results in the substances being leached into the groundwater.

   Direct contamination of groundwater caused by a direct release of blasting chemicals has been occasionally associated with the detection of nitrate, nitrite, and perchlorate. To a lesser extent, volatile organic compounds and semi-volatile organic compounds have been detected at blasting sites. It is possible that some substances (such as TNT and other explosive substances) associated with blasting may not be typically analyzed as part of standard laboratory drinking water analysis and therefore DES has no data describing the occurrence of these constituents in the groundwater. The detection of perchlorate in groundwater is most likely associated with the use of certain types of blasting caps and explosives. The detection of nitrate, nitrite, volatile organic compounds and semi-volatile organic compounds is most likely associated with the use of ammonium nitrate fuel oil ("ANFO") as an explosive material or other nitrogen based explosive products.

2) Agitation of the Subsurface May Cause Turbidity in Groundwater to Increase - Blasting shakes loose silt, sand and rock particles, and chemical precipitates that line fracture surfaces in the subsurface which can increase the turbidity in water derived from a bedrock well. High turbidity can damage household equipment and fixtures, be aesthetically unpleasing to drink, and increase concentrations of various metals and other contaminants. Water samples with high turbidity may exhibit high metal concentrations. This is because metal ions on flocculants or colloidal particles that carry metals may release the metals as the pH of the water changes in the plumbing system of the home or because preservatives used in sample collection bottles are acidic and dissolve the solid particles associated with the turbidity into solution. Moreover, if a well is situated in highly fractured bedrock and is in close proximity pf the blasting, blasting shocks and vibrations may also cause blocks of rock to fall into the well bore, which can cause the pump and other plumbing fixtures to get stuck, adding expense and inconvenience to well maintenance. Turbidity caused by rock blasting could be a short-term problem or persist for years.

3) Blasting May Expose New Rock Faces that Cause New Rock-water Geochemical Reactions to Occur - Blasting may also affect the flowpath of groundwater and pathway of the infiltration of acidic rain water to the bedrock which could alter the existing rock-water interfaces in the subsurface. These alterations could cause new geochemical reactions to occur that cause undesirable impacts to water quality. Also, blasting vibrations may disturb the aquifer matrix such that new interconnections among fractures may be opened or closed which can cause the introduction of water types that are significantly different in quality than the water that characterized the well prior to blasting. If blasting alters the geochemistry of the bedrock aquifer, these effects will likely be permanent or occur over many years as newly exposed minerals react with the groundwater, but generally decrease with time as reaction sites on minerals become less reactive over time.

4) Introduction of Carbon Sources in the Subsurface May Trigger New Geochemical Process or Promote Enhanced Microbial Activity - Blasting may introduce carbon monoxide into the subsurface which oxidizes and forms carbon dioxide and carbonic acid. The carbonic acid can react with the bedrock surface to leach metals. Also, the release of carbon into the subsurface can promote microbial activity which can reduce both the DO concentration and Eh. In this environment, bacteria remove electrons from carbon dioxide and deposit them on manganese +4 which converts manganese to its soluble form[2].

A water quality monitoring program associated with a blasting project should include baseline and ongoing water quality monitoring of raw (untreated) water. Raw water samples should be analyzed for benzene, pH, total iron, total manganese, total arsenic, dissolved iron, dissolved manganese, dissolved arsenic, nitrate, nitrite, and turbidity. It is recommended that the sampling program also include analyses for other constituents that are unique to the materials (explosives, primers, blasting caps etc.) that are used at a given blasting site. This information may need to

[2] Robbins - University of Connecticut - presentations on the internet at http://www.water.uconn.edu/presentations.html.

be obtained from the vendor or manufacturer of explosive materials. A municipality can incorporate the language suggested for site plan review regulations and excavation regulations presented in Attachment A in order for it to enable itself to hire experts to develop and implement water quality sampling programs. Attachment B provides guidelines for developing and implementing a water monitoring program.

3.0 POTENTIAL BLASTING BEST MANAGEMENT PRACTICES

The potential for introducing nitrogen-based compounds from explosives into the groundwater and surface water systems depends on a number of factors. Previous studies[3] have generally estimated that approximately 5% of various types of nitrogen based explosives enter surface or groundwater. The handling of explosive products has the most significant influence on the quantity of nitrogen entering the groundwater system. In the case of ANFO, losses can occur as spillage when explosives-loading equipment is filled, when blastholes are loaded, and during the disposal of excess product. Hydrogeologic conditions determine the volume and flow of water that contacts explosives or explosive residues in the ground which in turn will also influence the post-blasting concentration of nitrogen that develops in groundwater.

In this section, potential best management practices that can assist with reducing the introduction of nitrates in groundwater and surface water are provided. The following topics are addressed:

Section 3.1	Explosives Selection
Section 3.2	Drilling Practices
Section 3.3	Handling Practices
Section 3.4	Loading Practices
Section 3.5	Blasting Performance
Section 3.6	Fragmented Rock Storage, Handling, Processing and Use
Section 3.7	Management of Surface Runoff
Section 3.8	Spill Prevention Measures and Spill Mitigation Plan

The majority of the information and verbage in Section 3.0 of this document is taken from a report prepared by Golder Associates for the New Hampshire Department of Transportation in 2008 for a specific blasting project. The information contained in the document prepared by Golder Associates was not intended to be broadly applied to other sites or by entities other than the New Hampshire Department of Transportation. DES has reviewed this document and determined that best management practices summarized in this document would be potentially and partially useful at large scale blasting sites throughout New Hampshire where drinking water sources are nearby. Ultimately, the appropriate best management practices that prevent groundwater contamination associated with blasting that need to be applied at any given site need to be developed by licensed blasters and geologists/engineers on a site specific basis.

3.1 Explosives Selection

The amount of available nitrogen, the potential rate of release, and the ease of release into the groundwater are all functions of the specific explosive chosen. Most commercial grade explosives used in rock blasting can be assigned to three groups: ammonium nitrate/fuel oil (ANFO), watergel/slurry or emulsions. Although all explosives contain a large percent of ammonium nitrate, they do vary in water resistance. In general, explosive product price is proportional to water resistance. The more water resistant the product, the higher the cost.

[3] NHDOT Drinking Water Baseline Study Interstate 93 Widening Project Exit 3, Windham, Windham, NH - June 2008

Although water resistant products are often more costly, the selection of the proper type of explosive product is generally one of the most cost-effective approaches for preventing groundwater contamination and reducing long-term liability associated with contaminating groundwater. The following paragraph describe these groups of explosives

ANFO

ANFO is the most commonly used blasting agent, as it is relatively inexpensive to manufacture. ANFO is a mixture of about 94% ammonium nitrate and 6% #2 diesel fuel, containing about 33% nitrogen by weight. ANFO has no water resistance and will quickly absorb water, leading to leaching of ammonium and nitrate to groundwater as it dissolves in the blasthole or in the muck pile (the blasted pieces of rock). ANFO should not be used in wet blastholes (i.e., blastholes with standing water). Water resistant ANFO (ANFO-WR) contains additives to inhibit the infiltration of water in damp blastholes, but is not designed for use in wet blastholes. ANFO is commonly delivered to blast sites in 50 lbs. bags or in bulk delivery trucks which place ANFO into the blasthole.

To prevent loss of explosive, unpackaged/unsleeved ANFO and watergels should not be used if artesian or flowing groundwater conditions are encountered. ANFO should not be used in any blasthole containing water unless the water is removed from the blasthole and the blasthole does not rapidly recharge.

Watergels/Slurries

Watergels/slurries were developed for use in wet blastholes to provide water resistance. These explosives are primarily composed of a super-saturated aqueous solution of ammonium nitrate mixed with fuels, gum and a cross-linking agent, and sometimes solid ammonium nitrate. The cross-linking agent causes the gum to set, forming a barrier between the aqueous solution and outside water. The gelling agent provides structure to the explosive, limiting flow into fractures and thus resisting flowing water. These products typically contain 20 to 30% nitrogen by weight. These products are delivered to construction sites in plastic-wrapped packages sized appropriately for the blastholes or in bulk delivery trucks which pump the product into the blasthole.

Emulsion

Emulsion explosives were developed as a less expensive and more efficient replacement for watergel/slurry explosives. These explosives contain a super-saturated aqueous solution of ammonium nitrate (and sometimes other oxidizing salts such as calcium nitrate or sodium nitrate) as very fine droplets surrounded by an immiscible fuel. The thin film of impervious oil surrounding the aqueous ammonium nitrate provides water resistance. Like watergels/slurries, these products are delivered to the blast site in plastic-wrapped packages or in bulk delivery trucks. The bulk emulsions are more susceptible to mixing with borehole water/drill cuttings causing contamination and poor performance. Emulsions contain about 20 to 30% nitrogen by weight, with a typical ammonium nitrate content of 80 to 85%. In commercial mining applications, emulsions are sometimes blended with ANFO or ammonium nitrate to increase the potential energy and sensitivity. The emulsion provides the water resistance, surrounding the solid ANFO particles. Typical blends consist of 70% emulsion and 30% ANFO.

To prevent loss of explosive, unpackaged/unsleeved emulsions should not be used if artesian or flowing groundwater conditions are encountered.

Explosive Packaging

Explosives may be poured into paper or polyethylene packaging placed in blastholes. The use of packaging in the blastholes may reduce loss of explosive agents to fractures and the leaching rate of contaminants to groundwater. However, under certain conditions, packaged explosives may not provide additional protection to groundwater quality. This is because detonation of explosives in adjacent blastholes may cause rock or gas pressure to increase substantially and compress the explosives in undetonated blastholes to a level that does not allow complete combustion to occur. Additionally, packaging may rupture during the installation into the blasthole. Lastly, rocks within a blasthole may become dislodged and cause the packing to be pinched such that some of the explosive material is not detonated.[4]

Explosives may also be placed into waterproof cartridges. The use of cartridges is very expensive and may significantly reduce the efficiency of a blast because it is not possible to maximize the filling of a blasthole with explosive product when using cartridges.[5]

3.2 Drilling Practices

Appropriate drilling procedures and development of an understanding of rock conditions are vital for blasts to perform as designed, including minimization of environmental effects. Blasthole boring logs should be maintained by the driller and communicated directly to the blaster. The logs should indicate depths and lengths of voids, cavities, fault zones or other weak zones encountered, as well as groundwater conditions.

3.3 Handling Practices

The method in which explosive products are stored and handled on the site must ensure that these materials are managed in a way to prevent releases to the ground surface while on-site. Improper management of explosive products could result in groundwater contamination at

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[4] Practical methods to control explosive losses and reduce ammonia and nitrate levels in mine water. Mining Engineering, July 1996. http://arblast.osmre.gov/downloads/Water%20Wells/Revey%20Exp%20-%20Ammonia%20in%20water.pdf

[5] Explosives and Blasting Procedures Manual - Information Circular 8925, US Department of Interior, http://www.arblast.osmre.gov/downloads/USBM/IC%208925%20Blast%20Proceedures%20Manual%201983.pdf

blasting sites. The following handling practices should be employed at blasting sites to reduce the possibility of groundwater contamination:

a) Partially used bags of ANFO must be resealed and returned to the explosive magazine.

b) Spilled explosive products must be cleaned up immediately, either by placing the spilled product in a blasthole or removing it from the site.

c) Loading equipment must be cleaned in an area where the water can be properly contained and handled in a manner that prevents releases.

d) Explosive products should be either: 1) Not stored overnight on-site; or 2) Stored in appropriate staging areas (i.e. magazines) with impervious surfaces and secondary containment structures.

e) All excess product in hoses or other equipment associated with loading the blastholes must be recovered and used either in the next blasthole, recycled in the mixer or disposed of as waste at an appropriate waste disposal facility. <u>Excess explosive products must never be discharged to the environment.</u>

3.4 Loading Practices

Procedures for loading blastholes with explosives can impact the amount of explosive product that is successfully combusted, released via the borehole into groundwater or released on the land surface ultimately impacting groundwater. The following measures can be utilized to minimize the contamination of water as a result of loading a borehole with explosive products:

a) To prevent loss of explosive, unpackaged/unsleeved ANFO and emulsions should not be used if artesian or flowing conditions are encountered.

b) ANFO should not be used in any blasthole containing water unless the water is removed from the blasthole and will not refill with water prior to completing the blasting associated with a given shot.

c) Water resistant ANFO should not be used in blastholes that will recharge with groundwater prior to completing the shot.

d) Spills of any explosive products at the ground surface around the blasthole mouth or opening must be cleaned up promptly and either reused or taken off-site.

e) Adequate unloaded collar lengths must be established to reduce blasthole proximity effects. If explosives are loaded too close to the top of the blasthole when injecting under pressure, then the explosives are sometimes ejected from the hole as blowback. Blasthole proximity effects occur when the shock and pressure from initiating of the explosives in the blasthole blows away the collar of adjacent firing holes, resulting in the explosives within the collar region being cut off and undetonated.

f) Loaded explosives should be detonated as soon as possible and not be left in the blastholes overnight. This reduction in lag time (i.e., "sleep time") between loading and detonating reduces the amount of time groundwater may be in contact with the explosive product.

g) Contamination of explosive products can occur during loading from drill cuttings (either left in the bottom of the blastholes or that fall into the blastholes during loading). Blastholes should be cleaned out thoroughly using the compressed air stream from the drill to remove the drill cuttings. Drill cutting piles should be pulled back from the collar prior to loading.

h) Stemming (usually crushed stone) placed too forcefully can dilute the upper portions of the loaded explosive column, reducing the explosive's detonation velocity and potentially leaving undetonated explosives in the blasted rock stockpile. Stemming placed too rapidly can bridge above the loaded explosive column, causing rifling of blastholes and poor performance. The following best management practices are important when placing stemming in blastholes:
    - Drill cuttings should not be used as stemming, as they can dilute the upper portion of water-based emulsion explosives.
    - Stemming should be placed with care to prevent bridging, and should be appropriately sized for the blasthole diameter.
    - Weak zones, voids, and cavities should be stemmed as decks to prevent the loss of explosive products into bedrock. Alternatively, explosive products could be placed in plastic sleeves when fractures, creviced or cavitied blastholes are encountered.

i) All excess product in hoses or other equipment associated with loading the blastholes must be recovered and used either in the next blasthole, recycled in the mixer or disposed of as waste at an appropriate waste disposal facility. <u>Excess explosive products must never be discharged to the environment.</u>

3.5 Blasting Performance

Misfires during blasting can leave undetonated explosive products in the blasted rock stockpile (muck pile), which in most cases cannot be recovered and will leach into surface water and/or groundwater. Some of the more frequent causes of misfires are listed below.[6] Measures should be employed to ensure that the causes for misfires are prevented.

a) Inadequate or improperly made primers;

b) Use of nonwater-resistant explosive materials in wet work;

[6] Institute of Makers of Explosives, Safety Library Publication No. 17, March 2007

c) Improper loading practices;

d) Physical damage to leg wires of electric or electronic detonators, shock tube leads, detonating cord, or primers;

e) Failure to light fuse or to connect the delay detonators into the blasting circuit;

f) Failure or improper initiation system connection;

g) Insufficient or excessive electric current;

h) Damage to the fuse powder train;

i) Improper programming of electronic delay detonators;

j) Dead pressing or other damage caused by the detonation of nearby charges;

k) Lost or dropped downlines from the collar of the borehole during the loading or stemming process;

l) Inadequate or improper inert decking material;

m) Improper delay timing between decked charges or boreholes; and

n) Incomplete initiation of explosives caused by:

    1. Improper or inadequate priming;

    2. Deteriorated explosive materials;

    3. Improper loading or drill cuttings between cartridges or unplanned separation of explosive column;

    4. Effect of water or moisture on the explosive materials; and

    5. Dead pressing or other damage caused by the detonation of nearby charges.

When a misfire occurs, the blaster in charge should implement appropriate measures to mitigation the misfire safely. Without jeopardizing safety considerations, the mitigation approach should be protective of groundwater to the extent possible.

3.6 Fragmented Rock Storage, Handling, Processing and Use

Large rock excavation projects usually include processing blasted rock on site for reuse in construction. Residues from the explosive byproducts and undetonated explosive product can coat the surfaces of the broken rock fragments in the muck pile. If the muck pile is left in place, precipitation infiltrating through the muck pile can dissolve the nitrates and related blasting compounds and carry them to the groundwater. Placing the blasted rock on an impermeable surface such as a liner to contain impacted run-off may not be practical. However, the processing of the muck pile, including hauling and crushing, can be performed to reduce the effects of the infiltrating precipitation. Best management practices for processing muck pile material include:

a) Remove the "muck pile" from the blast area as soon as possible. Muck piles consist of the blasted pieces of rock and sometimes may contain residual from the blasting materials. Often muck piles are left in place due to lack of processing equipment, lack of space for storage, or as part of blast design.

b) During primary/secondary rock crushing, use water to control dust and collect any excess water for treatment if needed.

c) Store processed rock materials over low permeability areas such as clays, and/or place them such that runoff can be collected for treatment if needed.

d) Design the overall blasting progression such that runoff will collect in temporary or permanent stormwater run-off control structures, where it can be collected for treatment, if needed.

e) Distribute stockpiles of processed rock widely throughout the project and/or place the materials generated from them as soon as possible to distribute the processed rock over a large area, which will reduce the concentration of blasting byproducts in the groundwater.

f) If the blasted rock will not be reused on-site, remove the muck pile/processed rock as soon as possible.

3.7 Spill Prevention Measures and Spill Mitigation Plan

A spill prevention and spill mitigation plan should be developed to ensure the storage and handling of regulated substances comply with DES' regulations for regulated substances - Env-Wq 401: Best Management Practices for Groundwater Protection (see http://des.nh.gov/organization/commissioner/legal/rules/documents/env-wq401.pdf). The requirements of the rules are summarized below:

a) The storage requirements include:
   - Store regulated substances on an impervious surface;
   - Secure storage areas against unauthorized entry;

- Label regulated containers clearly and visibly;
- Inspect storage areas weekly;
- Cover regulated containers1 in outside storage areas;
- Keep regulated containers that are stored outside more than 50 feet from surface water and storm drains, 75 feet from private wells, and 400 feet from public wells; and
- Secondary containment is required for containers containing regulated substances stored outside, except for on premise use heating fuel tanks, or aboveground or underground storage tanks otherwise regulated.

b) Handling:
   - Keep containers containing regulated substances closed and sealed;
   - Place drip pans under spigots, valves, and pumps;
   - Have spill control and containment equipment readily available in all work areas;
   - Use funnels and drip pans when transferring regulated substance; and
   - Perform transfers over an impervious surface.

c) Release Response Information - Post information on what to do in the event of a spill.

In addition to handling and storing regulated substances in accordance with regulations, fuel storage and handling of equipment at a blasting site should comply with the best management regulations. Requirements for proper management of equipment refueling can be found in the Factsheet titled "WD-DWGB-22-6 Best Management Practices for Fueling and Maintenance of Excavation and Earthmoving Equipment." (see http://des.nh.gov/organization/commissioner/pip/factsheets/dwgb/documents/dwgb-22-6.pdf)

3.8 Surface and Groundwater Quality Restoration

The best management practices summarized in sections 3.2 to 3.7 are designed to prevent contamination of water resources. Should water become contaminated as a result of blasting, remedial measures to remove contamination from water and treatment systems for impacted water supplies may be required. Groundwater remediation and water supply treatment professionals should be consulted to develop appropriate processes to mitigate water quality impacts.

4.0 EXISTING LEGAL AUTHORITY TO REGULATE BLASTING ACTIVITIES TO PROTECT WATER QUALITY

4.1 Municipalities

For site improvements, subdivisions and utility installations, local government has a major role in the review and approval of the underlying work or project to be constructed pursuant to the powers granted to local planning boards by RSA Chapter 674. Therefore, local government has an important role in planning and project approval, inspectional services, local permitting of public works and in the provision of public safety services during construction operations (Local Government Center 2005)

RSA Chapter 155-E, Local Regulation Excavations, provides local control of aggregate operations in the state. This would include operations that blast and crush bedrock to make aggregate material. As determined by the local legislative body, either the planning board, the zoning board of adjustment or the selectmen serve as the regulator of the activity. Pursuant to RSA 155-E:8, conditions may be placed upon the operation of this activity. Such conditions could include the time of blasting, additional local safety concerns or notifications of local officials, or special protections for adjacent properties. Attachment A of this document contains suggested language that can be included in a municipal excavation regulation to monitor and protect water resources near blasting activities.

RSA 31:39, Power to Make By-laws, allows municipalities to adopt blasting by-laws that ensure blasting is protective of public health and property. Some communities have utilized this authority to develop blasting ordinances. Attachment A provides model language to include in a blasting ordinance to protect water resources.

RSA 147, Nuisances; Toilets; Drains; Expectoration; Rubbish and Waste, provides health officers with authority to make regulations relating to the public health, subject to the approval of the selectmen. RSA 147 also provide selectmen with the authority to investigate nuisances and other causes of danger to the public health.

RSA 674:43 authorizes municipalities to adopt site plan review regulations. A site plan is a plan which may be required to be submitted to the planning board prior to development of a particular tract of land for multi-family housing or non residential projects. The plan must show the proposed location of the buildings, parking areas, landscaping, drainage and other installations on the plot, and their relationship to existing conditions such as roads, neighboring land uses, natural features, public facilities, ingress and egress roads, interior roads, and similar features. Site plan review is an extremely important device to insure: 1) Only land uses permitted in the zoning ordinance are constructed on a given site; and 2) Projects are constructed in such a way that they fit into the area without causing problems. Site plan review regulations may only be established in municipalities that have established subdivision regulations and zoning ordinances. Local site plan review regulations, which are adopted and administered by the planning board may include:

- A provision for safe and attractive development or change or expansion of use of the site and guard against such conditions as would involve danger or injury to health, safety, or prosperity;

- A provision for the harmonious and aesthetically pleasing development of the municipality and its environs;

- A provision for adequate proportions of open spaces and green spaces;

- A requirement for the proper arrangement and coordination of streets within the site in relation to other existing or planned streets or with features of the official map of the municipality;

- A requirement for streets suitably located to accommodate existing and future traffic; and

- Provisions that will create conditions favorable to the health, safety, convenience, or prosperity of the municipality.

Attachment A of this document contains suggested language that can be included in a site plan review regulation to monitor and protect water resources near blasting activities.

4.2 State Legal Authority to Regulate Blasting Related Activities to Protect Water Quality

State law and regulations do not specifically identify requirements for addressing impacts to groundwater associated with blasting rock. However, several provisions in law and regulations protect groundwater and surface water from degradation from a general set of defined activities which can be associated with blasting.

Granite or rock quarries that will produce dimension stone are regulated pursuant to RSA Chapter 12-E by the state through the Department of Resources and Economic Development (DRED). RSA 21-O:12 states that the State Geologist shall assist DRED in its review of mining permit applications. A permit is required before mining operations commence, and one of the conditions specifically authorized by RSA 12-E:4 is the provision of a blasting plan. RSA 12-E:4 also requires that the Commissioner of DRED ensure the public health will be protected prior to issuing a mining permit.

DES can proactively or reactively utilize its authority pursuant to Env-Ws 384-Underground Injection Control (which incorporates by reference federal regulation 40 CFR 144) to regulate the injection of substances into the subsurface that results in endangering public health. To date, DES has utilized its authority under Env-Was 384 sparingly to address blasting issues when information it collected or that was provided by the public suggested blasting may have caused water quality impacts to occur. Staff at USEPA Region 1 have indicated that if an injection activity causes mobilization of a substance to drinking water supplies and endangers public health, that 40 CFR 144 is applicable.

DES can proactively utilize its authority pursuant to RSA 485A to protect surface and groundwater from impacts associated with blasting if approval to alter the terrain in accordance with RSA 485-A:17 is required for a project.

If blasting results in a release of a substance that violates the Ambient Groundwater Quality Standards of the state, then Env-Or 600, Contaminated Site Management rules, would be applicable. These rules would require: 1) a site investigation; 2) delineation of contamination; 3) development and implementation of a remedy to address the groundwater quality violations caused by blasting; and 4) groundwater monitoring until groundwater quality complies with the Ambient Groundwater Quality Standards.

All blasting projects that utilize more than household quantities of regulated substances must comply with state regulations for the Best Management Practices for Groundwater Protection - Env-wq 401 (see http://des.nh.gov/organization/commissioner/legal/rules/index.htm#envwq401). Projects that re-fuel equipment on-site must also comply with the best management practice regulations as well as fuel storage tank regulations. See the fact sheet titled. "WD-DWGB-22-6-Best Management Practices for Fueling and Maintenance of Excavation and Earthmoving Equipment" for more information.

ATTACHMENT A

WATER RESOURCES AND BLASTING - MODEL SITE PLAN REVIEW LANGUAGE AND BLASTING ORDINANCE LANGUAGE

Add Under a Town's Site Plan Review Regulations and Excavation Regulations

NOTE: The suggested language below should be added to both Site Plan Review Regulations and Excavation Regulations in a municipality to address blasting related water resource issues. Because certain excavations involving blasting such as projects pertaining to dimension stone production and building construction are exempt from Excavation Regulations, it is recommended that the language be included to both the Site Plan Review Regulations and Excavation Regulations. When adding the model language below to the Excavation Regulations, it may be necessary to replace the governing name from "planning board" to the governing body in charge of administering the excavation regulations in the municipality.

"Where the Planning Board is concerned that rock blasting will impact drinking water supplies, the Board may require the applicant to perform such studies as may be necessary to develop a water monitoring program to assess if blasting may adversely impact the quality or quantity of drinking water supplies."

"Reasonable fees may be imposed by the Planning Board to cover its administrative expenses and costs of special investigative studies, review of documents and other matters including baseline and ongoing groundwater monitoring requirements associated with site plan review applications that propose to blast rock."

"In order to confirm that blasting activities and associated water monitoring programs approved by the Planning Board and/or activities are complying with other applicable codes and standards, the Planning Board may, at the time of plan approval, require the applicant to establish an appropriate escrow, or other security in addition to any other Performance Guarantees required by the Planning Board. The escrow or security shall be used as security for the retention of appropriate engineers or other consultants to confirm that construction is in conformance with the approved plans and/or applicable codes and standards. The applicant shall reimburse the town for the cost of such engineers or consultants, prior to release of said security."

Add Under "General Regulations" section of a Town's Blasting Ordinance

Town blasting ordinances typically stipulate requirements for many issues associated with blasting including safety requirements and the protection of structures. The language below is intended to only address water resource protection. Municipalities should seek technical and legal assistance, and review blasting ordinances in other municipalities to address other aspects of blasting that are not addressed in the language below.

"**A. Best Management Procedures for Blasting.** All activities related to blasting shall follow Best Management Procedures (BMP's) to prevent contamination of groundwater including preparing, reviewing and following an approved blasting plan; proper drilling, explosive handing and loading procedures; observing the entire blasting procedures; evaluating blasting performance; and handling and storage of blasted rock.

(1) Loading practices. The following blasthole loading practices to minimize environmental effects shall be followed:

(a) The blasthole boring logs shall be maintained by the driller and communicated directly to the blaster. The logs shall indicate depths and lengths of voids, cavities, and fault zones or other weak zones encountered as well as groundwater conditions.

(b) Unpackaged/unsleeved ANFO, water gels and emulsions shall not be used if artesian or water flowing conditions are encountered.

(c) Loaded explosives shall be detonated as soon as possible and shall not be left in the blastholes overnight.

(2) Explosive Selection. The following BMPs shall be followed to reduce nitrate impacts when explosives are used:

(a) Identify blastholes containing water and remove water prior to loading with ANFO.

(b) Water resistant ANFO (ANFO-WR) explosive product shall be used in damp blastholes. Alternative blasting agents that exhibit equivalent or more water resistance than ANFO-WR may also be utilized in damp blastholes.

(c) Spills of ANFO or any other blasting agents, at the ground surface around the blasthole collars shall be cleaned up promptly and either reused or taken off site.

(d) Partially used bags of ANFO or any other blasting agent shall be resealed and returned to the explosive magazine or shall be taken off-site.

(e) Loading equipment shall be cleaned in an area where the water can be properly contained and handled in a manner that prevents releases to the environment.

(f) Explosives shall only be delivered to the site in approved magazine trucks and should not be stored overnight on-site.

(g) If groundwater conditions are severe, e.g., artesian/flowing conditions, packaged or explosives in sleeves shall be used instead of bulk products or as required by the local governing official.

(3) Blasthole stemming. The following BMPs shall be followed when placing stemming in blastholes:

(a) Blastholes shall be cleaned out thoroughly using the compressed air stream from the drill to remove the drill cuttings.

(b) Drill cuttings shall not be used as stemming.

(c) Stemming shall be placed to prevent bridging, and shall be appropriately sized for the blasthole diameter.

(d) Blastholes shall be completely stemmed to prevent incomplete detonation.

(e) Weak zones, voids, and cavities shall be stemmed as decks to prevent the loss of explosive products into the bedrock.

(4) Prevention of Misfires. Appropriate practices shall be developed and implemented to prevent misfires if shifting mats, uneven terrain or other conditions that are present that may result in the cutoff of the detonation and the occurrence of a misfire.

(5) Muck pile Management. Muck piles (the blasted pieces of rock) and rock piles shall be managemed in a manner to reduce the potential for contamination by implementing the following measures:

(a) Remove the muck pile from the blast area as soon as reasonably possible but no longer than 14 days after the blast occurs.

(b) Manage blasted rock piles and associated stormwater in a manner to prevent contamination of water supply wells or surface water.

(6) Spill Prevention Measures and Spill Mitigation. Spill prevention and spill mitigation measures shall be implemented to prevent the release of substances that may violate state water quality standards or regulated substances. The measures shall include at a minimum:

(a) The storage requirements shall include:
1. Store regulated substances on an impervious surface;
2. Secure storage areas against unauthorized entry;
3. Label regulated containers clearly and visibly;

4. Inspect storage areas weekly;
5. Cover regulated containers in outside storage areas;
6. Keep regulated containers that are stored outside more than 50 feet from surface water and storm drains, 75 feet from private wells, and 400 feet from public wells; and
7. Secondary containment is required for containers containing regulated substances stored outside, except for on premise use heating fuel tanks, or aboveground or underground storage tanks otherwise regulated.

(b) The handling requirements shall include:
1. Keep containers containing regulated substances closed and sealed;
2. Place drip pans under spigots, valves, and pumps;
3. Have spill control and containment equipment readily available in all work areas;
4. Use funnels and drip pans when transferring regulated substance; and
5. Perform transfers of regulated substances over an impervious surface.

(c) The training of on-site employees and the on-site posting of release response information describing what to do in the event of a spill.

(d) Fueling and maintenance of excavation, earthmoving and other construction related equipment will comply with the regulations of the New Hampshire Department of Environmental Services [note these requirements are summarized in WD-DWGB-22-6 Best Management Practices for Fueling and Maintenance of Excavation and Earthmoving Equipment" or its successor document. (see http://des.nh.gov/organization/commissioner/pip/factsheets/dwgb/documents/dwgb-22-6.pdf)"

ATTACHMENT B

BASELINE AND ONGOING BLASTING GROUNDWATER MONITORING AND MITIGATION APPROACHES

In order to assess and/or address the potential adverse impact that may arise when using substances to blast bedrock or when altering the surface of the bedrock, a plan that includes all or some of the following elements can be prepared and implemented to collect water quality data to determine if nearby water supply wells are being impacted from the effects of rock blasting:

1) <u>Establish an inventory of water users within 2,000 feet (or an alternative distance based on site specific conditions and magnitude of blasting) of the blasting sites, blasted rock stock pile, and water retention pond</u> - Using records of the New Hampshire Water Well Board and municipalities(s) and by surveying home owners with written questionnaires, identify the following to the extent possible for each water supply well.

   a) Well type (bedrock, dug, or driven point)

   b) Well driller

   c) Date installed

   d) Well depth

   e) Depth to groundwater

   f) Well diameter

   g) Well casing depth

   h) Estimated yield

   i) Estimated depth to bedrock

   j) Age of pump

   k) A description of any water treatment equipment being used and the frequency in which maintenance on the equipment is currently being performed

   l) Any historic or existing water quality or supply problems with the well

   m) A description of the most recent maintenance activity performed on the well

   n) Copies of all laboratory results associated with water samples collected from the well. Historic water quality analyses shall only be used if it can be reasonably determined what water treatment systems may have been online that could affect historic water quality sample results.

2) Complete a baseline water quality sampling program for public and private water supply wells listed on the Inventory ("Baseline Sampling Program"): Prior to initiating blasting at the site, obtain raw (untreated) water quality samples from each well identified in the Inventory and have them analyzed for benzene, pH, total iron, total manganese, total arsenic, dissolved iron, dissolved manganese, dissolved arsenic, nitrate, nitrite, and turbidity. It is recommended that the sampling program include analysis of other compounds that may be unique to the blasting materials used on a particular project. Water samples must be obtained at a point in the water system prior to any treatment unless it is demonstrated that access cannot be gained to sampling points that meet this requirement.

3) Develop and implement an ongoing water quality sampling program ("Continuing Sampling Program"): The Continuing Sampling Program shall include routine sampling of either all water supply wells in the Inventory or a sufficient number of monitoring wells that are representative of the water supply wells in the Inventory. The frequency of the water quality sampling shall be determined by the frequency of blasting, estimated travel time of contaminants and distance of receptors to the blasting location. The frequency of sample collection must reflect the fact that nitrate in drinking water is an acute health concern.

4) Develop and implement a baseline and ongoing bedrock aquifer water level monitoring program ("Water Level Monitoring Program"): The Water Level Monitoring Program shall consist of the use of pressure transducers and data loggers to measure water levels in a sufficient number of monitoring wells and/or drinking water supply wells in the Inventory that are representative of the existing water supply wells that are most susceptible to being impacted by blasting of bedrock or groundwater dewatering activities. Manual or automated measuring devices may be used at locations that are less susceptible to being impacted by blasting. The monitoring locations shall be adequate to provide representative data for all water supply wells located within 2,000 feet of the area being blasted. The monitoring program shall include provisions that ensure sanitary practices are being implemented when measurements are being collected in drinking water supply wells.

5) Develop and implement an adverse impact response and mitigation plan to mitigate water quality or quantity impacts caused by the blasting and/or dewatering activities ("Mitigation Plan"): The Mitigation Plan should include:

   a) Procedures (including time frames) to investigate complaints about impacts to wells associated with the rock blasting and/or dewatering activities.

   b) Provisions (including time frames) for immediate responses such as the provision of bottled water.

c) Provisions (including time frames) for longer-term responses, such as the installation of water treatment equipment or the repair, modification, deepening or replacement of wells adversely impacted by the blasting activity.

6) Blasting related activities that result in the violation of ambient groundwater quality standards, primary drinking water standards or secondary drinking water standards in untreated samples collected from water supply wells shall require mitigation in accordance with the Mitigation Plan.

7) For impacts to water levels, the adverse impact criteria shall be as follows:

a) Reducing the withdrawal capacity of a private water supply well of a single residence as a result of the reduction of available water that is directly associated with the blasting. This is determined by the following:

i. Any reduction in capacity for wells with a capacity which is less than water well board recommended optimum minimum of 4 gallons per minute for 4 hours before the blasting occurred;

ii. Any reduction in capacity below 4 gallons per minute for 4 hours, for wells that had a capacity greater than 4 gallons per minute for 4 hours, before the blasting occurred; or

iii. A reduction in capacity where the well still has a capacity between 4 gallons and 10 gallons per minute for 4 hours and the user provides information indicating that the reduction in flow has resulted in the inability to meet his or her water needs;

b) Reducing the capacity of a public drinking water supply below the minimum withdrawal rates required per consumer determined by the following:

i. Minimum daily amounts of drinking water shall be determined per use based on the design flow criteria established for public water supply systems established in rules adopted by the department; or

ii. Where it is verified that such wells were unable to produce the design flow before the withdrawal began, the adverse impact shall be any reduction in the ability to produce water.

c) Reducing the capacity of a water supply that is used for a multiple dwelling unit residence, but that is not a public water supply, that results in the inability to continue established activities or maintain existing water capacity requirements;

d) Reducing the capacity of a private, non-residential, non-drinking water supply that results in the inability of a commercial, industrial, agricultural, or retail facility to continue established services or production volumes; and

e) Reducing the ability of a registered water user to produce volumes equivalent to the average daily withdrawal for a specific calendar month as determined by discharge measurements and reports made to the department in accordance with the water user requirements under RSA 488 or other previous water use reporting requirements of the department.

8) Abutter Notification

a) At least 30 days prior to initiating blasting, update the Inventory as necessary to reflect current owners. Between 15 to 30 days prior to initiating blasting, provide written notice via certified mail to each owner of a water supply well listed on the Inventory about the initiation of blasting activities. Include the following in the notice:

(i) Contact information for a representative of the permittee;

(ii) Contact information for the staff member of the governing body assigned to the project;

(iii) A statement concerning the potential for impacts of blasting on water supply wells should be forwarded to the representatives of the permittee and the Department as listed on the notification; and

(iv) Date that blasting is expected to commence.

b) Send a written notice as specified in (i) to each owner listed on the Inventory via certified mail every 6 months after blasting commences until such time blasting is completed.