ALGONQUIN INCREMENTAL MARKET PROJECT

Analysis of the West Roxbury Crushed Stone Operations on Construction and Operation of the West Roxbury Lateral

March 31, 2014

Spectra Energy Partners

TABLE OF CONTENTS

1.0 EXECUTIVE SUMMARY

Algonquin Gas Transmission, LLC ("Algonquin") has completed a comprehensive evaluation of: (1) the potential impacts on the West Roxbury Crushed Stone Quarry ("Quarry") associated with the proposed AIM Project West Roxbury Lateral and meter and regulating ("M&R") station; and (2) the potential impacts of Quarry operations on the construction and operation of the West Roxbury Lateral and M&R station.

With regard to the potential impact on the Quarry's operations, Algonquin has discussed the anticipated schedule and logistics associated with constructing the West Roxbury Lateral and M&R station with the owners of the Quarry. No direct conflicts were identified that would inhibit the construction of the West Roxbury Lateral and M&R station or the continued day-to-day operation of the Quarry. Algonquin has committed to continue to consult with the Quarry owners to establish traffic management measures that will be implemented during construction. As was outlined in Resource Report 5 of Algonquin's formal certificate application filed with the FERC on February 28, 2014, a detailed Traffic Management Plan is in development for the West Roxbury Lateral. Algonquin expects to file the Traffic Management Plan with the FERC on or before May 30, 2014. Once construction is complete, Algonquin does not anticipate any further impact on the Quarry from the operation and maintenance of the West Roxbury Lateral and M&R station.

In order to evaluate the potential impacts to the proposed pipeline and M&R station from the blasting operations at the Quarry, Algonquin retained the services of a local third-party geotechnical firm, GZA GeoEnvironmental, Inc. ("GZA"). Algonquin tasked GZA with analyzing the effects of current and potential future Quarry blasting operations. GZA's report is provided in Attachment A. A description of the current operation as well as the limits of future Quarry expansion is included in the GZA report. In order to ensure that the report reflected a conservative approach in estimating possible impacts on Algonquin's facilities, GZA assumed, hypothetically, that such future blasting within the Quarry would occur up to five feet from the Quarry property line along Grove Street, thereby minimizing the setback distance between Algonquin's facilities and the Quarry's blasting. The GZA report determined that the current or future blasting operations at the Quarry will not affect the safe operation and integrity of the pipeline or M&R station.

As described in detail in the report in Attachment A, studies have been performed and published discussing the resistance of buried pipelines to blast-induced vibrations. Calculations to evaluate the reserve strength within pipelines to resist the applied energy from blasts allow designers to analyze the site-specific and project-specific tolerance of a pipeline to stresses caused by vibrations. Assuming that hypothetical aggressive set of circumstances where the Quarry might extend its operation to within 5 feet of Grove Street, the GZA report determined that the proposed West Roxbury Lateral pipeline will be subject to vibrations well within pipeline design, with a minimum factor of safety of 10 to 20 times for the proposed gas pipeline. Thus, the GZA report concluded that ground vibrations from future blasting at the Quarry will not damage the proposed pipeline.

The proposed West Roxbury Lateral pipeline will be installed by specialized pipeline construction contractors using proven industry practices. The pipeline will be buried to a depth from the top of the pipe of at least 3 to 5 feet below existing ground surface and will consist of externally coated high strength steel with welded connections. The pipe will be installed within an excavation and enveloped in an engineered backfill consisting of either compacted sand or flowable fill (a low density concrete sand mixture) extending a minimum of 8 inches below the pipe, a minimum of 6 inches on both sides of the pipe and a minimum of 6 inches over the pipeline. This engineered backfill is designed to support the pipe evenly while maintaining the integrity of the pipe's protective coating. The flowable fill layer will also provide a warning barrier to protect the pipe from third-party contractors.

The M&R station buildings will be engineered pre-fabricated pre-cast concrete structures designed for industrial use and will not contain large exterior glass windows, or finishes susceptible to cracking. The in-line tool receivers/launchers and the heaters will be above-grade, steel construction, and are not considered especially sensitive to vibrations. The M&R station facilities are all bolted onto foundations and well supported. The GZA report concluded that the components of the M&R station, which will be located further away from the Quarry than the pipeline in Grove Street, are not considered to be any more sensitive to vibration disturbance or damage than the below-grade pipeline and that ground vibrations from future blasting at the Quarry will not be disruptive or damaging to the M&R station.

After review, the GZA report states that based on the location of the proposed M&R station relative to the Quarry, the probability of a projectile stemming from a blast operation at the Quarry (i.e., fly-rock) landing on the M&R station site is highly unlikely, potentially in the range of 10,000,000 to 1, with the probability of such a rock inflicting a direct strike on a segment of the limited amount of exposed pipe much lower still. Based on its analysis, the GZA report concludes that fly rock does not pose a concern for interruption of service or the release of natural gas at the M&R station.

Algonquin would also note that blasting in proximity to a natural gas pipeline is not an unusual occurrence along its pipeline system. Algonquin utilizes industry-wide recognized procedures for ensuring the safety and integrity of steel pipelines adjacent to blasting activity. The integrity of Algonquin's pipelines are therefore protected by well-established criteria on blasting vibrations, based upon extensive research by the Pipeline Research Committee International, blasting consultants, the United States Bureau of Mines, and through Algonquin's own direct observation of existing blasting operations near its existing in-service pipelines. Furthermore, Algonquin currently owns and operates a pipeline that runs through the active Riverdale Quarry near Pompton Lakes, New Jersey. In that location, Algonquin is notified prior to each blast and its facilities are then monitored during blasting operations to ensure that no harm is done to the safety and integrity of the pipeline. The same monitoring by Algonquin personnel will occur as necessary during blasting operations conducted by the West Roxbury Crushed Stone Quarry.

ATTACHMENT A

GZA GEOENVIRONMENTAL, INC.
GEOTECHNICAL REVIEW OF QUARRY BLASTING

MEMORANDUM

TO: Michael Stellas, Spectra Energy Transmission, LLC

FROM: Gary R. McAllister, P.E.

DATE: March 28, 2014

FILE NO.: 09.025818.00

RE: Geotechnical Review of Quarry Blasting
Proposed West Roxbury Lateral M&R Station and Pipeline
Algonquin Incremental Market (AIM) Project
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GZA GeoEnvironmental, Inc. (GZA) is pleased to submit this memorandum summarizing our review of the potential impacts of nearby blasting from an active quarry on the operation of the proposed West Roxbury Lateral metering and regulating (M&R) station and pipeline. This service was performed at the request of Spectra Energy Transmission, LLC on behalf of Algonquin Gas Transmission, LLC (Algonquin). References and sources used in preparation of this review are listed at the end of this memorandum. This memorandum was prepared with the assistance of Mr. James Cleveland, P.E., Mr. Bradford Roberts, P.E., and Mr. Andrew Blaisdell, and is subject to the Limitations in **Appendix A**.

To complete this scope of work, GZA completed the following steps:

- Background information describing the Quarry and the proposed M&R station and pipeline project was compiled. The results of the potential effects of the West Roxbury Crushed Stone Company (Quarry) and its operations on the M&R station and pipeline are summarized herein.
- Industry reference documents regarding quarry blasting and vibrations were researched. This is summarized and presented in **Appendix B**.
- Industry reference documents specific to protection of pipelines from blasting vibrations were researched. This is summarized and presented in **Appendix C**.
- The Quarry blast records over the last four years were reviewed. This is summarized and presented in **Appendix D.**
- The potential effects of blasting ground vibrations, if blasting is performed proximate to the proposed pipeline, were evaluated. This is summarized and presented in **Appendix E**.
- The potential effect of airborne rock (a.k.a., fly rock), if created from the blasting operations, on the above-ground portion of the M&R station were evaluated. This is summarized and presented in **Appendix F.**
- Based on the research, evaluations and review performed above, conclusions regarding the potential impacts of nearby blasting from the active Quarry on the operation of the proposed West Roxbury Lateral metering and regulating (M&R) station and pipeline were developed and summarized herein.

BACKGROUND

Algonquin is proposing the construction and operation of a new natural gas pipeline and M&R station on Grove Street in West Roxbury, Massachusetts. A quarry that actively performs rock blasting is also located on Grove Street. The blasting operations occur at the Quarry located at 10 Grove Street, West Roxbury, Massachusetts. The location of the Quarry and the proposed locations of the M&R station and pipeline are illustrated on **Figure 1**.

QUARRY

The approximate area of the Quarry, as measured along the crest (top) of the Quarry excavation, is approximately 33 acres. According to the Quarry General Manager, the base of the Quarry is currently approximately 420 feet below the elevation of the Quarry entrance on Grove Street. Based on MassGIS elevation data (referencing North American Vertical Datum 1988), the base of the Quarry excavation would therefore be at approximately elevation -300 feet below mean sea level. The topography surrounding the Quarry to the east is approximately 40 feet higher than the Quarry entrance, resulting in a Quarry side slope as high as 460 feet on its east side. Aerial photography indicates that the Quarry side slopes are configured of varying slope angles with benches (plateaus) to facilitate working areas and to carry the vehicular access road to the base of the excavation.

The geologic setting in the area of the Quarry and proposed M&R station and pipeline is characterized by relatively shallow bedrock, which can be observed at the ground surface along the sides of Grove Street. The bedrock lithology is mapped as Dedham Granite within the Avalon terrain, a series of related rock formations (Mass GIS). Dedham Granite is a fine-grained to very coarse-grained, alkali-feldspar granite, granite, quartz-monzonite, and granodiorite which is pink, pink and light-green, and light gray in color (Kaye, 1980).

Since 2010, the Quarry blasting has been performed by A-1 Drilling & Blasting Company (A-1). According to A-1, blasting at the Quarry is performed under a permit issued by the City of Boston Fire Department, which specifies a limit on the allowable blast-induced vibration magnitude (e.g., amplitude or peak particle velocity, PPV) at any abutting property of 1.0 inch per second (ips).

M&R STATION AND PIPELINE

Based on GZA's review of the project plans, and Spectra's standard construction specifications, the project is planned to consist of a 16-inch-diameter natural gas pipeline entering the south side of the M&R station, and a 24-inch-diameter natural gas pipeline exiting the north side of the M&R station. Both sections of the pipe are planned to be constructed within Grove Street, at a depth of approximately 5 feet below pavement grade. The pipeline will consist of high strength Grade X-52 steel with welded connections. The pipe will be installed within an excavation and be enveloped in an engineered backfill (e.g., compacted sand or cementitous fill (a.k.a., flowable fill)) extending a minimum of 8 inches below the pipe and minimum of 6 inches on both sides of the pipe. The engineered backfill is designed to support the pipe evenly, and protect the pipe's corrosion-protection coating.

The M&R station is planned to consist of two (2) internal inspection tool (pig) barrels (one launcher, one receiver), a metering building, two exterior gas heaters, a regulating building, and above-ground and underground gas pipelines. All above-ground components will be enclosed in a security fence. The two buildings will be engineered, single-level structures with minimum 4-inch thick reinforced concrete walls and 4- to 6-inch thick reinforced concrete roof. The exterior above-ground structures, pipes, and supports will be steel construction. The buildings, pig barrels and heaters will be supported on concrete foundations.

The piping and associated facilities are required to undergo quality control and testing during manufacturing and construction. Algonquin's quality assurance / quality control includes having its inspectors at the manufacturing facilities and on-site during all welding, coating, and backfill operations. All welds for the pipeline are required to be tested (non-destructively) by a third-party radiographic inspection company. After construction is complete, and prior to being commissioned for service, the pipeline and its associated facilities are then hydrostatically tested to pressures at least 1.5 times the planned operating pressure for eight (8) hours.

RELATIVE PROXIMITY OF EXISTING AND PROPOSED STRUCTURES TO QUARRY

The proposed M&R station will be located on the opposite (west) side of Grove Street approximately across from the main entrance to the Quarry, as shown on **Figure 1**. The proposed M&R station property is approximately 2.5 acres in area, and situated at approximately elevation 120 feet. The proposed pipeline will be located beneath Grove Street, which ranges between approximately elevation 120 feet and 150 feet in the general area of the Quarry.

The future extent of the Quarry excavation is not known at this time. However, for the purpose of evaluating the potential effect on the proposed facilities, a scenario was developed and evaluated, which conservatively assumes that future rock blasting could theoretically occur adjacent to Grove Street, at the nearest location on the Quarry property to the proposed pipeline.

Other existing features considered in this evaluation included the existing underground utilities located within the Grove Street right-of-way. As shown of **Figure 2**, multiple underground utilities are currently located within the Grove Street right-of-way between the Quarry and the M&R Station. Two existing water lines and one existing gas line are located between the proposed natural gas pipeline and the Quarry. The closest of these three existing utilities to the Quarry is a 12-inch-diameter water line, which ranges in distance between approximately 10 and 20 feet from the Quarry property line.

POTENTIAL EFFECTS OF QUARRY BLASTING ON THE M&R STATION AND PIPELINE

In general, the potentially negative effects of Quarry blasting to surrounding receptors (i.e., structures, humans, natural resources, etc.) include ground vibrations, air vibrations, hydro-geologic disturbance, and projectiles (e.g., fly rock). Air vibrations (i.e., noise or overpressure) at higher frequencies can be audibly disturbing to humans and animals, and at lower frequencies can cause rattling of walls and windows. These conditions can be a nuisance to the building occupants; however, audible disturbance is not anticipated to pose an operational concern to the proposed M&R station or pipeline. Hydro-geologic disturbance (i.e., changes in rock fracture and joint opening size and chemical/sediment content) can change water supply well yield and quality; however, the M&R station will not have an on-site water supply well.

The various structural components of the proposed M&R Station will be constructed of reinforced concrete and steel. These components are not considered more sensitive to blast-related ground vibrations than the underground piping. The proposed pipeline is closer to the Quarry than the M&R Station. Therefore, the focus of this analysis is toward the potential for ground vibrations to impact the proposed underground natural gas pipeline. The underground natural gas pipeline will be constructed approximately 5 feet below grade, and as such the discussion of fly rock is limited to the potential effects on the above-ground components of the project. The subject of ground vibrations is discussed and presented in **Appendices B through E**. The subject of fly rock is presented in **Appendix F**.

CONCLUSIONS

Based on our evaluations, which are presented in **Appendices B through F,** we have concluded the following:

- The vibration peak particle velocity (PPV) limit promulgated by the City of Boston under the current blasting permit at the Quarry is 1.0 ips, and is considered conservative in the protection of residential buildings.
- Underground pipelines are significantly more tolerable to vibrations than residential buildings, and at a minimum, the proposed gas pipeline can tolerate a vibration PPV of 12 ips.
- Vibrations recorded during the last four years of Quarry blasting were observed to correlate well with calculated vibration levels.
- From the blast data, we have derived site-specific scaling relations with statistical basis to obtain the relationship between PPV and blast energy.
- Quarry blasting is required by regulation to consider the protection of residences, as well as all utilities. Several utilities currently exist beneath Grove Street including a water line, which is located closer to the Quarry property than the proposed gas pipeline.
- The existing water line is closer in proximity to the Quarry than the proposed natural gas pipeline, and represents the nearest receptor to the blast for vibrations. A theoretical scenario of blasting within 5 feet of the Grove Street right-of-way would result in PPV levels 33% to 67% higher at the existing water line than at the proposed gas pipeline.
- Under this theoretical scenario and assuming a conservative set of circumstances, the vibrations at the proposed natural gas pipeline would be 1.2 ips. The resulting PPV of 1.2 ips is equal to $1/10^{th}$ of the proposed gas pipeline's tolerable PPV of 12 ips, resulting in a factor of safety of 10. Other potential scenarios were considered, and would result in factors of safety of greater than 10. Ground vibrations from future blasting at the Quarry are therefore not anticipated to be disruptive or damaging to the proposed pipeline and M&R station.
- Fly rock was reported to have landed on property located on Centre Lane to the north of the Quarry in 2009. Due to the location of the proposed M&R station relative to the Quarry, and changes to the blasting operations as a result of the 2009 incident, fly-rock is not anticipated to land on the M&R station parcel. However, an analysis was made to evaluate the potential effects of a similar rock fragment striking the proposed above-ground portions of the M&R Station. Based on this analysis, a fly rock scenario similar to that reported in 2009 would potentially result in minor chipping of the concrete building exterior and minor denting of the exposed pipe resulting in some repair. However the fly rock does not pose a concern for interruption to service or release of natural gas.
- Based on our evaluation, the nearby Quarry blasting is not anticipated to have a significant negative impact on the operation of the proposed West Roxbury Lateral metering and regulating (M&R) station and pipeline.

APPENDIX A – LIMITATIONS

Use of Report

1. GZA GeoEnvironmental, Inc. (GZA) prepared this report on behalf of, and for the exclusive use of our Client for the stated purpose(s) and location(s) identified in the Proposal for Services and/or Report. Use of this report, in whole or in part, at other locations, or for other purposes, may lead to inappropriate conclusions; and we do not accept any responsibility for the consequences of such use(s). Further, reliance by any party not expressly identified in the agreement, for any use, without our prior written permission, shall be at that party's sole risk, and without any liability to GZA.

Standard of Care

2. GZA's findings and conclusions are based on the work conducted as part of the Scope of Services set forth in GZA's Proposal for Services and/or Report, and reflect our professional judgment. These findings and conclusions must be considered not as scientific or engineering certainties, but rather as our professional opinions concerning the limited data gathered during the course of our work. If conditions other than those described in this report are found at the subject location(s), or the design has been altered in any way, GZA shall be so notified and afforded the opportunity to revise the report, as appropriate, to reflect the unanticipated changed conditions .

3. GZA's services were performed using the degree of skill and care ordinarily exercised by qualified professionals performing the same type of services, at the same time, under similar conditions, at the same or a similar property. No warranty, expressed or implied, is made.

Subsurface Conditions

4. The generalized soil profile(s) provided in our Report are based on widely-spaced subsurface explorations and are intended only to convey trends in subsurface conditions. The boundaries between strata are approximate and idealized, and were based on our assessment of subsurface conditions. The composition of strata, and the transitions between strata, may be more variable and more complex than indicated. For more specific information on soil conditions at a specific location refer to the exploration logs.

5. In preparing this report, GZA relied on certain information provided by the Client, state and local officials, and other parties referenced therein which were made available to GZA at the time of our evaluation. GZA did not attempt to independently verify the accuracy or completeness of all information reviewed or received during the course of this evaluation.

6. Water level readings have been made in test holes (as described in the Report) at the specified times and under the stated conditions. These data have been reviewed and interpretations have been made in this Report. Fluctuations in the level of the groundwater however occur due to temporal or spatial variations in areal recharge rates, soil heterogeneities, the presence of subsurface utilities, and/or natural or artificially induced perturbations. The water table encountered in the course of the work may differ from that indicated in the Report.

7. GZA's services did not include an assessment of the presence of oil or hazardous materials at the property. Consequently, we did not consider the potential impacts (if any) that contaminants in soil or groundwater may have on construction activities, or the use of structures on the property.

8. Recommendations for foundation drainage, waterproofing, and moisture control address the conventional geotechnical engineering aspects of seepage control. These recommendations may not preclude an environment that allows the infestation of mold or other biological pollutants.

Compliance with Codes and Regulations

9. We used reasonable care in identifying and interpreting applicable codes and regulations. These codes and regulations are subject to various, and possibly contradictory, interpretations. Compliance with codes and regulations by other parties is beyond our control.

Cost Estimates

10. Unless otherwise stated, our cost estimates are only for comparative and general planning purposes. These estimates may involve approximate quantity evaluations. Note that these quantity estimates are not intended to be sufficiently accurate to develop construction bids, or to predict the actual cost of work addressed in this Report. Further, since we have no control over either when the work will take place or the labor and material costs required to plan and execute the anticipated work, our cost estimates were made by relying on our experience, the experience of others, and other sources of readily available information. Actual costs may vary over time and could be significantly more, or less, than stated in the Report.

Additional Services

11. GZA recommends that we be retained to provide services during any future: site observations, design, implementation activities, construction and/or property development/redevelopment. This will allow us the opportunity to: i) observe conditions and compliance with our design concepts and opinions; ii) allow for changes in the event that conditions are other than anticipated; iii) provide modifications to our design; and iv) assess the consequences of changes in technologies and/or regulations.

APPENDIX B – QUARRY BLASTING AND VIBRATIONS

DISCUSSION – BLAST-INDUCED VIBRATIONS

Ground vibrations and the effects on structures are well studied and documented based on extensive research of nuclear explosions and seismic events. These studies have identified the major types of ground vibrations, and their respective propagation and attenuation rates through and along the surfaces of soil and rock, and the effects of these vibrations at various magnitudes and frequencies on structures over long distances from the energy source. Rock blasting is typically comprised of a series of blasts separated by delays to split and pulverize the rock in a controlled manner. The resulting vibration from rock blasting and the distances the vibrations travel are a function of the individual blast energies per delay rather than the total blast energy. The resulting shear and compressive body waves and Raleigh surface waves created by quarry blasting travel shorter distances, and are not as easily distinguished and evaluated to the same degree as nuclear or seismic events. However, extensive observational data has been compiled, which provides guidance in predicting rock-blasting-induced vibrations as a function of explosive charge and distance from the blast (Dowding, 1996).

The resulting vibration intensity at any distance from a blast is generally a function of the blast energy per delay, radial distance from the blast, and site-specific subsurface conditions in the area. These variables affect how vibrations transmit, attenuate, and reflect to various degrees before reaching the location of concern. Rock-blasting-induced vibrations are therefore practically and commonly measured and evaluated simply on the basis of vibration magnitude (e.g., amplitude or peak particle velocity or PPV) measured in inches per second (ips), and dominant frequency measured in cycles per second (Hertz, Hz.). The monitoring equipment commonly used to measure the vibrations is a seismograph. For rock blasting, the seismograph instrument is typically capable and set up to be triggered by the vibrations, to record the vibration time history, and to report the "peak component" PPV and associated dominant frequency in the three principal directions (X, Y, and Z, or longitudinal, transverse, and vertical components).

The empirical relationships of observed building damage were established on the "peak component" PPV (Dowding, 1996) and therefore the "peak component" PPV reported in the seismograph reports are referenced herein when describing PPV. The peak "true vector sum" of the three component PPV levels can also be used to quantify vibration intensity; however, deriving the "true vector sum" can be a time-intensive and iterative exercise. The "maximum vector sum" is sometimes used for quantifying vibrations for regulatory purposes. The "maximum vector sum" combines the peak component PPVs for ease of use; however neglects that the peak component PPVs typically occur at different times on the vibration time history, and are therefore inaccurate and not recommended for use in evaluating vibrations.

Blast-induced PPV is typically controlled by designing the blast based on scaling relations relative to the nearest sensitive receptor(s), (i.e., typically buildings and/or utilities), and/or monitoring the vibrations during the blast at the receptor location(s). Scaling relations take into account the charge per delay and distance from the blast and degree of confidence in estimating the maximum PPV. In addition to the charge per delay and distance from the blast, vibration PPV induced by rock blasting can also be a function of a number of other components of the blast design (i.e., total charge, blast pattern, stemming depth, hole spacing, etc.), overburden, bedrock geology, and topography, all of which are unique to each blast. Accordingly, the site-specific scaling relationship can be evaluated using blast vibration data specific to each site, and the site-specific relationship is well-suited to predict PPV from future blasts at the same general location. This evaluation was performed as part of this study and the findings are presented in **Appendix D**.

Publications and industry guidelines present scaling relations, which in conjunction with the blaster's experience, provide a predictive methodology for determining the maximum charge per delay based upon the allowable PPV and distance to the sensitive receptor at each blast location (Hopler, 1998). The published scaling relations are based upon statistical analysis of thousands of recorded quarry blast vibrations. The scaling relation takes the form:

$$PPV = A\ (R/\sqrt{W})^{B}$$

Where:

PPV = Allowable peak particle velocity at the sensitive receptor (inches per second)
A = Variable based upon scaling relation referenced.
R = Radial distance between blast and sensitive receptor (feet)
W = Charge weight per delay (pounds)
B = Variable based upon scaling relation referenced.

The term $(R/\sqrt{W})$ is known as the "scaled distance".

The variable A is a function of the site specific conditions, as well as the desired degree of confidence that the resulting PPV is equal to or below the calculated PPV. The upper bound value of "A" based on the last year of blast reports, is presented in **Appendix D**. The variable B is taken as -1.6 based on a majority of publications on the subject (Siskind, et al., 1980; Konya, 1991).

DISCUSSION – IMPLICATIONS OF GROUND VIBRATIONS

The level of vibration a receptor (e.g., building, structure, utility, etc.) can tolerate is a function of the PPV, frequency, and duration of the vibrations, along with the definition of "tolerable" for that receptor. The total duration of rock-blast-induced vibrations is typically not longer than one second, and the maximum peak PPV is often not repeated, such that duration is typically not considered in rock-blast-induced vibrations.

The U.S. Bureau of Mines (USBOM 8507) proposed vibration PPV levels relative to the protection of residential dwellings from coal mine blasting as a function of vibration frequency (Siskind, et al., 1980). The term "protection" refers to controlling the racking or shifting of a timber-framed residential building, based on observed cracking of concrete and interior and exterior finishes. The USBOM 8507 criteria do not address other types of buildings or above- and below-ground infrastructure. However, USBOM 8507 is widely accepted by practitioners and regulatory authorities as guidance for evaluating the magnitude of blast-induced vibrations for buildings in general (527 CMR 13).

> *"Allowable limits of airblast and ground vibrations [USBOM 8507] are based, with a conservative factor of safety, upon extensive government, university, and engineering research which has established the amount and character of vibration so as to prevent damage and to insure the safety of the public and protection of property adjacent to the blast area."*(527 CMR 13.09(a))

The Office of Surface Mining (OSM) limit for residences near long-term, large-scale surface mine operations at distances of 300 to 5,000 feet (Hopler, 1998) is 1.0 ips, for any frequency. According to A-1 Drilling and Blasting, the Quarry's blasting operations are permitted by the City of Boston, with a PPV limit of 1.0 ips for any frequency similar to the OSM limit. This PPV limit of 1.0 ips is more restrictive than the USBOM 8507 limits within the majority range of blast-induced frequencies. The USBOM 8507 (527 CMR 13) limits and the OSM (Quarry permit) limits are illustrated on **Figure D1.**

Table B1 provides a compilation of vibration limits obtained from a variety of references to help illustrate the range of tolerances to vibrations by structures, materials, and humans (Bender, 2007).

Table B1

In order to provide some idea of what various PPV intensities represent, their effect on various structures and materials is contained in the following listing. These have been documented by researchers and organizations as referenced. Because of the many variables that could be encountered in the field, this listing should not be used to establish limits or be considered as the absolute point where the effect will always occur. To do so would also require consideration of frequencies. PPV units are inches per second.

PPV	Application	Effect	Reference
600	Explosive inside concrete	Mass blowout of concrete	j
375	Explosive inside concrete	Radial cracks develop in concrete	j
200	Explosive inside concrete	Spalling of loose/weathered concrete skin	j
> 100	Rock	Complete breakup of rock masses	a
100	Explosive inside concrete	Spalling of fresh grout	j
100	Explosive near concrete	No damage	l
50 - 150	Explosive near buried pipe	No damage	n
25 - 100	Rock	Tensile and some radial cracking	a
40	Mechanical equipment	Shafts misaligned	d
25	Explosive near buried pipe	No damage	o
25	Rock	Damage can occur in rock masses	c
10 - 25	Rock	Minor tensile slabbing	a
24	Rock	Rock fracturing	b
15	Cased drill holes	Horizontal offset	d
> 12	Rock	Rockfalls in underground tunnels	b
12	Rock	Rockfalls in unlined tunnels	g
< 10	Rock	No fracturing of intact rock	a
9.1	Residential structure	Serious cracking	b
8.0	Concrete blocks	Cracking in blocks	d
8.0	Plaster	Major cracking	h
7.6	Plaster	50% probability of major damage	g
7.0 - 8.0	Cased water wells	No adverse effect on well	m
> 7.0	Residential structure	Major damage possible	e
4.0 - 7.0	Residential structure	Minor damage possible	e
6.3	Residential structure	Plaster and masonry walls crack	b
5.44	Water wells	No change in well performance	k
5.4	Plaster	50% probability of minor damage	g
4.5	Plaster	Minor cracking	h
4.3	Residential structure	Fine cracks in plaster	b
> 4.0	Residential structure	Probable damage	f
2.0 - 4.0	Residential structure	Plaster cracking (cosmetic)	e
2.8 - 3.3	Plaster	Threshold of damage (from close-in blasts)	g
3.0	Plaster	Threshold of cosmetic cracking	h
1.2 - 3.0	Residential structure	Equals stress from daily environmental changes	i
2.8	Residential structure	No damage	b
2.0	Residential structure	Plaster can start to crack	d
2.0	Plaster	Safe level of vibration	g
< 2.0	Residential structure	No damage	e
< 2.0	Residential structure	No damage	f
0.9	Residential structure	Equivalent to nail driving	i
0.5	Mercury switch	Trips switch	d
0.5	Residential structure	Equivalent to door slam	i
0.1 - 0.5	Residential structure	Equates to normal daily family activity	i
0.3	Residential structure	Equivalent to jumping on the floor	i
0.03	Residential structure	Equivalent to walking on the floor	i

Table B1 (cont.)

List of References Used:

a) Bauer, A., & Calder, P.N. (1978), Open Pit and Blast Seminar, Kingston, Ontario, Canada.

b) Langefors, Ulf, Kihlstrom, B., & Westerberg, H. (1948), Ground Vibrations in Blasting.

c) Oriard, L.L., (1970), Dynamic Effect on Rock Masses From Blasting Operations, Slope Stability Seminar, Univ. of Nevada.

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APPENDIX C – VIBRATIONS AND PIPELINES

The various structural components of the proposed M&R Station will be constructed of reinforced concrete and steel, and not considered more sensitive to blast-related ground vibrations than the underground piping. The proposed pipeline is approximately 100 feet closer to the Quarry than the M&R Station. Therefore, the focus of this analysis is toward the potential for ground vibrations to impact the proposed underground natural gas pipeline.

PROPOSED PIPELINE

The proposed pipeline will be installed according to Spectra standard details. We understand this includes a minimum of 6 inches of bedding material laterally between the piping and trench sidewalls and a minimum of 8 inches of bedding material between the piping and base of the trench. Bedding material beneath and around the pipe will consist of either sand or controlled density fill.

EXISTING UTILITIES

The proposed gas pipeline will be installed along Grove Street. Within the length of Grove Street that abuts the Quarry, the proposed gas pipeline will be located approximately 30 feet from the Quarry property line. There are multiple existing utilities beneath Grove Street, including a water main line and a sanitary sewer line, both of which are closer to the Quarry property line than the proposed gas pipeline in this area. The existing water line is closest to the Quarry, ranging between 5 and 20 feet away from the Quarry property line. The age, condition, depth, and material of the existing utilities are not known.

PEAK PARTICLE VELOCITY AND VIBRATION IN PIPELINES

Historically, pre-blast prediction and subsequent measurement of PPV has been the primary tool to predict and measure vibrations from a blast. The PPV can be easily measured by portable seismographs. Several references have been reviewed that correlate PPV to buried pipelines. The available references and corresponding PPV values are presented in the table below.

Table C1
Pipeline PPV Limits

PPV (ips)	Application / Effect	Reference
50-150	Explosive near a buried pipe with no damage	Siskind, D.E. & Stagg, 1993 *(Compiled in Bender, 2007)*
25	Explosive near a buried pipe with no damage	Oriard, 1980 *(Compiled in Bender, 2007)*
>12-15	Predicted PPV of an explosive near buried pipe that resulted in no damage	Bender, 1981
12	Vibration limit of pipeline trench parallel to existing high-pressure gas lines	ISEE Handbook
10	Blasting 50' from buried pipe with no loss of pipe integrity	US Bureau of Mines (Siskind, 1994)
5-10	Any steel buried pipe under any conditions or use the calculations for allowable PPV based on the allowable stress of pipe	Pipeline Engineering Journal, 2009 pg. 260-262

PIPE STRESSES AND VIBRATIONS

Studies have been performed and published describing the resistance of buried pipelines to blast-induced vibrations. These studies provide correlations between scaled distance with pipe bending and hoop stresses. The studies have concluded that pipe stresses are more accurately predicted based upon scaled distance than indirectly through PPV (Esparza, 1991). A scaled distance of 10, which corresponds to a PPV of 12.5 to 15 ips, has been considered conservative for buried pipelines.

Calculations to evaluate the reserve strength within pipelines to resist the applied energy from blasts allow designers to analyze site-specific and project-specific tolerance of a pipeline to stresses caused by vibrations. The project-specific variables include pipe properties (diameter, wall thickness, and yield strength), operating pressure, blasting energy, and the blast distance from the pipe. Based on the equation proposed by Esparza, 1981, the reserve strength within the 16-inch-diameter transmission gas pipeline operating at full pressure is 35,000 psi. This amount of reserve strength within the pipe can resist the stresses induced by ground vibrations in excess of 100 ips.

Based on the above references, and understanding the details of the pipe construction, installation, and operating pressure, we consider 12 ips to be a conservative PPV limit for the protection of the proposed West Roxbury Lateral pipeline.

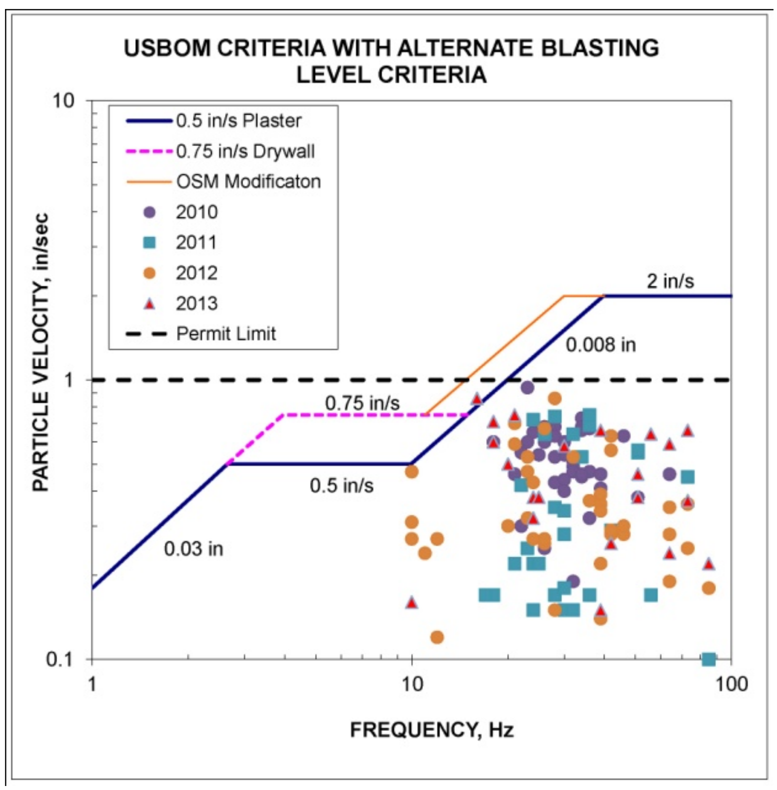
APPENDIX D – REVIEW OF QUARRY BLAST REPORTS

As part of this study, GZA evaluated the historical documented blast designs and levels of blast-induced vibrations at the Quarry. GZA obtained 139 blast reports from the Quarry spanning March 10, 2010 through December 12, 2013. The blast reports describe the blast design details and vibrations recorded at nearby residential areas. Due to the amount of blast data, GZA reviewed of the 139 blast vibration results and more closely evaluated the most recent 12 months of blast reports, comprising 26 blasts.

LAST FOUR YEARS OF BLAST DATA

GZA reviewed the maximum vibration monitoring results of the 139 blasts performed between 2010 and 2013. GZA compared the maximum recorded PPV for each blast to the Quarry's permitted allowable peak particle velocity (PPV) limit of 1.0 ips and the U.S. Bureau of Mines suggested vibration limits for buildings (USBOM 8507). The reported PPV levels represent the maximum recorded PPV and associated frequency per blast. A-1 monitored the blast vibrations using a seismograph that recorded the vibration time history, peak component PPV, and associated frequency for each of the X, Y, and Z directions. These 139 peak component PPVs are shown below.

Figure D1



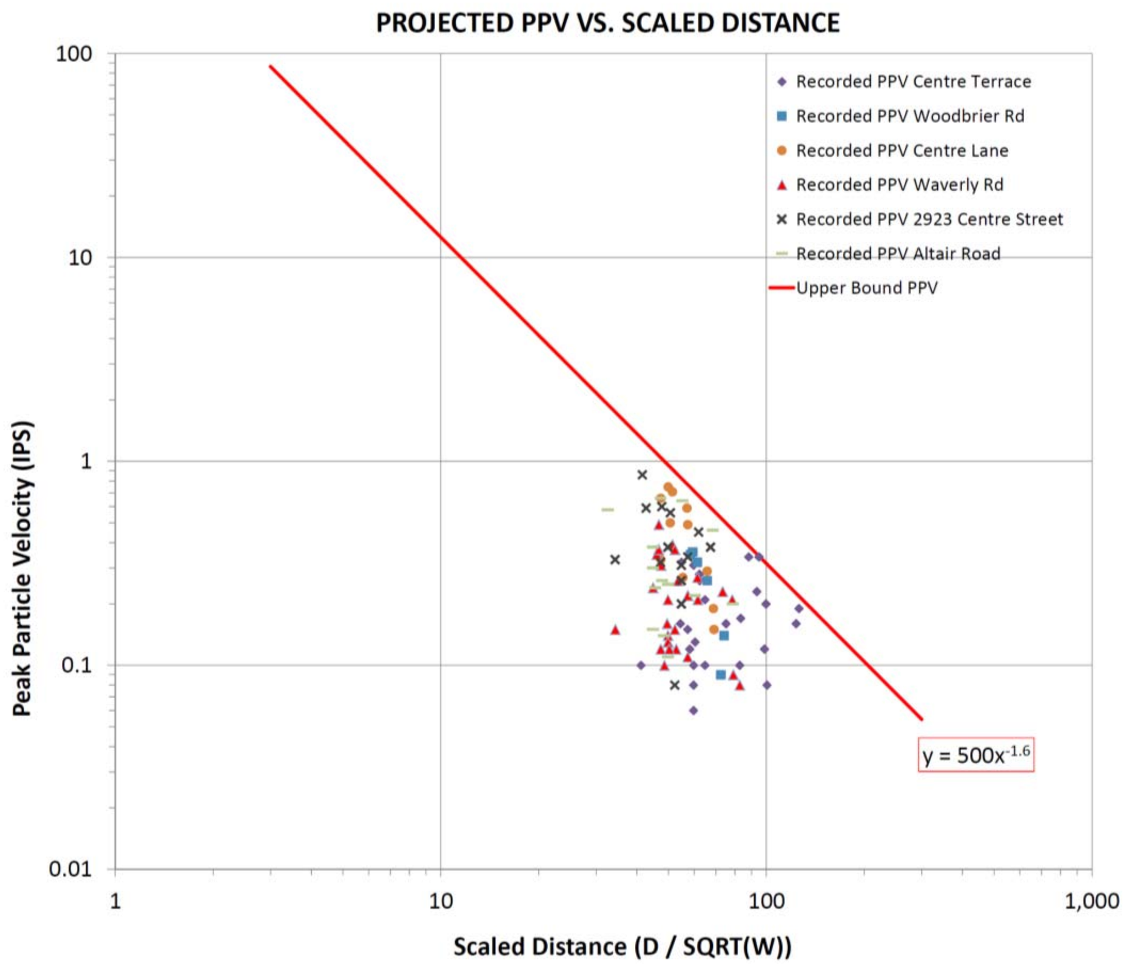
The maximum PPV of each of the 139 blasts spanning 2010 to 2013 fell within the permitted PPV limit of 1.0 ips. All but one of the 139 recorded peak PPVs were also within the USBOM 8507 criteria. The blast in question, Blast # 08-1, occurred June 26, 2013 and is among the blasts more closely reviewed in the followed paragraphs. This review suggests that the Quarry blasting vibrations have been effectively maintained within the permitted and limit over the last four years.

LAST 12 MONTHS OF BLAST DATA

GZA evaluated the most recent 12 months of A-1's reports of the Quarry blasting and made the following observations:

- Blast 08-1 resulted in a recorded vibration of 0.86 ips at 16 Hz. This recorded vibration was within the permitted limit of 1.0 ips. Blast 08-1 was the only blast with a recorded maximum vibration level that exceeded the USBOM 8507 criteria of 0.84 ips for that frequency.
- A-1 calculated the scaled distance and maximum energy per delay for each blast based on the nearest residence to the blast. The scaled distances of the 26 blasts ranged between 32 and 70, averaging 49. It is our opinion that the scaling relations method in conjunction with vibration monitoring remains the generally accepted industry standard for predicting and controlling the magnitude of rock-blasting-induced vibrations.
- A site-specific scaled distance plot is presented below for all of the recorded PPV data in the last year. The red line represents the upper bound limit of PPV based on the measured data. The correlated A-value upper bound limit for the last 12 months of blast vibration results is 500.
- Review of the last 12 months of blast energies and respective measured PPVs and distances illustrate that the Quarry geology propagates and attenuates blast-induced vibrations consistent with the published "scaled distance" equations at other quarry operations.

Figure D2


PROJECTED PPV VS. SCALED DISTANCE
Peak Particle Velocity (IPS)
Scaled Distance (D / SQRT(W))
100
10
1
0.1
0.01
1
10
100
1,000
Recorded PPV Centre Terrace
Recorded PPV Woodbrier Rd
Recorded PPV Centre Lane
Recorded PPV Waverly Rd
Recorded PPV 2923 Centre Street
Recorded PPV Altair Road
Upper Bound PPV
y = 500x^-1.6

APPENDIX E – BLASTING PROXIMATE TO THE PROPOSED PIPELINE

The portion of the proposed pipeline route closest to the Quarry is along a section of Grove Street shown on **Figure 2.** That portion of the Quarry is currently used as a haul road and stockpile area. For the purposes of this evaluation, we have considered a scenario that the Quarry will move the stockpile and haul road and blast along the property line abutting Grove Street. Under such a scenario, we further assumed that the blasting would take place as close as 5 feet from the property line in this area. This 5-foot setback is conservative in that it only leaves room to walk around the Quarry, and does not factor any regulatory setback requirements that may be imposed by the City of Boston, the Mine Safety and Health Administration, Occupational Safety and Health Administration, or other operational considerations by the Quarry operator (i.e., to maintain vehicular access to the rear of the Quarry property, etc.) any of which would likely require more than a 5-foot setback.

Assuming blasting did take place near Grove Street, the nearest sensitive receptor would be the existing water line. Massachusetts State Regulation 527 CMR 13.09(o) requires that prior to blasting in the vicinity of utility lines or rights-of-way, the blaster shall notify the appropriate utilities in advance of blasting, and obtain a Dig-Safe number. In doing so the blaster would find the water line markings in the road and be required under 527 CMR 13.09(k) to conduct a blast analysis. The blast analysis shall include all of the overall factors affecting the blasting operations, considering adjacent area structure(s), building(s), utilities, including gas and water supply lines within 250 feet of the center of the blast site and other underground objects that might be damaged by the effects of a blast.

Per 527 CMR 13, the blaster is required to maintain blast vibrations below the USBOM 8507 or 1.0 ips limits. This scenario assumes that the blaster based his blast design around a maximum allowable PPV of 2.0 ips (USBOM 8507 limits, above 40 Hz) at the water line:

Location along Grove Street where the proposed gas pipeline would be closest to the Quarry (pipeline station 218+50).

Blast is designed using the scaled distance approach based on the nearest structure / utility (e.g., the existing water line)

Distance from blast to water line: 25 feet

- Maximum allowable PPV at water line: 2.0 ips (assume using highest PPV limit on the USBOM 8507 curve, rather than the currently permitted PPV limit of 1.0 ips)
- Scaled distance for blast design: 31
- Maximum charge / delay: 0.66 Lb.

Resulting PPV at water line: 2.0 ips

Distance blast to the proposed gas pipeline: 35 feet
Resulting upper bound PPV at the proposed gas pipeline: 1.2 ips

Conservative upper bound PPV for the proposed West Roxbury gas pipeline = 12 ips (Refer to Appendix C).
Minimum Factor of Safety for the proposed Gas Pipeline (12 / 1.2) = 10.

If the water line is subject to the City of Boston permitted PPV limit of 1.0 ips, the resulting upper bound PPV at the proposed gas pipeline would be 0.6 ips, resulting in a minimum factor of safety of 20 for the proposed gas pipeline.

This scenario concludes that if future blasting occurs adjacent to Grove Street, the proposed gas pipeline will be subject to only nominal vibrations, with a conservative factor of safety of at least 10.

The water line is located approximately 20 feet from the Quarry property line along the stretch of Grove Street in the above scenario. The existing water line is closer to the Quarry property line and the proposed gas pipeline is further away from the property line at other locations along this stretch of Grove Street. Other theoretical blast scenarios at other locations near Grove Street would therefore conclude with lower ground vibrations being experienced at the proposed gas pipeline.

APPENDIX F – POTENTIAL EFFECTS OF FLY ROCK TO THE PROPOSED M&R STATION

The underground natural gas pipeline will be constructed approximately 5 feet below grade, and as such the discussion of fly rock is limited to the potential effects on the above-ground components of the project.

Blasting is fundamentally intended to split, pulverize and mobilize the rock mass in a controlled fashion. When performed properly, the resulting rock particles move horizontally, away from the rock face resulting in a stockpile at the base of the rock face. There is no benefit to the Quarry in spreading the blast rock over a large area, as this will result in a loss of rock and require greater effort collecting the blast rock for processing.

All of the rock faces of the Quarry point inward to the Quarry property. In the event that blast rock particles are projected beyond the intended collection area at the base of the rock face, the blast rock will still be contained within the Quarry. There are rare circumstances where blast rock will be projected in a steep angle. This is often caused by inadequate blast design and improper stemming. In such an instance, the resulting blast rock will still be primarily directed within the Quarry.

In the very rare event that blast rock is projected to the side or behind the rock face, the rock could theoretically leave the Quarry property. It is our understanding that such an event was reported in 2009 by the property owner of 19 Centre Lane (Ertischek, 2009). The property at 19 Centre Lane abuts the Quarry. Based on aerial photography and Mass GIS, the shared property line is located 200 feet from the nearest Quarry face. According to one news report, blasting was taking place in the northwest portion of the Quarry at the time. The article reported that the fly rock created imprints in the lawn and dislodged rocks from a landscape wall.

It is our understanding that immediately following this reported event, the Quarry implemented modifications in the blasting operations to reduce the potential for fly rock, and since incorporating these changes, fly rock has not been reported by abutters.

The M&R station is planned to consist of two (2) internal inspection tool (pig) barrels (one launcher, one receiver), a metering building, two exterior gas heaters, a regulating building, and above-ground and underground gas pipelines. All above-ground components will be enclosed in a security fence. The buildings will be engineered, single-level structures with minimum 4-inch thick reinforced concrete walls and 4- to 6-inch thick reinforced concrete roof. The exterior above-ground structures, pipes, and supports will be steel construction. The buildings, pig barrels and heaters will be supported on concrete foundations. All sensitive M&R Station piping, instruments and components will be located inside of the reinforced concrete buildings.

A fly rock scenario was evaluated at the proposed M&R station parcel with respect to the building and the exposed above-ground piping. Information produced by the U.S. Naval Ship Research and Development Center (CIRIA/UEG, 1989) provides the results of test missiles similar to the size, mass and velocity estimated from the 2009 reported fly rock event. The missiles were observed to cause chipping of less than 1 inch deep in the concrete face, with no damage to the back side of the concrete.

The same dynamic forces were used to evaluate the potential of above-ground piping to dent or puncture the exposed portions of the pipeline. Calculations based on the pipe diameter, thickness, and steel strength, indicate that a dent may be formed on the order of 2 inches in depth or less.

However, the pipe's resistance to puncture is over 10 times the applied force of the fly rock. (Fuglem, 2001).

Based on this analysis, a fly rock scenario similar to that reported in 2009, would potentially result in minor chipping of the concrete building exterior and minor denting of the exposed pipe resulting in some repair. However the fly rock does not pose a concern for interruption to service or release of natural gas.

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ALOGONQUIN INCREMENTAL MARKET (AIM) PROJECT
PROPOSED M&R STATION AND PIPELINE
WEST ROXBURY, MASSACHUSETTS

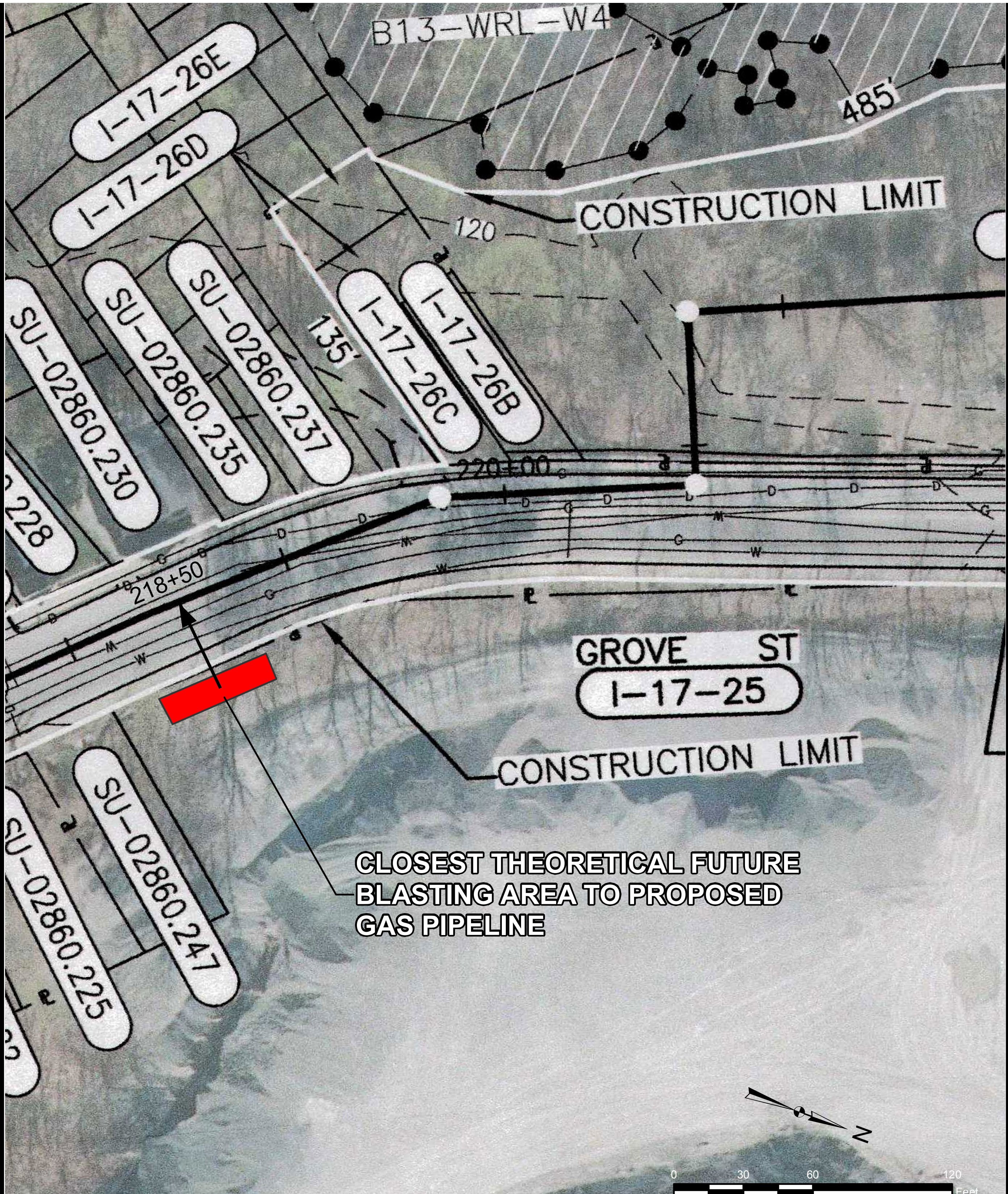
PREPARED BY:
GZA GeoEnvironmental, Inc.
Engineers and Scientists
www.gza.com

PREPARED FOR:
SPECTRA ENERGY TRANSMISSION

LOCATION OF ADJACENT WEST ROXBURY CRUSHED STONE (QUARRY)

PROJ MGR: GRM	REVIEWED BY: GRM	CHECKED BY: GRM	FIGURE
DESIGNED BY: GRM	DRAWN BY: ADM	SCALE: 1 in = 400 ft	1
DATE: 03/28/2014	PROJECT NO. 09.0025818.00	REVISION NO.	

2014 - GZA GeoEnvironmental, Inc. T:\Clients\office_PORTLAND\SpectraEnergy\Figure1\Figure1.mxd, 3/28/2014, 10:19:01 AM, patrick.finnerty



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ALGONQUIN INCREMENTAL MARKET (AIM) PROJECT
PROPOSED M&R STATION AND PIPELINE
WEST ROXBURY, MASSACHUSETTS

PREPARED BY:
GZA GeoEnvironmental, Inc.
Engineers and Scientists
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LOCATION OF ADJACENT WEST ROXBURY CRUSHED STONE (QUARRY) ALIGNMENT SHEET

PROJ MGR: GRM	REVIEWED BY: GRM	CHECKED BY: GRM	FIGURE
DESIGNED BY: GRM	DRAWN BY: PCF	SCALE: 1 in = 60 ft	2
DATE: 03/28/2014	PROJECT NO. 09.0025818.00	REVISION NO.	