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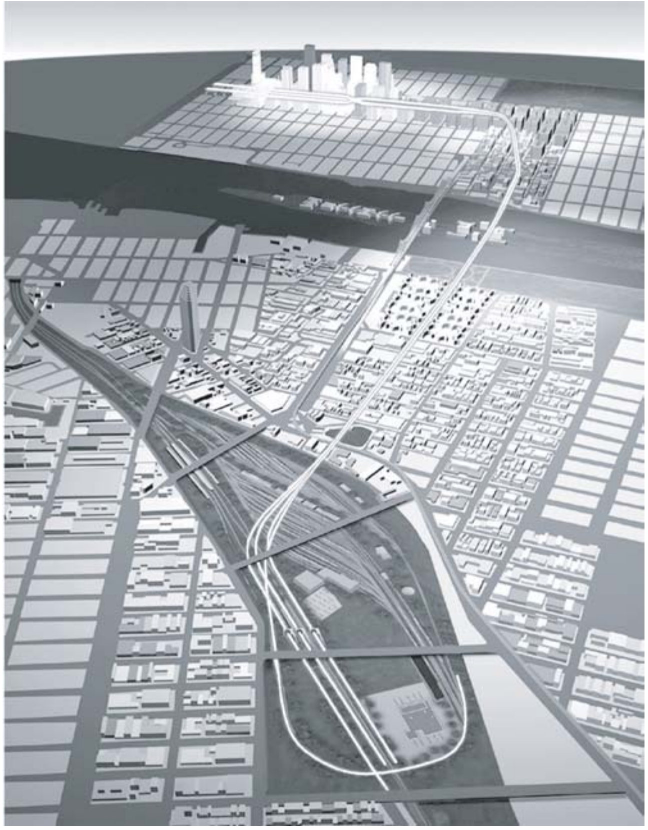

Long Island Rail Road
East Side Access

CONTRACT DOCUMENT

GEOTECHNICAL BASELINE REPORT

Contract CM009 (Re-Bid)
Manhattan Tunnels Excavation

BOOK 5 of 5
May 2006

CONFORMED, Addenda 1-10 Incorporated

Metropolitan Transportation Authority
Capital Construction
State of New York

MTA CC – LIRR/EAST SIDE ACCESS PROJECT
GEOTECHNICAL BASELINE REPORT
CONSTRUCTION CONTRACT CM009
MANHATTAN TUNNELS EXCAVATION

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1. INTRODUCTION

1.1 General Considerations

This Geotechnical Baseline Report (GBR) describes the anticipated subsurface conditions for the construction of Contract CM009, Manhattan Tunnels Excavation, of the East Side Access (ESA) Project. This report is limited to excavations in Manhattan only, including TBM tunnels, approach tunnels, TBM assembly chamber and adjoining starter tunnels, GCT 5 wye caverns and adjoining starter tunnels, GCT 3, cross passages, central instrument room, and cross flue, and the initial support. The Contract work also includes concrete lining of all excavations with the exception of those sections where future drill-and-blast enlargements for cavern construction will take place. The TBM driven tunnels will receive either a precast concrete segment liner concurrent with excavation or a cast-in-place liner following TBM excavation.

This GBR provides an interpretation of the available geotechnical data and describes the anticipated subsurface conditions and ground behavior considered likely to influence the excavation support selection, excavation activities and underground construction. The report presents ground and groundwater conditions that are anticipated to be encountered during the performance of construction and includes expressly identified baseline statements with respect to ground and groundwater conditions, ground behavior, and initial support. It also includes certain design parameters of subsurface materials. It includes discussions of certain geologic and manmade features of significance and discusses the instrumentation and monitoring requirements for some of the existing buildings, structures, and tunnels within the area likely to be affected by construction operations.

While the descriptions of the subsurface conditions provided in this report are based on geotechnical investigations, interpretation, and analyses, they should not be understood or interpreted as a guarantee or warranty, express or implied, that the conditions encountered during construction will be consistently, precisely, or completely as described. No amount of investigation or analysis can precisely predict the characteristics, quality or quantity of anticipated subsurface and site conditions. Ground behavior will vary and is significantly dependent upon and influenced by the construction means and methods selected and used by the Contractor. In the interpretation of the data, and the anticipation of ground behavior during construction, assumptions have been made regarding construction means and methods of the TBM and drill-and-blast excavation, and sequence of excavation and initial support installation, as stated here or shown on the Contract Drawings. Additionally, this GBR makes no representation regarding the type of TBMs or the method and type of the final liner in the TBM driven tunnels, rather the ground behavior is described on the basis that the initial support, as shown on the Contract Drawings, will be installed. If different methods are employed by the Contractor, ground behavior is likely to be different from that described herein.

The baselines were developed from the geotechnical information and data gathered from borings and laboratory testing as well as from predictions and evaluations concerning anticipated ground behavior during TBM operations and drill-and-blast excavation of a type that may be employed by the Contractor. The objectives for establishing the expressly identified baselines are to provide a more uniform basis upon which the bidders may evaluate the risks and base their bids, and to assist the parties in identification and evaluation of differing site conditions during construction. The contractual significance of the expressly identified baselines is set out in the Supplemental Terms and Conditions of this Contract.

The Contractor shall not rely exclusively on this report for the planning or performance of any aspects of his work, including and without limitation as to means, methods, techniques, sequences and procedures of construction, and safety precautions to be employed by the Contractor. The Contractor must undertake its own independent review and evaluation of the entire Contract Documents, the Geotechnical Baseline Report (GBR), the Geotechnical Data Report (GDR), and other relevant Reference Documents to arrive at decisions concerning the planning of the work and the means, methods, techniques, sequences and procedures of construction. The Contractor shall submit documentation in accordance with the Contract submittal procedures to demonstrate an understanding of the Contract scope of work, specific requirements, procedures, and means and methods necessary to complete the work under the conditions described and in accordance with the Contract Documents.

Construction activities for the excavation of tunnels, caverns, and chambers will be affected by restrictions in working adjacent to New York City Transit (NYCT) Subway tunnels, Metro North Railroad (MNR) tunnels, Grand Central Terminal, dense urban residential and commercial development, and adjacent to certain sensitive areas of public concern with respect to noise and vibration. These are incorporated in the Contract Documents and have not been addressed in this GBR.

The identification of source documents, references, citations, quotation of excerpts or other sources of information in this GBR should not be construed as incorporating such sources or cited documents into the GBR or the Contract Documents. All such sources are Reference Documents as defined in the Supplemental Terms and Conditions, absent an express statement that they are incorporated as a Contract Document. In this respect, this GBR is divided into two separate sections. Chapters 1 through 12 and Figures 1 through 6 are Contract Documents. The Appendices A, B, and C (attached) and cited documents (listed within the Chapters) are Reference Documents, unless they are expressly identified as Contract Documents elsewhere.

1.2 Baselined Items

Certain geotechnical parameters and conditions are baselined in the Geotechnical Baseline Report (GBR). Those are the only baselined geotechnical parameters and conditions. All other geotechnical interpretations and conclusions stated in this GBR constitute Contract indications, unless expressly stated otherwise or unless identified as reference information. Provided however that any Contract indications herein are subject to the baselines in this GBR, which, as stated in the Supplemental Terms and Conditions, take precedence over any Contract indications herein and elsewhere in the Contract.

The following geotechnical parameters and conditions are baselined in this GBR and given in Chapter 12 of this document:

- Discontinuity Attitudes
- Rock Engineering Properties
- Groundwater Inflow
- Rock Conditions

Assessment of the baselined items will be determined in the field through a process of systematic tunnel wall mapping and quantification of actual rock support installed. Rock coring will be required from the tunnel walls for inspection and subsequent laboratory testing.

2. PROJECT DESCRIPTION

2.1 The East Side Access (ESA) Project

The Long Island Rail Road (LIRR) presently provides passenger service from 10 branch lines on Long Island through Amtrak's tunnels under the East River to the west side of Manhattan into Penn Station. The East Side Access (ESA) Project will enable the LIRR to provide direct service to the east side of Manhattan. This service will connect the LIRR main lines through the lower level of the existing NYCT 63rd Street Subway tunnel East River tunnel into a new terminal station to be constructed beneath Grand Central Terminal (GCT) in Manhattan (Figure 1). A portion of the Madison Yard at the GCT lower level will be reconstructed to serve as a concourse for the new LIRR underground station. The ESA will provide commuters from Long Island an alternate access to the Manhattan business district, direct access to mid-town Manhattan on the east side, and connections to the north and east via Metro-North Railroad (MNR). In addition, it will provide commuters direct access to New York City Transit's Lexington Avenue Line and Times Square Shuttle.

The Manhattan Segment of the ESA project consists of following major underground construction elements:

- Existing 63rd Street Tunnels (LIRR Level)
- Approach Tunnels
- GCT Caverns, tunnels and shafts connecting the new LIRR terminal to the Madison Concourse
- Tail track tunnels and caverns
- Ventilation Structures

The Manhattan Segment tunnels and caverns will be built under various existing operating New York City Transit (NYCT) subway lines, Metro-North Railroad (MNR) lines and the Grand Central Terminal (GCT). Construction of the ESA Project will also include railroad systems and trackwork under the operating NYCT tracks in the existing NYCT 63rd Street Subway tunnel. The project is situated under mid-town Manhattan's densely populated residential and business hub considering that the entire length of the alignment extends from East 63rd Street and Second Avenue to the intersection of Park Avenue and East 38th Street.

2.2 Construction Contract CM009

Contract CM009 in Manhattan includes excavation of four single track tunnels in Manhattan using two tunnel boring machines (TBMs), and several drill-and-blast excavations including, GCT 5 wye caverns and adjoining starter tunnels, GCT 3 wye caverns, cross passages, central instrument room, and cross flue. The Contract will also include those excavations (assembly chamber) and facilities needed to deploy and operate the TBMs. The initial construction is the drill-and excavation of the approach tunnels and a chamber for the assembly and starter tunnels for deployment of the TBMs. TBMs will be moved to the starter tunnels, and launched, then driven to the end of the tail tracks at East 38th Street. The TBMs will be re-launched from East 59th Street (GCT 5) and again driven to East 38th Street. The GCT 5 wye cavern at East 59th Street will be used to reassemble the TBMs and re-launch them.

Upon completion of the TBM tunneling, the TBMs will be disassembled and backed-up to the Queens shaft/open-cut for final removal.

The TBM tunnels will be excavated to a diameter required to produce a finished tunnel diameter of 19-foot 6-inches, with a precast concrete segment or cast-in-place concrete final liner, as shown on the Contract Drawings. The minimum tunnel clearances shown on the Contract Drawings and construction tolerances indicated on the Contract Specification shall be maintained. TBM mobilization, demobilization, mucking, and all other tunnel services required for construction will be conducted through an access area constructed in Queens under a separate construction contract.

The eastbound approach tunnel from the existing tunnel stub at East 63rd Street and Second Avenue has been excavated under a separate Construction Contract (Contract CM016 – Manhattan Approach Tunnels Excavation by Roadheader) and will be the existing condition for this Contract. Details of this excavation is a Reference Document for this Contract.

Contract CM009 work elements will be considered 'pre-existing' conditions for the future construction contracts to complete the construction of the major underground structures in Manhattan. Updated geological and geotechnical information revealed during Contract CM009's execution will be incorporated in these construction contracts. Future and concurrent construction contracts for the Manhattan segment of the ESA project currently include:

- GCT Concourse Civil & Structural
- GCT Caverns, 63rd Street Tunnel Rehabilitation, and Bellmouth Closure
- Various Ventilation Plant Facilities

2.3 Contract CM009 Tunnel Alignment

The tunnel alignments will generally follow the track alignments except at GCT3 and GCT 4 interlockings areas near 51st Street where the tunnel alignments diverge from the track alignments to provide a rock pillar of sufficient width. Construction of the Manhattan Segment will begin at the western terminus of the existing NYCT 63rd Street Subway tunnels beneath the intersection of East 63rd Street and Second Avenue. The two existing tunnels, spaced 29-feet 6-inches on center. The eastbound stub has been extended under Contract CM016. The approach tunnels will extend the two existing tunnels to the southwest, to approximately East 59th Street where each tunnel will bifurcate into two separate tunnels and each tunnel will continue southwest under Park Avenue to East 38th Street.

Initially the approach tunnels will be horse-shoe shape, constructed by drill-and-blast for approximately 180 linear feet, The assembly chamber will be excavated at the western terminus of the approach tunnels such that a minimum of 20 feet of clear separation from the existing NYCT tunnels is maintained. This location defines the easterly limit of the assembly chamber. The chamber dimensions will be determined by the Contractor to meet the requirements for machine assembly and launch. A suggested configuration of the assembly chamber has been shown on the Contract Drawings. Excavation sequences and initial support for the assembly chamber have been designed based on this assumed configuration. Contractor will design his own configuration of the assembly chamber and initial support, subject to the above restriction with regard to the adjacent NYCT tunnels. The initial supports for the tunnels, caverns and chambers have been designed taking into consideration the proximity of adjacent facilities/structures and the delay in placing the final liner. Starter tunnels, which will be marginally larger than the bored tunnels, will be needed to launch the machines. All of these excavations will be accomplished using drill-and-blast methods, subject to controls specified to minimize overbreak and to reduce the noise and vibration levels. The tunnel alignment extends from East 63rd Street and Second Avenue to East 59th Street, where each of the two tunnels bifurcates to two additional tunnels. The four tunnels extend southwest to Park Avenue, where they follow Park Avenue south to East 38th Street.

Beginning at the western terminus of the existing approach tunnels, the alignment will continue about 1300 feet in a curve to the southwest. The existing -3.00% grade will continue for about 100 feet, and then the grade will change through a vertical curve to +1.00% under Third Avenue. After crossing beneath East 60th Street, the two single-track tunnels will continue on a tangent until the tunnels are beneath the express level of the NYCT-Lexington Avenue Line. Once the tunnels pass beneath the NYCT structures, each one will be widened into the GCT 5 wye cavern structures, each about 480 feet long. This enlargement is required for the reassembly of the TBMs for their second drives.

South of the East 59th Street wye cavern (GCT 5), four TBM tunnels will continue for 1700 feet. Once they cross East 56th Street, the tunnels will lie entirely beneath Park Avenue and the MNR tunnel. Beneath East 58th Street, the tunnels will enter vertical curves that will change the alignment to +2.00% for the outer two TBM tunnels and –2.00% for the inner two TBM tunnels. The diverging grades will align the tunnels for the upper and lower level platforms at the GCT caverns. At East 53rd Street, the two outer tunnels will begin to swing above the two inner TBM tunnels and enter another vertical curve to change the alignment to –2.00%.

Beneath East 51st Street, crossovers of GCT3 and GCT 4 interlockings will be constructed (in a future Contract) on each track level to allow routing of trains to and from either of the future station caverns. The crossovers will be housed in two two-track curvilinear caverns separated by at least 15’ of rock. In this Contract, two TBM drives separated by an eight-foot rock pillar will be made on each level through the future crossover. The TBM tunnel alignment at this location differs from the track alignment.

The GCT 3 will require wye caverns for the bifurcations of each of the two TBM tunnels.

South of the crossover structures, the tunnels will enter vertical curves that change the grade to +0.30%. The TBM tunnels will continue on this grade to the south end of the proposed tail tracks at East 38th Street. At East 38th Street, each TBM will be partially disassembled and backed through the bored tunnel. The TBMs will be backed to either the East 59th Street Wye caverns for the addition tunnel drives or for final removal from the assembly chamber near East 63rd Street and Second Avenue.

2.4 Reference Stationing

Rock mass descriptions, rock mass behavior and engineering properties and baselines presented in this document apply to all TBM tunnels, starter tunnels and caverns. The EB2-T402-L302 tunnel stations are used only as reference stations to subdivide the alignment into several geologic zones for presentation of the associated geotechnical properties, rock mass descriptions, rock mass behavior and baselines. The equations for converting from tunnel stations to track stations are given in the Contract drawings (STA T402 34+78.06 = STA EB2 1045+37.02 and STA T402 17+52.50 = STA L402 17+52.50).

3. SOURCES OF INFORMATION

3.1 Geotechnical and Geological Information

The sources of geotechnical and geological information for the Manhattan segment of the ESA project are presented in the Geotechnical Data Report (GDR) Volumes 1 to 9, and pole plots, Q and RMR values and histograms of the data are appended to this GBR. The principal sources are published geological information, trial pits and test borings, sampling, in-situ testing, geophysical surveys, laboratory testing and field mapping of existing exposed rock faces. The contents of the GDR are shown in Table 3-1. In addition, the Reference Documents on excavations under Contract CM016 have also been used to characterize certain portions of the alignment.

Table 3-1: Contents of the Geotechnical Data Report (GDR)

Volume No.	Contents
Volume 1	Table of Contents, Lists of Tables and Figures, Description of Geotechnical Investigation Program and Packer Permeability Test results.
Volume 2	Appendix A ESA Project Boring Logs (MA-Series)
Volume 3	Appendix A (continued) A: ESA Project Boring Logs (MG and VM Series)
Volume 4	Appendices A (continued) and B A: ESA Project Boring Logs (MD and TT series) B: Existing Boring Logs
Volume 5	Appendix C Rock Core Photography
Volume 6	Appendices D, E, F D: Geophysical Testing-Seismic Refraction Studies E: Rock Face Mapping of GCT Lower Level South and West Walls and GCT Substation M42 Stairwell F: Stereophotogrammetric Survey of Stub Tunnel Rock face, NYC 63rd Street Subway
Volume 7	Appendices G, H, I, J, K, L, M G: Hydraulic Fracturing Test Data H: Dilatometer Test Data I: Borehole Acoustic Televiewer Survey Data J: Oriented Core Data K: Observation Well Installation Logs L: Soil Laboratory Test Data M: Ground Water Chemistry Test Reports
Volume 8	Appendix N N: Rock Laboratory Test Data
Volume 9	Appendix N (continued) N (continued): Rock Laboratory Test Data and Voest-Alpine Reports

The principal sources of published information are the geologic map for the region (Baskerville, C. A., "Bedrock And Engineering Geologic Maps Of New York County and Parts of Kings and Queens Counties, New York, and Parts of Bergen and Hudson Counties, New Jersey", *U. S. Geological Survey,* 1994) (relevant excerpt shown in Figure 2), refereed published papers, conference papers and books (all listed in Chapter 4 of this GBR). The published sources reveal a controversy between that published geologic map and recent interpretation of the stratigraphy, tectonic argument and nomenclature for the region. The relevant portion of that published geologic map (Baskerville, 1994, Figure 2) is reproduced as Figure 2 of this GBR. This Figure 2 is a part of the Contract documents and was given precedence over other sources in developing the interpretations in this GBR. The Geotechnical Data Report (GDR) and other published documents (listed in Chapter 4) are Reference Documents for this Contract.

3.2 Subsurface Environmental Information

Existing environmental conditions within the areas of the proposed construction can be found in the Reference Document, entitled, "Supplemental Environmental Site Investigation Findings Report Summary, Contract No. CM009 Manhattan Tunnel Excavation", dated March 2004. Evaluation of these conditions according to applicable environmental regulations and project protocol can also be found in this document.

4. PROJECT GEOLOGIC SETTING

4.1 General Considerations

This Chapter describes the general geology of the project area on a regional scale, including the various rock types, structural features of the rock mass and discontinuity properties, as available in the literature (references cited at the end of this Chapter in Section 4.7). The information presented here provides for a general understanding of the general geologic regime through which the tunnels are to be excavated. Project specific geotechnical information is provided in Chapter 5 and the data presented there takes precedence over any information given in this Chapter which is inconsistent with the Project specific information.

4.2 General Geology of the Work Site

New York City is underlain by three physiographic units with complex geological structure, namely, the New England Upland to the northwest, the Triassic Lowland to the southwest, and the Atlantic Coastal Plain to the southeast. The rocks underlying Manhattan, the Bronx, and a part of Staten Island belong to the New England Upland, and are locally known as the Manhattan Prong. The rocks of New York City comprise three lithologically distinct sequences of a metamorphic assemblage of Proterozoic to lower Paleozoic age consisting of schist, gneiss and marble (Baskerville, 1994; Fuller et al., 1999). The rocks in the project area belong to the Hartland Formation of Lower Cambrian to Middle Ordovician in age and overlie the Manhattan Schist of Lower Cambrian in age (Baskerville, 1989, Sanders and Merguerian, 1997) (Figure 2). The Hartland Formation lies in thrust contact with the underlying Manhattan Schist on a regional strike-slip thrust fault known as Cameron's Line (Baskerville, 1994).

The rocks of the Manhattan Prong were tightly folded and metamorphosed during the Taconian Orogeny that occurred about 450 million years ago (Isachsen, et. al., 1991). The established sequence is the lower Fordham Gneiss, with its type locality at the Fordham Heights in the Bronx overlain by the Inwood Marble named after the type exposure in the Inwood section of the northeastern tip of Manhattan Island, followed by the Manhattan Schist and the Hartland Formation.

4.3 Overburden Geology

The location of old stream channels, exposed rock and marshland are illustrated in historical documents (Viele, 1874, contained in the GDR). The stream channels are postulated to be influenced by glacial activity exploiting weaknesses in the rock but the effects may be masked by glacial till in places. Old streambeds have been identified in the vicinity of 45th Street, 54th to 55th Streets, 58th to 59th Street and between 61st and 62nd Street, along the tunnel alignment. The stream channels will have exploited weaknesses in the rock mass. Fault zones and high water inflows are generally associated with the location of stream channels.

The overburden deposits above the bedrock vary substantially in depth. In the Central Park region, the soil cover is relatively thin and increases southward toward lower Manhattan. The soils generally consist of glacial till, modified glacial drift, sands and gravels, some glacial lakebed silts and clays, and artificial fills.

4.4 Structural Geology and Metamorphic Fabric

The rocks of Manhattan have a complex structural history due to several superposed phases of deformation (Shah, et. al., 1998). The multiple deformation phases have created an intensely folded and locally sheared rock mass with penetrative fabric, total recrystallization and localized partial melting of the rocks.

The most prominent fold phase consists of asymmetrical and associated folds that define the regional structure of Manhattan. The axial planes strike N35ºE and generally plunge at low to moderate angles (about 10º to 15º) toward the south-southwest. The general style of these folds is a relatively long limb dipping gently toward the east and a shorter limb dipping steeply toward the west. These folds are characterized by flexural-slip surfaces along foliation (Baskerville, 1989, Sanders and Merguerian, 1997).

4.5 Discontinuities

Published information states that at least four major joint sets have generally been recognized in Manhattan Island (Cording and Mahar, 1974). The most prominent joint set, Set No. 1, lies parallel to the plane of weakness formed by foliation and strikes N30º to 35ºE with a 70º to 80º SE or 60º to 70º NW dip. Set Nos. 2 and 4 generally strike perpendicular to the foliation jointing with dips in the range of 70º to 80ºSW for Set No. 2 and about 75ºNE for Set No. 4. Set No. 3 appears to run parallel to the foliation, but dips 60º to 70º in a direction opposite to Set No.1 and has been termed its conjugate. In addition, there exist low-angle joints, essentially striking parallel to Joint Sets 2 and 4 with dips of about 25ºSW. Secondary joints, whose strikes and dips differ slightly from those for the four dominant joint sets, have also been observed. The attitudes of the Joint Set Nos. 2, 3, and 4 appear to change with changes in the attitude of foliation.

The existence of four dominant joint sets in this rock mass have been confirmed by geological mapping of the south wall of the Grand Central Terminal, oriented core borings, joint traces in the borehole walls, and historical data. However, the attitudes of the joint sets occurring along the ESA alignment are different from the published data presented above. Section 5.4 of this GBR discusses the results of the geotechnical investigation program regarding attitudes of the discontinuities, and takes precedence over the published discontinuity data presented above. Mapping results are presented in full in the GDR, Appendix E of this GBR, and discussed in Chapters 8 and 9 of this GBR. The dip angle and direction data along the alignment are summarized in Table 5-1.

Foliation shear zones are present throughout the rock mass and are oriented within 35º of North and dip at angles of 40º to 80º in a west or east direction, essentially paralleling Set No. 1 (Cording and Mahar, 1974). Transverse fault zones, cutting across foliation, are present in these rock formations. These zones are well developed and are generally much wider than the foliation or conjugate shear zones. Rock within these fault zones is very blocky and seamy, and many surfaces are likely to be sheared (Cording and Mahar, 1974).

4.6 Hydrogeology

Manhattan is slightly raised above sea level, and is bounded by the East River to the east, the Harlem River to the north, the Hudson River to the west, and the New York Harbor to the south. The area is heavily urbanized with the exception of Central Park, and so infiltration of rainfall is likely to be low. There are no records of major groundwater usage in the area and the Five Boroughs were ranked in the lowest abstraction category for fresh groundwater withdrawals in 1985 (U.S. Geological Survey, 1985).

More intense conductive fracturing occurs at the locations of the buried stream channels where the water courses followed the weaker rock in the shear zones. These fractures are conduits for groundwater with much greater hydraulic conductivity than other fractures in the undisturbed rock mass.

4.7 Cited Documents

The following documents, cited in this Chapter, are Reference Documents for this Contract:

Baskerville, C. A., 1994, "Bedrock And Engineering Geologic Maps Of New York County and Parts of Kings and Queens Counties, New York, and Parts of Bergen and Hudson Counties, New Jersey", *U. S. Geological Survey*, 1994 .

Baskerville, C. A., 1989, "Geology and Engineering Geology of the New York Metropolitan Area", Field Trip Guidebook T361, *28th International Geological Congress*, New York, July 20-25, 1989.

Cording, E.J., and Mahar, J.W., "The Effect of Natural Geologic Discontinuities on Behavior of Rock in Tunnels", *Proceedings of the Rapid Excavation and Tunneling Conference*, 1974.

Fuller, T., Short, L. and Merguerian, C., "Tracing the St. Nicholas Thrust and Cameron's Line Through the Bronx NYC", *Proc. Conf. Long Island Geology*, SUNY, 1999.

Isachsen, Y.W., Lauber, J.M., Rickard, L.V., and Rogers, W.B., (editors), "Geology of New York, A Simplified Account", Chapter 5 in *New York State Museum/Geological Survey*, The State Education Department, The University of the State of New York, Albany, NY 12230, 1991

Sanders, J.E., and Merguerian, C., "Geologic Setting of a Cruise from the Mouth of the East River to the George Washington Bridge, New York Harbor", A Field Trip for Participants of the 36th U.S. Rock Mechanics Symposium, Columbia University, New York, June 29-July 2, 1997.

Shah, A. N., Wang, J., and Samtani, N. C., "Geological Hazards in the Consideration of Design and Construction Activities of the New York Area*", Environmental & Engineering Geoscience*, Vol. IV, No. 4, 1998, pp. 524-533.

Viele, E.L., "Topographic Atlas of the City of New York", 1874.

U.S. Geological Survey, "Fresh Groundwater Withdrawals during 1985", *US Geological Survey National Water Data Storage and Retrieval System*, 1985.

5. GEOLOGICAL FEATURES OF ENGINEERING SIGNIFICANCE

5.1 General Considerations

The principal rock types that will be encountered during construction of the Manhattan segment of the ESA Project possess a variety of geological characteristics. The engineering behavior of the rocks will be a function of the interaction of geological characteristics, environmental conditions and a particular construction activity. This Chapter of the GBR describes the geological features of the rock mass along the CM009 alignment as interpreted from the geotechnical investigations undertaken for this Project. The information presented in this Chapter is considered to be specific to this Project and is directly applicable to the specific Project locations and therefore takes precedence over any published information on general geology of the region presented in Chapter 4. The general occurrence, descriptions, persistence and extent of the characteristics of the rock mass are described below. The physical properties of the rocks are presented, quantified and interpreted in Chapters 8 and 9.

5.2 Mineralogy

The site investigation has recovered core samples of schist, schistose gneiss, gneiss, granofels, amphibolite and pegmatite. All of these rock types, with the exception of amphibolite, contain significant proportions of hard minerals that are abrasive to metal, specifically quartz, garnet, sillimanite, kyanite and andalusite. The amphibolite is relatively scarce but where recovered it tends to be relatively weak and friable.

5.3 Metamorphic Fabric

The dominant metamorphic fabric of engineering significance is the foliation in the schistose rocks and the mineral layering or banding in the gneissic rocks.

The foliation due to alignment of minerals, particularly the platy crystals of mica produces strength anisotropy, which is manifest as preferential splitting along planes formed by the foliation. The full range of strength anisotropy will be encountered, from isotropy to persistent separation in the more intensely folded and faulted areas. The orientation and the frequency of foliation fractures along the tunnel alignment are presented in Chapter 9 of this GBR, shown in Figures 4 and 5, and in the Reference Documents entitled Appendices A-1, A-2, and A-3.

In general the foliation is less pronounced in the schistose gneiss although in places the quartz and feldspar bands are so thick that the rock type between the bands is classified as schist. The gneiss possesses distinct concentrations of quartz and feldspar separated from the mafic minerals. The bands of quartz and feldspar possess a high aggregate hardness and abrasivity because of the reduction in minerals with hardness less than 7 on the Mohs scale.

The granofels has a relatively isotropic fabric and preferential splitting and is less likely to occur in this rock type. The amphibolite has a faint foliation but there is no distinct preferred separation.

5.4 Discontinuities

The discontinuities in the rock mass are the metamorphic fabric and joints caused by tectonic activity and granitization. The quantification and distribution of fracturing throughout the project area are presented in Chapters 8 and 9 of this GBR. The foliation, foliation discontinuities, and other discontinuities exhibit a wide range of spacing values that is typical of this rock which has undergone major tectonic episodes such as folding, faulting and intrusions. Definitions of the spacing terminology are given in Figure 6 of this GBR. Joint clustering is another consequence of the intense tectonic disturbance that this rock has undergone. Joint clusters are defined as several discontinuities of similar characteristics that are spaced closely together (spacings are defined in Figure 6 and the glossary).

The existence of four dominant Joint Sets for the rock mass at the project site have been confirmed by geological mapping of the exposed rock and oriented core borings. However, the dip directions and dip angles are different from the published values presented in Chapter 4 of this GBR and vary across the Manhattan alignment. However, the terminology in defining and numbering of the joint sets as given in Chapter 4 has been followed here. Set 1 is the foliation joints, Set 2 is the steeply dipping joints, Set 3 is the conjugate joint set to the foliation joint Set 1. Set 4 joints are divided into two categories, namely, 4 Low and 4 High, due to their shallow and steep dip directions respectively.

Exposure mapping results are presented in full in Appendix E of the GDR. A summary of the dip angles and dip directions for the joint sets are presented in Table 5-1. Graphical representation of discontinuity data is given in Figures 4 and 5 and the reference documents entitled Appendices A-1 and A-3 (attached). The data presented in Table 5-1 indicate substantial variation in both dip angles and dip directions for the four joint sets.

Table 5-1: Observed Joint Dip Angles and Dip Directions (Range and Mean Values)

Joint Set Attitudes		**Tunnel Stations (Note: STA T402 34+78.06 = STA EB2 1045+37.02 ; STA T402 17+52.50 = STA L402 17+52.50)**							
		EB2 1076+50 to EB2 1084+00	EB2 1066+00 to EB2 1076+50	EB2 1063+00 to EB2 1066+00	EB2 1054+00 to EB2 1063+00	EB2 1052+00 to EB2 1054+00	T402 31+00 to EB2 1052+00	T402 18+50 to T402 31+00	L402 0+75 to T402 18+50
Set 1	**Dip**	**5° to 55°** Mean: 25°	**5° to 75°** Mean: 25°	**5° to 60°** Mean: 30°	**5° to 55°** Mean: 30°	**5° to 65°** Mean: 30°	**5° to 55°** Mean: 25°	**15° to 55°** Mean: 35°	**15° to 60°** Mean: 40°
	Dip Direction	**20° to 360°** Mean: 145°	**0° to 360°** Mean: 155°	**0° to 350°** Mean: 140°	**45° to 310°** Mean: 180°	Not Determined *	**110° to 340°** Mean: 230°	**195° to 300°** Mean: 250°	**135° to 290°** Mean: 220°
Set 2	**Dip**	**65° to 90°** Mean: 75°	**60° to 90°** Mean: 70°	**60° to 80°** Mean: 65°	**60° to 75°** Mean: 65°	**	**65° to 90°** Mean: 80°	**75° to 90°** Mean: 85°	**60° to 85°** Mean: 75°
	Dip Direction	**175° to 225°** Mean: 210°	**105° to 220°** Mean: 175°	**105° to 230°** Mean: 165°	**95° to 215°** Mean: 140°	**	**95° to 225°** Mean: 160°	**155° to 250°** Mean: 190°	**200° to 230°** Mean: 215°
Set 3	**Dip**	**15° to 55°** Mean: 35°	**15° to 60°** Mean: 35°	**30° to 60°** Mean: 50°	**10° to 60°** Mean: 30°	**	**15° to 60°** Mean: 40°	**25° to 50°** Mean: 35°	**5° to 50°** Mean: 30°
	Dip Direction	**30° to 345°** Mean: 270°	**5° to 345°** Mean: 135°	**5° to 325°** Mean: 150°	**10° to 350°** Mean: 25°	**	**335° to 10°** Mean: 355°	**35° to 140°** Mean: 75°	**10° to 130°** Mean: 60°
Set 4 Low	**Dip**	**10° to 40°** Mean: 20°	Not Detected***	Not Detected***	Not Detected***	**	**10° to 40°** Mean: 30°	Not Detected***	**10° to 25°** Mean: 20°
	Dip Direction	**335° to 10°** Mean: 355°	Not Detected***	Not Detected***	Not Detected***	**	**265° to 285°** Mean: 275°	Not Detected***	**300° to 360°** Mean: 320°
Set 4 High	**Dip**	**55° to 60°** Mean: 60°	**55° to 85°** Mean: 70°	**60° to 80°** Mean: 75°	**55° to 70°** Mean: 65°	**	**65° to 85°** Mean: 75°	**85°** Mean: 85°	**70° to 85°** Mean: 75°
	Dip Direction	**335° to 15°** Mean: 355°	**245° to 15°** Mean: 290°	**245° to 5°** Mean: 325°	**265° to 35°** Mean: 315°	**	**295° to 320°** Mean: 305°	**320°** Mean: 320°	**290° to 325°** Mean: 300°

Notes:
* Not Determined: Joint orientation could not be determined because the borings in this reach of the tunnels were not oriented.
** Joint sets other than foliation jointing could not be determined because this reach of the tunnels lie in a shear zone.
*** Not Detected: This joint set was not detected in the borings in the geologic zones indicated.

The most prominent joint set, Set No. 1, corresponds to the plane of weakness formed by the foliation. In general, the dip angles of the foliation joints as determined from the geotechnical investigation conducted for this Project are shallower than the values reported in the literature (as referenced in Chapter 4 of this GBR). From East 38th Street to the north of the GCT (to about 52nd Street), the dip of the foliation is typically west to southwest. From East 52nd to East 56th Street the dip direction is typically south. North and east of East 57th there is intense folding and faulting that produces a highly variable dip direction until approximately East 62nd Street where the dip direction is to the East. Set 1 foliation joints are typically planar to undulating and rough.

The Set 2 cross fabric joints display welding, healing, infill, open aperture, and coating. The Set 2 joints are steeply dipping southeast to southwest. They are typically undulating, rough to very rough with occasional infill of sand and clay and surface staining by iron oxide, particularly close to shear zones and in areas of more intense pegmatite formation. They are more closely spaced near the top of rock and close to previous excavations where they occur in clusters with a much smaller spacing.

The Set 3 joints are conjugate to the foliation joints, dipping to the east beneath Park Avenue and varying in association with the folding and faulting east of Park Avenue. These are a fresh, closed set, typically undulating and rough to very rough with no infill.

The Set 4 joints occur in clusters with a wide variation of dip direction typically to the NW. The dip angle clusters into shallow or steep groups (4 Low and 4 High) and alteration and decomposition appear to be characteristic.

Mapping at Substation 42 located approximately 300 feet east of the Project area and approximately 40 feet below the GCT lower level (under 43rd Street near Lexington Avenue) indicates a 60° to 75° clockwise shift of the foliation dip direction to the northwest as compared to data from the south and west wall mapping undertaken in the GCT lower level. A 35° to 105° clockwise shifts in joint sets 2, 3, 4L, 4H has also been observed. Examination of the jointing frequency and orientations, and joint conditions indicate the presence of a localized fault displacement, however there is insufficient geologic evidence to indicate the orientation and extent of such a fault.

Figure 4 shows stereographic pole plots of dip angles and dip directions of foliation and foliation joints at selected locations (for clarity) along the alignment. The trends (strike) and relative frequencies of occurrence of foliation and joints at selected locations (for clarity) along the alignment are shown in rose diagrams in Figure 5. The entire set of stereographic pole plots of foliation and non-foliation joints is given in the reference document entitled Appendix A-3 (attached to this GBR).

The pegmatite observed at most locations appears to be conformable with the foliation, although a pegmatite vein exposed in the TBM end wall in the 63rd Street Tunnel cuts across foliation. The pegmatite is discontinuous with the metamorphic rock. This discontinuity can be distinctive, mixed, altered, fractured and decomposed. In general, the discontinuity is distinct and not associated with a fracture. However, there are occurrences where the rock has a broken, weathered, altered and sheared margin ranging from one inch to three feet thick. There are occasional occurrences of granofels juxtaposed on the pegmatite that are inferred as baked margins.

The welded joints tend to conform to the joint sets. In some cases there is slight displacement and dissolution. Although the welding is tight, it is an incipient weakness.

Healed joints occur in the breccia. The metamorphic rock and pegmatite have been fractured, dilated, and displaced. The breccia has been bound together by mylonite, quartz and feldspar. These joints are tortuous and do not conform to a joint set.

The Set 3 joints may be infilled with mixed clay, silt, and sand in thicknesses ranging from a coating to 1/4 inch although the typical thickness is 1/16 inch or less. The clay mineralogy has not been determined but chlorite has been visually identified. Infill is rarely associated with evidence of faulting suggesting that the products are not gouge. The infill is from the degradation of the joint walls rather than transported by groundwater through the fractures.

Slickensides have been identified throughout the project area. They tend to form on the Set 1 foliation surface although there are some occurrences of slickensides on non-foliation joints. The slickensides are present as single occurrences or in clusters at inch to foot spacing.

5.5 Faults and Shears

The tectonic history of the rocks has left the rock underlying Manhattan fractured and dislocated. The faults are singular or narrow features with relative displacement of individual planes or groups of planes. The shears range from inch scale features to major regional features.

The published map (Baskerville, 1994) shows the 125th Street Fault approximately 1.5 miles to the north of the Work Site. The 42nd Street fault is shown approximately 1 mile to the west of the Work Site trending NW-SE, and dipping to the SE.

Shear zones occur at various scales, from thin bands on inch scale to regional-scale features. The inch scale features are classified as micro-shears and they are subtle and only noticeable by a distinct zone of weak, friable and extremely fractured rock. These are typical of this rock, occurring throughout the Work Site, with typical thicknesses less than 6 inches. Shear planes identified by the wall mapping retained an undulating profile and rough to very rough surface.

Cording et. al. (1974) states "*If the joint has a polished or slickensided surface it is termed a shear. Shears commonly contain up to ¼ inches clay gouge filling. A shear zone is a zone of fractured rock containing several parallel shears and one or more ½ to 12 inches thick gouge zones. The width of the entire shear zone typically ranges from ¼ inches to 10 ft.*" The clay fraction in the gouge zones predominantly contains montmorillonite or interlayer montmorillonite-chlorite. The shear zones occur in swarms, generally 10 to 50 feet apart and are located near changes in rock type or where the foliation is pronounced.

Minor shear zones are characterized by thicknesses of fractured rock on a one-foot scale with a zone of influence on a 10-foot scale with associated clusters of infilled, stained or mineralized joints and slickensides. These have persistence on the project scale and are likely to be encountered anywhere along the alignment.

Major shear zones are characterized by fractured rock greater than 10-foot scale with a zone of influence on 100-foot scale; with more intense destructive effects. The breccia is distinct and bounded with mylonite. The fractures are healed by quartz and mylonite. The boundary of the breccia and the undamaged rock is distinctive but the zone of influence includes clusters of open infilled and mineralized joints. Shear zones have been identified along the CM009 construction contract alignment in the East 57th Street to East 58th Street area and in the vicinity of East 54th Street. Descriptions of these major shear zones are given in Chapter 9 of this GBR and shown in Figure 3. However, other unidentified shear zones are likely to be encountered along the alignment during construction.

5.6 Pegmatite

Pegmatite is common in the project area and occurs as very thin veins on inch scale to thick layers of massive rock generally in layers parallel to foliation. The thin pegmatite often occurs in clusters of similar thickness that can be continuous over several feet of core. A major pegmatite approximately 15 feet thick dipping to the west exists beneath Park Avenue from East 56th Street to East 52nd Street along the CM009 Construction Contract alignment.

The pegmatite is a relatively strong and competent rock and generally shows a distinctive contact with the host rock, although in places the contact can be mixed.

5.7 Alteration and Decomposition

Although the rocks have conventional schist mineralogy there are minerals, and types of mineralization that indicate alteration after metamorphism. The alteration is related to passage of water, steam and volatile gases through pre-existing fractures in the rock mass. The mineralization includes deposition of chlorite and other minerals on fracture surfaces, dissolution and decomposition of mica and feldspar and growth of epidote.

Decomposition is rare and generally associated with alteration. It is limited to degradation of certain minerals, such as, mica and feldspar. Decomposition has occurred in some extremely fractured zones as the product of weathering rather than alteration. A zone of alteration has been identified along the CM009 Construction Contract alignment from about Third Avenue and East 62nd Street to about East 58th Street. Descriptions of these geologic zones are given in Chapter 9 of this GBR and shown in Figure 3. Other zones similar to this one are likely to be encountered along the alignment during construction.

5.8 Groundwater

The sources of groundwater recharge in Manhattan are surface infiltration, leaking sewers, drains and water lines, and the adjacent East River and Hudson River. On a regional scale, surface water bodies also include the Harlem River and New York Bay.

The network of fractures will control the groundwater conditions for the rock mass. The permeability of the discontinuities will be influenced by several factors including the intimacy of adjacent surfaces, alteration processes that have removed or placed minerals on fracture surfaces, and joint wall material that has been fragmented or crushed by faulting and shearing. These geological processes can increase or decrease the permeability of individual joints. Also, larger scale features, such as mylonite, act as a regional hydraulic barrier whereas major shear zones act as regional storage and conduits for groundwater.

Water levels measured in the borehole standpipes range from 15 feet below street level to less than 5 feet below the invert of the existing lower level of the Grand Central Terminal. The groundwater readings and packer test data are presented in the GDR.

6. MANMADE FEATURES OF ENGINEERING SIGNIFICANCE

6.1 General Considerations

During the construction period of CM009, impacts to the existing structures along the proposed tunnel alignment must be minimized. This includes NYCT structures, MNR structures (GCT and Metro North railroad tunnels), NYC DOT structures (Park Avenue Tunnel and Park Avenue Viaduct) and privately owned properties above or adjacent to, or in the vicinity of the proposed alignment. In the areas where drill-and-blast construction methods are to be used, carefully designed and controlled blasting methods are required by the Specifications to reduce overbreak and to minimize the noise and vibration effect on existing structures. The installation of in-tunnel geotechnical instrumentation is required during construction for the monitoring of ground movement within the tunnels. A monitoring program will also be implemented during construction to measure ground vibrations (peak particle velocity, acceleration, and displacement). Descriptions of the major existing structures are given below. Installation of geotechnical and structural instrumentation for surface structures, NYCT subway tunnels, and air-right structures above GCT in the vicinity of the tunnel excavation will performed under this Contract. Installation of geotechnical and structural instrumentation in the MNR Railroad tunnels and GCT structures will be performed by others. Instrumentation and monitoring is discussed in Chapter 11 of this GBR.

6.2 Grand Central Terminal and Metro North Railroad Facilities

The CM009 tunnel alignment passes directly beneath the MNR Park Avenue tunnel from approximately East 57th Street to GCT. The tunnels continue south under the GCT lower level and its concourse, to approximately East 38th Street. Descriptions of the MNR tunnels and GCT are given in the following sections. These railroad facilities must remain operational during the construction. Portions of the CM009 tunnels are to be enlarged (in future Contracts, except GCT 3 and GCT 5) to their final configurations (station caverns and associated cross passages and shafts, crossover caverns at East 51st Street, tail track wye caverns, ventilation plant structures and shafts at East 55th Street and East 38th Street) under future construction contracts. No final liner is placed in the TBM driven tunnels under this Contract. Therefore the proper and timely installation of adequate initial support is of prime importance. The initial support was designed taking into consideration that the final liner in the TBM tunnels will be placed in a future Contract. The GCT 3 and GCT 5 caverns will however be excavated to their final configuration and final liner will be installed under this Contract.

GCT is used by MNR as the Manhattan terminal for all services originating from the northerly suburban areas. The terminal and its approaches were constructed from 1908 to 1913. The structures for the railroad were constructed in open cut and then decked over for the street crossing locations namely Park Avenue, Vanderbilt Avenue and the various cross streets. Starting at East 60th Street, the existing MNR tunnel is a four track steel framed structure with concrete arches and retaining walls on both sides of the excavation. At East 57th Street, the four tracks branch out to a ten track configuration with four tracks continuing to the lower level, also known as the Suburban Level, and six tracks continuing to the upper or Express Level. At approximately East 52nd Street, the track configurations, using ladder tracks and the associated switches, lead into the various platform and storage tracks that exist on both the upper and lower levels of the GCT. The upper level tracks are supported on an independent steel framed structure with foundation footings founded in rock below the lower level. The various building columns passing through the upper and lower levels of the terminal are founded on separate foundations. There are numerous tunnels and passageways to adjacent buildings. In addition there are numerous utility lines and utility connections throughout the facility.

Beneath the lower level tracks there are cross passages that were constructed to accommodate facilities in support of the railroad operations. These are located at East 48th Street, East 45th Street and East 43rd Street. Additional levels were constructed below the lower level between Lexington Avenue and a point east of Park Avenue and from East 42nd Street to the East 43rd Street area. In recent years MNR constructed the North End Access, which now uses the East 45th Street passageway as part of the GCT passenger circulation system.

At East 45th Street, four existing shafts that once housed hydraulic elevators have been abandoned. The plungers for these elevators and the casings for the in-ground cylinders may or may not have been removed along with the elevators. It is not known whether the plungers and/or casings are made of cast iron, wrought iron or steel. If these plungers and casings still remain in place, the upper level TBM drives are likely to intersect two of these plungers. The locations of these elevators are shown on the Contract Drawings. The Contractor shall be prepared to negotiate the TBMs through these plungers and/or casings, and is not considered to be a differing site condition for the purposes of this Contract.

The CM009 tunnel and ESA track alignment lie beneath the Park Avenue and the MNR underground structure starting at East 57th Street. At East 56th Street all four tunnels will be within the Park Avenue corridor, which is 140 feet wide between building lines. The four-tunnel alignment continues south to East 50th Street where the alignment diverges into an eight-track configuration (parts of this excavation will be executed under future contracts). The ESA terminal station (enlarged to final configuration under future contracts) will be housed in two caverns each accommodating two tracks on each of two levels separated by a mezzanine level. South of the ESA terminal the tunnel alignment will provide for four tail tracks, which will extend south of GCT to East 38th Street. The track profile has been developed to provide a rock cover that ranges from approximately 25 feet to 35 feet between the base of the existing GCT and the MetLife building foundations and the crown of the ESA station cavern arch. The crown of the tunnels to be constructed under Contract CM009 lies approximately 40 feet below the base of the GCT and building foundations.

6.3 New York City Transit (NYCT) Facilities

The approach tunnels, TBM assembly chamber, starter tunnels and the TBM tunnels will be excavated adjacent to or beneath the following NYCT subway lines (crossing locations are shown in Figure 3):

- NYCT 63rd Street Line: Located close to the initial approach tunnels at a minimum distance of 6.5 feet at approximately STA EB2 1083+30, and about 20 feet away from the assembly chamber at approximately STA EB2 1082+25.
- NYCT 60th Street Line: Located above the running tunnels, crossing the alignment at approximately STA EB2 1071+00 at a distance of about 62 feet.
- NYCT Lexington Avenue Line (59th Street): Located above the running tunnels, crossing the alignment at approximately STA EB2 1069+00 (at the north end) at a distance of about 30 feet.
- NYCT 53rd Street Line: Located above the upper running tunnels, crossing the alignment at approximately STA EB2 1050+50 at a distance of about 12 feet.

- NYCT Flushing Line: Located above the upper running tunnels, crossing the alignment at approximately STA L302 11+00 (at the north end) at a distance of about 20 feet.
- NYCT Lexington Avenue Line (38th to 42nd Street): Located above the upper running tunnels approximately between STA L402 2+00 to STA L402 9+50 at a distance of about 60 feet.

Descriptions of each of these facilities are given below. These facilities must remain in operation during the construction. The construction sequencing and initial support has been designed so as not to compromise the structural integrity of these NYCT facilities. The greatest impact of the construction will be on the NYCT 63rd Street Line, due to its close proximity to the approach tunnels and the TBM assembly chamber, and the NYCT 53rd Street Line due to its close proximity to the running tunnels. Controlled blasting methods have been specified for the starter tunnels and assembly chamber, and the East 59th Street wye caverns. Initial support must be installed immediately following excavation.

6.3.1 NYCT 63rd Street Line

The two existing LIRR tunnels that presently terminate at the west side of Second Avenue beneath East 63rd Street, will have been extended approximately 180 LF under a separate construction contract. The two NYCT tunnels were constructed by a TBM and are lined with 18 inches of plain concrete. The two NYCT tunnels were built in a stacked configuration, one above the other, on the south side of East 63rd Street, between the building line and the center of the 60-foot wide street. Initial support consisted of 8" WF steel support members, four feet on center. The existing lower NYCT tunnel (Track T2 Northbound) and the new ESA proposed structure are approximately 6.5 feet apart vertically.

6.3.2 NYCT 60th Street Line

The NYCT 60th Street Line is an east-west two track line beneath East 60th Street. The NYCT structure at the CM009 tunnel crossing location was built by drill and blast construction. The NYCT structure within the limits of the East 59th Street Lexington Avenue Line station is a two-track island platform with an overhead mezzanine. The NYCT 60th Street Line tracks are approximately 56 feet below the surface of East 60th Street and approximately 62 feet above the CM009 tunnels and proposed ESA structure.

6.3.3 NYCT Lexington Avenue Line (59th Street)

The NYCT Lexington Avenue Line is a four-track line, consisting of two local and two express tracks. The CM009 tunnel alignment will cross beneath the Lexington Avenue Line between East 59th Street and East 60th Street. At this location the Lexington Avenue line has a station stop, the East 59th Street Station, for both the local tracks on the upper level and the express tracks on the lower level. Both levels have two side platforms. The local tracks are, approximately, 31 feet below the street surface of Lexington Avenue. The station structure was constructed using cut and cover methods. The express level tracks are approximately 86 feet below the street surface. The station stop for the express level was constructed in the 1950's by enlarging the original drill and blast tunnels by mining out (also by drill and blast) the rock to create the space for the two side platforms and the passenger connections to the local level. The CM009 tunnels and ESA proposed structure is approximately 30 feet below the NYCT express tracks.

6.3.4 NYCT 53rd Street Line

The NYCT 53rd Street Line is a two track east-west line running beneath East 53rd Street. The portion of the NYCT line that crosses beneath Park Avenue and MNR tracks was constructed by drill and blast tunnels. In this area the track profiles transition from a side by side alignment at the Lexington Avenue Station to a stacked alignment at the Fifth Avenue Station. The rock tunnels are lined with 13 inches of concrete. The distance between the NYCT 53rd Street EB Track # 5, the lower of the two tracks, and the upper CM009 tunnels and proposed ESA structure is approximately 12 feet.

6.3.5 NYCT Flushing Line

The NYCT Flushing Line, also known as the #7 Line, is a two track east-west line running beneath East 42nd Street. Directly above where the CM009 tunnels (ESA tail tracks) cross beneath the Flushing Line, the NYCT structure was constructed as a rock tunnel which houses an island platform. West of Park Avenue and above the CM009 alignment and the Flushing Line is the 42nd Street-Grand Central Shuttle Station with a three track two island platform configuration. This structure is part of the original subway line, historical Contract No. 1, and was placed into operation in 1904. A connecting passageway to the Lexington Avenue Line's Grand Central Station crosses beneath Park Avenue. The distance between the Flushing Line and the ESA upper tail tracks is approximately 20 feet.

6.3.6 NYCT Lexington Avenue Line (East 38th to East 42nd Street)

The CM009 alignment will provide tail tracks located beneath Park Avenue extending to East 38th Street. Along this same corridor, the NYCT has four tracks of the Lexington Avenue Line, a single connecting track that leads to the 42nd Street Shuttle, and abandoned tracks from the construction of Contract No. 1 built in 1901 to 1904. The original Contract No. 1 alignment was a four-track subway beneath Park Avenue that curved westerly and continued beneath East 42nd Street. In the 1920's the alignment beneath Park Avenue was reconstructed to reroute the line to Lexington Avenue. The present day NYCT Grand Central Station is located on the diagonal leg of the modified alignment. The Contract No. 1 tracks beneath East 42nd Street were converted into the 42nd Street Shuttle. A connecting track, tying into the Lexington Avenue South Bound Local track, was maintained to provide access for the trains onto the shuttle tracks. The remainder of the Contract No. 1 structures housing trackage no longer needed for service were either abandoned or reused as support areas. The distance between the existing NYCT tracks and the proposed ESA upper tail tracks (CM009 tunnels) structure ranges from 75 feet at East 38th Street to 60 feet at East 41st Street. The NYCT tracks are approximately 53 feet below the surface at East 38th Street and 50 feet at East 41st Street.

6.4 Buildings

Land use along the CM009 alignment is mixed, including but not limited to high-rise office buildings, residential structures, health care facilities, houses of worship, and hotels. North of East 42nd Street, between Fifth and Third Avenues and north to East 60th Street is the heart of the East Midtown office district. East of Third Avenue, the land use is generally residential. The area along East 42nd Street, south of and including GCT, is densely developed with large office buildings and residential buildings. Several high rise buildings rise directly above the GCT, including the Helmsley Building and the MetLife building. The area along Park Avenue, from GCT to East 59th Street is marked by tall office buildings containing corporate headquarters for companies such as Chase Manhattan Bank, Westvaco, and Bankers Trust. Side streets to the east and west of Park Avenue contain buildings of relatively smaller scale. Also located along this corridor, are historic landmark structures identified in the Specifications and drawings of this Contract.

Eastwards around Second Avenue are several of the city's prestigious residential neighborhoods, including Treadwell Farms. Residential development includes townhouses and brownstones, high-rise apartments, and walk-up apartments. The southern portion of East Midtown between East 34th Street and East 40th Street, and centered on Park Avenue is a residential area known as Murray Hill. However, areas to the east and west of Park Avenue contain commercial properties.

A building condition assessment survey along the ESA alignment has been implemented during the design process. Emphasis was placed on buildings within the influence zone of the drill and blast sections. The existing buildings' susceptibility to possible impacts due to the construction methods proposed for the CM009 tunnels and ESA structures was assessed during this process. Generally, the limit of the survey was 200 feet from the planned excavation limits of the rock tunnels and related structures (crossovers, wye structures, GCT caverns). Façades for buildings five stories or less were inspected from the public right of way. For structures six stories and higher, available Technical Façade Reports from the New York City Department of Buildings in accordance with Local Law 11, were reviewed. Interiors of the basements of a number of buildings adjacent to and above the drill and blast areas were inspected, depending on accessibility constraints. Based on the information obtained for the properties inside the 200 feet influence zone, a general condition assessment of good, fair or disrepair was determined for the building façades. Results of the condition survey are provided as Reference Documents for this Contract.

The Resident Engineer will conduct a pre-construction survey along the CM009 tunnel alignment. Pre-construction documents will be provided to the Contractor for review. If required, the Contractor may further document the condition of these buildings before commencement of tunneling work.

The Contractor should review the conditions of the buildings and provide additional instrumentation and monitoring as deemed necessary, and as reviewed by the Resident Engineer. Of special note is a highly sensitive residential area at East 63rd Street and Second Avenue (Treadwell Farms), which will require special measures in terms of ground vibration, airblast, and drilling noise limits, in addition to monitoring for settlements. Construction methods, sequencing, and initial support are shown on the Contract Drawings and described in Chapter 10 and in the Specifications, so as to limit any ground settlements in the vicinity of the foundations within specified limits.

6.5 DOT Structures

Two NYC DOT structures overlie the tail tracks area of the ESA project: namely the Park Avenue Viaduct and the Park Avenue Tunnel.

The portion of the Park Avenue Viaduct affected is an elevated structure from East 42nd Street to East 40th Street along Park Avenue with two-way traffic running in the north-south direction. The structure consists of a three span steel arch bridge (B.I.N. 2-24655-0, 2-24546-0, and 2-24547-0) with spans approximately 109 feet in length, two reinforced concrete piers located between East 42nd and East 41st Streets and an approach runway from East 41st Street to East 40th Street. The viaduct at East 42nd Street is connected to the southbound and northbound roadway structure that surrounds GCT and the Met Life building.

The Park Avenue Tunnel is a two-lane roadway beneath Park Avenue that runs from East 40th Street to 33rd Street carrying two-way traffic in the northbound and southbound directions.

6.6 Utilities

A utility mapping of specific areas above the Manhattan Segment directly affected by construction activities was prepared. Utilities were surveyed at East 38th Street, East 55th Street, MNR's 45th Street cross-passageway, and 43rd Street tunnel (Burma Road). The location of these utilities can be found in the reference drawings for this Contract. While construction of the CM009 Contract is not likely to directly affect these utilities, the Contractor must nevertheless be aware of their existence and care shall be taken to avoid any damage to these utilities, as required by the Specifications.

7. PREVIOUS CONSTRUCTION EXPERIENCE

7.1 General

This Chapter gives a listing of past and present tunneling projects in New York City involving both tunnel boring machine and drill-and-blast methods that are considered applicable to the CM009 Contract. Summaries of most of these projects including pertinent quotations from these documents that are applicable to the CM009 Contract are presented in a separate memorandum entitled, "Previous Construction Experience in Manhattan", which is a Reference Document for this Contract. Contractors are encouraged to read the complete published documents in addition to the memorandum. Contractors are charged with knowledge of all Reference Documents. Some of these Reference Documents contain information from projects that were completed several years earlier. These documents should therefore be reviewed in light of current construction practice and improved ground characterization, construction materials and equipment, and changes in regulatory requirements and public awareness. In addition, the Reference Document on the excavations carried out under Contract CM016 should also be reviewed.

7.2 Published Information from Past TBM Tunneling Projects in New York City

Six instances of tunnel excavation using tunnel boring machines in New York City have been found, namely:

- Construction of NYCTA 63rd Street Subway Line, Route 131-A, Section 5B
- Construction of the Brooklyn Tunnel, a part of NYCDEP City Water Tunnel No. 3, Stage 2.
- Construction of the Queens Tunnel, a part of NYCDEP City Water Tunnel No. 3, Stage 2
- Construction of a portion of the North River Intercepting Sewer Project, NYC Environmental Protection Administration, Department of Water Resources (presently, NYC DEP)
- Construction of a steam distribution tunnel for Con Edison, located on First Avenue in Manhattan between East 20th and East 36th Streets.
- Construction of the Manhattan portion of NYCDEP City Tunnel No. 3, Stage 2.

The reader's attention is drawn to the following published information regarding the tunnel boring machine excavation experiences on the above projects (these are Reference Documents). Relevant discussions with quotes can be found in the reference memorandum mentioned above. The steam distribution tunnel mentioned above has been recently completed and the Manhattan Leg of the NYCDEP City Tunnel No. 3 is under construction at the time of this writing. Very little substantial published information is available on the construction of these tunnels at this time.

- Ziegler, G. and Loshinsky, M., "Rock Tunneling and Rock Excavation in New York City, Methods, Problems, Innovations", *Proceedings of the Rapid Excavation and Tunneling Conference*, 1979.
- Ziegler, G. and Loshinsky, M., "Tunneling Under City Streets with Tunnel Boring Machine, Route 131-A Section 5B", *Proceedings of the Rapid Excavation and Tunneling Conference*, 1981.
- Loshinsky, M., "Tunneling Case Histories, New York City and Environs, Construction Aspects", *Foundations Soil and Mechanics Group Construction Seminar, ASCE Metropolitan Section*, New York, December 6, 1983.

- Liguori, G., Feddock, E., Bach, T., "Tunnel Boring Machine Operations on the East 63rd Street Subway Line", *Alternate Methods of Tunnel Construction Seminar, ASCE Metropolitan Section*, New York, February 2-3, 1981.
- Del Vescovo, A., and Rosteck, J.W., "Construction of City Tunnel No. 3, Stage 2 from Brooklyn to Queens", *Proceedings of the Rapid Excavation and Tunneling Conference*, 1997.
- Schnock, E.M., "Case History-Excavation of the Brooklyn Tunnel", *International Journal Of Rock Mechanics and Mining Sciences*, Vol. 34, No. 3-4, Paper No. 272, 1997.
- Chesman, S.C., Steiner, J.C., and Isaacs, L., "Microstructural Study of Tonalitic Gneisses Exposed by TBM-Mining of New York City's Third Water Tunnel", *International Journal Of Rock Mechanics and Mining Sciences*, Vol. 34, No. 3-4, Paper No. 052, 1997.
- Schnock, E.M., "Construction of the Brooklyn Tunnel", Mega Projects, ASCE Metropolitan Section, Construction Division Annual Seminar, February 1999.
- Khalighi, B.B., and Diehl, J.J., "High Performance Tunnel Boring Machine for Queens Water Tunnel No. 3: A Design and Case History", *Proceedings of the Rapid Excavation and Tunneling Conference*, 1997.
- Dowey, E.M., "Concreting the Queens Tunnel, New York City Water Tunnel No. 3", *Proceedings of the Rapid Excavation and Tunneling Conference*, 2001.
- McCusker, T.G., and Dietl, B., "Small Diameter Tunnels in Manhattan Schist", *Proceedings of the Rapid Excavation and Tunneling Conference*, 1974.
- Cooper, M., and Sigman, S., "Material Handling in Urban Areas", *Proceedings of the Rapid Excavation and Tunneling Conference*, 1974.

7.3 Published Information from Past Drill-and-Blast Tunneling in New York City

Drill-and-blast construction experience is also relevant to the CM009 Contract, which requires this type of construction for the approach tunnels, assembly chamber and adjoining starter tunnels, GCT 5 wye cavern and adjoining starter tunnels, GCT 3 wye caverns, cross passages, central instrument room, and cross flue. Published material that has been found relating to the drill and blast construction in New York City that is relevant to the CM009 Contract is listed below (these are Reference Documents). The papers describe the nature of rock in Manhattan and there are several indications relating to the shear zone predicted around 58th Street along the alignment. The paper by McCusker and Dietl (1974, above), also describe the authors' experience in conducting drill and blast excavation adjacent to existing operating structures. Discussions of this experience with pertinent quotes can be found in the reference memorandum as mentioned earlier.

- Fisher, P.B., "The Subway Under Central Park, Route 131A – Sections 2 & 3", Paper No. 490, MTA.
- Werbin, I.V., "Tunnel Work on Sections 8, 9, 10, and 11, Broadway-Lexington Avenue Subway, New York City", *Transactions of the American society of Civil Engineers, Paper No. 1388*, Presented at the meeting of September 20, 1916.
- Interborough Rapid Transit Company, "The New York Subway – Its Construction and Equipment", New York, 1904, http://www.nycsubway.org/irt/irtbook/.
- Guertin, Jr., J.D., and Plotkin, E.S., "Observation of Construction Behavior of a Major Rock Tunnel", *Proceedings of the Rapid Excavation and Tunneling Conference*, 1979.
- State of New York, Public Service Commission, "The Dual System of Rapid Transit", New York City, 1913, http://www.nycsubway.org/dual/newsubways.html.
- Lavis, F., "The New York Rapid Transit Railway Extensions", *Engineering News*, 1914, http://www.nycsubway.org/dual/engnewsdc.html.
- Almeraris, G.A., Peyton, T.F., and Plotkin, E.S., "High Speed Tunneling Beneath the Streets of Manhattan", *Proceedings of the Rapid Excavation and Tunneling Conference*, 1985.

8. PROPERTIES OF SUBSURFACE MATERIALS

8.1 General

The engineering properties of the rock mass and the rock material to be encountered during excavation have been evaluated from the results of in-situ testing in exploratory boreholes and laboratory tests on the rock core. Detailed test results are presented in the GDR.

8.2 In-situ Testing

The in-situ testing in exploratory boreholes comprised 11 hydraulic fracture tests, 27 borehole dilatometer tests and 7 borehole televiewer surveys.

8.2.1 Hydraulic Fracturing Tests

Hydraulic fracturing tests were conducted to determine the magnitude and direction of the local in-situ stress field. The details of the test method and the results are presented in the GDR.

The measured vertical stresses, maximum and minimum horizontal stresses, and in-situ stress ratios (maximum horizontal stress to vertical stress against test depth) are presented in the GDR. The measured vertical stresses are higher than the equivalent overburden weight due to surcharge loads from overlying building column footings and Metro-North Railroad facilities. The in-situ stress ratio, k_o ranges from 1.4 to 3.2. However, stress relief due to previous construction, building loads and rock mass anisotropy may have influenced the results.

8.2.2 Borehole Dilatometer Tests

Borehole dilatometer tests were conducted to evaluate the in-situ elastic modulus. The details of the test method and the results are presented in the GDR. The test depths range from 18 feet to 107 feet below Metro North track level. The most probable observed range of in-situ modulus is 1000 Ksi to 5000 Ksi.

Elastic modulus values obtained from laboratory tests on intact rock specimens are higher than the in-situ modulus obtained from in-situ Dilatometer tests. The difference is attributable to the size of the core sample tested and the effect of discontinuities in the rock mass.

8.3 Laboratory Testing on Rock Core

8.3.1 Types and Number of Tests

A large number of rock cores have been tested in the laboratory for the determination of engineering properties of the rock material. In addition laboratory tests have been conducted on rock core to estimate TBM performance indices along the alignment. The complete set of the results of laboratory tests on rock core is presented in the GDR. A summary of the type and number of laboratory tests that have been conducted is given in Table 8-1.

Table 8-1: Types and Number of Laboratory Tests

Test Type	Number of Tests	Conducted by
Index and Strength Tests:		Colorado School of Mines
Density (pcf)	127	
Uniaxial Compressive Strength (UCS) (psi)	126	
Brazilian Tensile Strength (BTS) (psi)	124	
Point Load Strength Index (PLSI)	116	
Punch Penetration Index	6	
Rock Joint Direct Shear (psi)	23	
Elastic Property Tests:		
Static Elastic Modulus (ksi)	110	
Dynamic Elastic Modulus (ksi)	108	
Seismic Velocities – P-Wave (ft/sec)	108	
Seismic Velocities – S-Wave (ft/sec)	108	
Schmidt Hammer Tests	38	
Abrasivity, Wear, and Mineralogy Tests:		
Cerchar Abrasivity Index	136	
Thin Section Petrography	133	
TBM Performance Indices:		SINTEF, Trondheim
Density (gm/ft^3)	15	
Brittleness	15	
Flakiness	15	
Compaction Index	15	
Abrasion Value	15	
Abrasion Value Cutter Steel	15	
Siever's J Value	15	
Calculated Indices (DRI, CLI, BWI)	15	
Thin Section Petrography	16	

8.3.2 Engineering Properties of Rock

Results of laboratory tests conducted on the rock material have been analyzed by frequency of occurrence and presented in histogram form in the reference document entitled Appendix B attached to this GBR. Presentation of the data in frequency form allows the estimation of the range of each property that is anticipated to be encountered during excavation (Table 8-2).

Examination of the laboratory test results indicates that the engineering property values do not show a significant variation in range across the project alignment or between rock types. Therefore, the baseline ranges for each parameter are considered applicable to the entire project alignment.

The uniaxial compressive strength, Brazilian tensile strength, and point load index data are separated to account for the effects of metamorphic fabric on ultimate strength. Test values that have been influenced by metamorphic fabric, mica concentrations, mineral veins or other features are classified as structural failures and do not represent the maximum value for the rock material. Test values that have not been influenced by such features are classified as non-structural failure. The data for pegmatite fall within the range for the metamorphic rocks, and have therefore not been differentiated.

8.4 Ranges of the Engineering Properties of Rock

The anticipated most probable range for each engineering property is presented Table 8-2. The maximum and minimum observed values of the properties, representing the range of test results are also presented.

Table 8-2: Engineering Properties of Rock Based on Laboratory Tests

Property	Most Probable Range of Values		Minimum and Maximum Test Values	
	Failure Type	**Most Probable Range**	**Minimum Test Value**	**Maximum Test Value**
Density and Strength Properties				
Density (air-dried)		170 pcf – 180 pcf	158 pcf	184 pcf
Uniaxial Compressive Strength (UCS)	Structural Failure	4000 psi – 16000 psi	2751 psi	19686 psi
	Non-structural Failure	7000 psi – 22000 psi	6540 psi	28177 psi
Brazilian Tensile Strength (BTS)	Structural Failure	600 psi – 1700 psi	490 psi	1764 psi
	Non-structural Failure	800 psi – 2300 psi	357 psi	2550 psi
Point Load Strength Index (PLSI)	Structural Failure	100 psi – 750 psi	71 psi	1242 psi
	Non-structural Failure	150 psi – 1280 psi	64 psi	1281 psi
Elastic Properties				
Static Elastic Modulus		4400 ksi – 9900 ksi	1567 ksi	14626 ksi
Dynamic Elastic Modulus		6040 ksi – 10000 ksi	3037 ksi	10059 ksi
P-wave velocity		14000 ft/sec – 18000 ft/sec	9811 ft/sec	18270 ft/sec
S-wave velocity		8500 ft/sec – 10400 ft/sec	5886 ft/sec	10400 ft/sec
Quartz, Garnet/Almandine, Hard Mineral Contents and Abrasivity				
Quartz content		10% - 60%	4%	95 %
Garnet/Almandine		0% - 10%	0%	17%
Hard mineral content*		1% - 8%	1%	30%
Cerchar Abrasivity Index		2.7 – 5.2	1.7	5.2
TBM Performance Indices as determined by SINTEF				
Drilling Rate Index (DRI)		48 – 58	34	58
Bit Wear Index (BWI)		30 – 42	30	62
Cutter Life Index (CLI)		5 – 21.5	4.9	21.5

* Minerals with Mohs' hardness equal to or greater than 7 excluding quartz, garnet/almandine

9. ANTICIPATED GROUND CONDITIONS

9.1 General

The anticipated characteristics of the rock mass that will be encountered during the construction are presented in this Chapter. Engineering properties of the rock material are presented in Chapter 8 of this GBR. Anticipated behavior of the rock mass during construction of the tunnels under the CM009 Contract is presented in Chapter 10 of this GBR.

Geologic characteristics of the rock mass along the alignment are very complex and variable. The rock mass characteristics have been generalized and presented as several geologic zones along specific tunnel reaches, identified by Station numbers, based on the field investigations and laboratory testing data, (Figure 3, Geologic Zones and Summary Descriptions). Although some specific characteristics are observed within each geologic zone, they are not unique only to that geologic zone, and similar characteristics can be found in other geologic zones throughout the alignment. Since the geologic zones are developed from boring information, the boundaries of each geologic zone are very approximate and are shown for simplicity in presentation.

It is known that foliation shear zones exist in this rock mass and it is anticipated that they will be encountered along the alignment at random intervals. Although the borings were reasonably spaced, they have not encountered all the shear zones and results do not preclude their existence.

9.2 Geologic Interpretation

The interpretation of the characteristics of the rock mass and ground conditions is based on the boring data for the project supplemented by field mapping and archive information as presented in the GDR. The discussion of the site investigation, including the core logging methods, core orientation measurements and discontinuity classification are presented in the GDR. The definitions of joint spacing terms are included in Figure 6, Sheets 1 and 2, Rock Classification System Terminologies, and the Glossary. Foliation spacing data are compiled in the Reference Document entitled Appendix A-2 (attached to this GBR).

9.3 Rock Mass Classification

The rock mass along the alignment has been classified using the Q and RMR classification systems. Definitions for rock classification terms are presented in Figure 6 (Sheets 1 and 2) of this GBR. The Q and RMR analyses included in the reference document entitled Appendix C (attached to this GBR) are for the rock core only. For this project, a pervasive three joint set system is assumed as a minimum. In determining the estimated range of Q values, precedence has been given to the values in boreholes nearest to the CM009 alignment and to values nearest to the tunnel horizon. RMR values have generally been calculated from the “Q” values using the equation: RMR=15 Log Q+50.

The anticipated range of Q and RMR values for each geologic zone is presented in the following sections.

9.4 Groundwater Levels

Groundwater levels have been measured in observation wells installed along the project alignment. The standing water level readings are included in the GDR and summarized here in Table 9-1.

9.5 Permeability

The coefficient of permeability has been derived from packer tests conducted in boreholes along the alignment. Detailed packer test data are included in the GDR.

The coefficient of permeability derived from the packer tests is given as a range for each geologic zone. However, the volumetric inflow will be controlled by the aperture of discrete fractures, as well as joint surface conditions, character of filling materials and tortuosity. These discrete fractures were not necessarily straddled by the injection length or activated during the test.

Table 9-1: Standing Water Levels

Geologic Zone (Identified by Tunnel Reach) **(Note: STA T402 34+78.06 = STA EB2 1045+37.02** **STA T402 17+52.50 = STA L402 17+52.50)**	**Depth to standing water (ft)** **(bgl: below ground level)**
STA EB2 1076+50(±) to STA EB2 1084+00(±)	20ft bgl at STA EB2 1076+50 to 13ft bgl at STA EB2 1084+00
STA EB2 1066+00(±) to STA EB2 1076+50(±)	10ft below ground level
STA EB2 1063+00(±) to STA EB2 1066+00(±)	20ft below ground level
STA EB2 1054+00(±) to STA EB2 1063+00(±)	20ft below street level and 5ft below the Metro North Railroad track level
STA EB2 1052+00(±) to STA EB2 1054+00(±)	5ft below the Metro North Railroad track level
STA T402 31+00(±) to STA EB2 1052+00(±)	5ft below the Metro North Railroad track level
STA T402 18+50(±) to STA T402 31+00(±)	5ft below the GCT track level
STA L402 0+75(±)** to STA T402 18+50(±)**	5ft below the GCT track level and approximately 50ft below Park Avenue to the south of the GCT

The anticipated most probable range of coefficient of permeability for the rock mass is 10^{-5} cm/sec to 10^{-7} cm/sec except in the shear zones. The geotechnical investigation program has identified major shear zones between approximately STA EB2 1063+00 to STA EB2 1066+00 (discussed in Section 9.7.3), and the western area of the tunnel reach between approximately STA T402 31+00 to STA EB2 1052+00 (discussed in section 9.7.6), where the ranges are 10^{-4} cm/sec to 10^{-6} cm/sec. However, additional shear zones are anticipated to be encountered along the alignment at random intervals and is expected to have permeability of a comparable range to the identified shear zones.

It is also anticipated that throughout the alignment, there are very widely spaced open steeply dipping fractures with an associated coefficient of permeability of 10^{-4} cm/sec and these fractures will transmit water at velocities greater than the indications of the permeability tests.

The fractures displaying alteration that are characteristic of the geologic zone between approximately STA EB2 1066+00 to STA EB2 1076+50 have an associated coefficient of permeability of 10^{-5} cm/sec. These fractures are infilled with clay and other deposits. Flowing water can remove this material and is likely to result in an aperture of the rock with permeability of the order of 10^{-2} cm/sec. Unidentified additional zones where fractures display alteration are anticipated to be encountered along the alignment at random intervals.

9.6 Overburden Characteristics

The thickness of overburden beneath the project site ranges from 0 feet to 58 feet below the existing ground surface. The general sequence of overburden material encountered along the project site, defined as Strata 1 through 3, is given below. The presence or absence and extents of each of the strata in specific geologic zones, along with detailed descriptions, are given in later sections of this Chapter.

Stratum 1 – Fill:	Heterogeneous mixture of mostly sand, with silt, gravel, and miscellaneous debris such as rock fragments, concrete, cinders, and roots.
Stratum 2 – Glacial Till:	Cohesive, poorly sorted heterogeneous mixture of clay, sand, silt and gravel intermixed with fluvio-glacial and reworked deposits.
Stratum 3 – Decomposed Rock:	Gray and black, very stiff to hard silt, clay and sand with relict structure of the parent rock.

9.7 Rock Mass Characteristics

This section describes the rock mass characteristics that are expected to be encountered during excavation of the tunnels. Rock mass characteristics are presented in geologic zones defined by specific tunnel reaches with approximate Station numbers and are based upon the interpretation of the geotechnical data. RQD values have been presented in terms of the range observed in each geologic zone and weighted average RQD values have been given based on observed RQD values at the elevation of the excavations. Joint spacings are defined in Figure 6.

9.7.1 STA EB2 1076+50(±) to STA EB2 1084+00(±)

The depth to bedrock ranges from 0 feet to approximately 30 feet below the existing ground level. Stratum 2 was not encountered.

Stratum	Thickness	Description
1: Fill	0 – 20 feet	Mixture of reddish brown to greenish gray fine to medium sand, little to some silt, trace fine gravel and micaceous, SW and SM, N-value range 6 to >100, typically 15-25.
2: Glacial Till	0 feet	Absent.
3: Decomposed Rock	0 – 10 feet	Gray coarse to fine sand, little fine gravel decomposed mica schist), N-value range 10 to > 100.

The rock types are foliated garnetiferous schistose gneiss, and gneiss with approximately 10% granofels. The essential minerals are interlocking quartz, feldspar and mica with trace quantities of sillimanite, kyanite, apatite and clinopyroxene. The rock mass has moderately to very widely spaced joints, widely spaced clusters of closely spaced joints, very widely spaced thin seams of moderately to highly weathered rock and very widely spaced micro-shears.

During the prosecution of Contract CM016, two horizontal borings were drilled along the EB2 and WB1 alignments from the existing tunnel stubs at 63rd Street and Second Avenue. Details of these borings can be found in the Reference Documents for the CM009 Contract. The borings indicated a possible 10-foot thick fault zone in the WB1 tunnel at approximately STA WB1 1082+88(±) (with 0% recovery and 0% RQD) and traces of this fault zone appear to be present in the EB2 tunnel at approximately STA EB2 1083+33(±).

The average depth of the tunnels below the street surface in this geologic zone is 120 feet. The anticipated typical range of rock mass properties and rock mass classification values for this geologic zone along the tunnel alignment are as follows:

RQD Range:	55% to 95% ; Weighted Average RQD: 91%
Q-value Range:	1.5 to 25
RMR Range:	53 to 71

9.7.2 STA EB2 1066+00(±) to STA EB2 1076+50(±)

The depth to bedrock ranges from 0 feet to approximately 41 feet below the existing ground level.

Stratum	Thickness	Description
1: Fill	0 – 38 feet	Mixture of brown to light brown medium to fine sand, little clayey sand, with brown to grayish brown Clay and Silt, trace of roots and trace cinders, SP, SM, ML, and CL-ML, N-value range 2 to >100 but typically 7-25.
2: Glacial Till	0 – 20 feet	Yellowish brown to dark brown clayey silt with fine sand and gravel, SM or ML or CL, N-value range 3 to 28 but typically 9-15.
3: Decomposed Rock	0 – 10 feet	Gray clayey silt and coarse to fine sand, completely weathered mica schist, N-value typically > 100.

The rock types are foliated garnetiferous schistose gneiss, gneiss with approximately 5% granofels and less than 5% amphibolite that occurs up to 3 feet thick that is friable to decomposed. The rock is characterized by alteration, folding and dislocation. The essential minerals are interlocking quartz, feldspar and mica with accessory garnet and trace quantities of chlorite, epidote, sillimanite, kyanite, apatite and clinopyroxene.

The foliation shows a westerly dip to the west of Lexington Ave and an easterly dip to the east of Lexington Avenue. A major fold axis is postulated between Lexington and Third Avenue with subordinate and parasitic folding. The rock mass comprises very closely to closely spaced foliation fractures and closely to very widely spaced joints. The moderately spaced discontinuities contain alteration minerals such as epidote and joint surfaces are coated with chlorite and other clay minerals. The fractures are often welded and healed by the alteration.

The average depth of the tunnels below the street surface in this geologic zone is 115 feet. The anticipated typical range of rock mass properties and rock mass classification values for this geologic zone along the tunnel alignment are as follows:

RQD Range:	55% to 95% ; Weighted Average RQD: 88%
Q-value Range:	0.1 to 20
RMR Range:	35 to 70.

9.7.3 STA EB2 1063+00(±) to STA EB2 1066+00(±)

The depth to bedrock ranges from 0 feet to approximately 46 feet below the existing ground level.

Stratum	Thickness	Description
1: Fill	0 – 24 feet	Brown to light brown medium to fine sand, little clayey sand, with brown to grayish brown Clay and Silt, trace of roots and trace cinders, SM, ML, and CL-ML, N-values from 7 to 34, typically 7-15.
2: Glacial Till	0 – 20 feet	Yellowish brown to dark brown clayey silt with fine sands and gravel, SM or ML or CL, N-value from 3 to 28 typically 9-15.
3: Decomposed Rock	0 – 6 feet	Gray clayey silt and coarse to fine sand, completely weathered mica schist, N value typically > 100.

The rock types are foliated garnetiferous schistose gneiss, gneiss, granofels and pegmatite. The rock is heavily brecciated in places and the fragments have been bound in a weak to moderately strong mylonite and healed by quartz veins. The rock is characterized by alteration, folding and dislocation. The essential minerals are interlocking quartz, feldspar and mica with accessory garnet and trace quantities of chlorite, epidote, sillimanite, kyanite and apatite.

A major shear zone east of Park Avenue intersects the project alignment between East 57th and East 58th Street. The general trend of the shear zone is approximately NNW. The effects of shearing are identified in the geologic zone between STA EB2 1063+00 and STA EB2 1066+00. The shearing and folding described in the adjacent geologic zone has created a complex and variable discontinuity system.

The rock surface has been incised by surface water along the shear zone due to its lower resistance to erosion. There is penetrative decomposition up to 15 feet thick below estimated top of rock demonstrating that the rock mass has a greater permeability and lower durability in this zone in comparison to the rock mass in adjacent geologic zones.

There is a high proportion of pegmatite in this geologic zone that occupies the full face of the tunnels in places. The boundary of the shear zone is transitional and there are smaller scale shears and discontinuities with slickensides beyond the geologic zone.

There is a high proportion of granofels in this geologic zone and this is the strongest rock that will be encountered during construction. The granofels occupies the full tunnel face in places and the strength classification is very strong to extremely strong.

The rock changes with depth from decomposed to slightly weathered. There are alteration effects of decomposition, dissolution and mineralization. The alteration products include chlorite, calcite, iron oxides and sulfides on fracture surfaces. At tunnel level the discontinuities are very closely to moderately spaced, although the abundance of healed fractures have the potential to form closer discontinuity spacing due to construction stresses.

The complexity of the shearing has created commingling of the rock types. Due to the brecciated and healed nature of the rock, adequate lengths of rock core samples could not be recovered for testing. Proximate data are used as a baseline where specific data are considered to be insufficient or inappropriate.

The average depth of the tunnels below the street surface in this geologic zone is 107 feet. The anticipated typical range of rock mass properties and rock mass classification values for this geologic zone along the tunnel alignment are as follows:

RQD Range:	45% to 95%; Weighted Average RQD: 61%
Q-value Range:	0.05 to 1
RMR Range:	30 to 50.

9.7.4 STA EB2 1054+00(±) to STA EB2 1063+00(±)

The depth to bedrock ranges from 0 feet to approximately 40 feet below the existing ground level. Stratum 2 was encountered on the east side in boring MA-303.

Stratum	Thickness	Description
1: Fill	0 – 24 feet	Mixture of brown silty sand with rock fragments, loose to very dense, and sandy gravel with little silt, greenish brown silty clay, SM, GM , SW-SM, and CL-ML, N-values 2 to >100 but typically 4-30.
2: Glacial Till	0 – 26 feet	Yellowish brown to dark brown clayey silt with fine sands and gravel, SM or ML or CL, N-value range 6 to 35, typically 15.
3: Decomposed Rock	0 – 19 feet	Schist fragments, N-value range 20 to 78.

This geologic zone comprises garnetiferous schist, gneiss and granofels, a significant thickness of amphibolite in the vicinity of East 55th Street and a major 10-foot to 15-foot thick pegmatite zone dipping to the west across Park Avenue.

The rock mass includes occasional open, infilled and slickensided fractures. There are occasional micro shears and weathering and alteration products typical for this rock type such as epidote, calcite and chlorite. In general the joints are closely to moderately and moderately to widely spaced but there are distinct sub domains of lower quality rock, characterized by clusters of very closely spaced fractures and persistent steeply dipping infilled fractures.

The average depth of the tunnels below the street surface in this geologic zone is 112 feet and 95 feet below Metro-North Railroad (MNR). The anticipated typical range of rock mass properties and rock mass classification values for this geologic zone along the tunnel alignment are as follows:

RQD Range:	55% to 100%; Weighted Average RQD: 91%
Q-value Range:	0.5 to 60
RMR Range:	45 to 77.

9.7.5 STA EB2 1052+00(±) to STA EB2 1054+00(±)

The depth to bedrock ranges from 0 feet to 44 feet below the existing ground level.

Stratum	Thickness	Description
1: Fill	0 – 22 feet	Yellow silty sand with rock fragments, loose to dense, brown to yellowish brown clayey silt and coarse to medium gravel, trace cinders, SW and SM, SW-SM, N-values 8 to 60 typically 5-18.
2: Glacial Till	0 – 20 feet	Yellowish brown to dark brown clayey silt with fine sand and gravel, SM or ML or CL, N-values 6 to 35 typically 15.
3: Decomposed Rock	0 – 7 feet	Schist fragments, N-values 20 to 78.

This is a shear zone postulated to cross the tunnel alignment with an approximate E-W trend. The joints are typically closely to moderately spaced but with distinct clusters of very broken rock and healed breccia up to 10 ft thick, slickensided joints and mylonite.

The average depth of the tunnels below the street surface in this geologic zone is 107 feet and 82 feet below MNR. The anticipated typical range of rock mass properties and rock mass classification values for this geologic zone along the tunnel alignment are as follows:

RQD Range: 35% to 100%; Weighted Average RQD: 82%
Q-value range: 0.01 to 3
RMR Range: 20 to 57.

9.7.6 STA T402 31+00(±) to STA EB2 1052+00(±)

There is no soil cover beneath the GCT complex. To the west, soil cover is approximately 16.5 feet (measured from street level) consisting of fill, black and brown coarse to medium sand, some clayey silt, loose with N-values from 6 to 8.

East Zone

This East zone is a subdivision of this geologic zone and comprises garnetiferous schist, gneiss and granofels and a major 10-foot to 15-foot thick pegmatite dipping parallel to foliation to the west across Park Avenue from East 52nd to East 56th Streets.

In general the rock mass is high quality, with few open, infilled and slickensided fractures. There are occasional micro shears and joint weathering and alteration products typical for this rock type such as epidote, calcite and chlorite. The rocks contain a wide variety of minerals including essential interlocking quartz, feldspar and mica, and accessory to trace augite, hornblende, andalusite and tourmaline. In general the joints are closely to widely spaced with distinct sub domains of lower quality rock, characterized by clusters of very closely to closely spaced fractures and persistent steep infilled fractures.

From STA EB2 1044+50 to STA EB2 1047+65, the average depth of the tunnels below GCT in this geologic zone is 46 feet. From STA EB2 1047+65 to STA EB2 1052+00, the average depth of the tunnels below MNR tunnels 76 feet. The anticipated typical range of rock mass properties and rock mass classification values for the east zone along tunnel alignment are as follows:

RQD Range: 55% to 100%; Weighted Average RQD: 95%
Q-value Range: 0.6 to 40
RMR Range: 47 to 74.

West Zone
This West zone, a subdivision of this geologic zone, is an area of brecciated and heavily fractured rock, interpreted to be a fault due to an identifiable displacement of the 10 to 15 feet thick pegmatite layer present in this area. The fault zone trends NW or NE between East 51st and East 52nd Streets. Evidence of faulting has been found in borings from rock surface to below tunnel invert along the west of Park Avenue but not to the east of Park Avenue. The interpreted location of the fault and its assumed eastern boundary are shown in Figure 3. The zone of influence of the fault is anticipated to extend eastward to the center of Park Avenue. The fault zone comprises fragmented rock with slickensided joint surfaces, healed joints and mineralization. The healed fractures in the pegmatite have an aperture greater than 1/16" and a can be broken by strong hand pressure or light blows with a hammer.

The estimated range of rock mass properties and rock mass classification values for the west zone are as follows:

RQD Range: 10% to 100%; Weighted Average RQD: 75%
Q-value Range: 0.007 to 2
RMR Range: 18 to 55.

9.7.7 STA T402 18+50(±) to STA T402 31+00(±)

There is no soil cover beneath the GCT complex. To the west, the depth to bedrock ranges from 0 feet to approximately 22 feet below the existing street level.

Stratum	Thickness	Description
1: Fill	0 – 22 feet	Brown medium to fine sand, very loose to dense sands with trace to some silts, and gravels, SW and SM, SW-SM. SPT- N value 5 to 60, typically 5 to 22.
2: Glacial Till	0 – 1 feet	Dark brown soft to moderately stiff clayey silt with sands and gravel, SM or CL-ML. SPT-N value from 5 to >60 typically 5 to 22.
3: Decomposed Rock	0 – 1 feet	Green to gray, very stiff silts and clays with sands and gravel of decomposed rock and schist fragments, ML-CL or SP -SM. SPT-N value from 17 to >100 typically 25 to >60.

The rock types beneath the existing Grand Central Terminal are dominantly garnetiferous schistose gneiss and gneiss. The rock mass is typically competent, with 50% of the rock mass comprising moderately to very widely spaced foliation fractures and widely spaced joints, quartz, feldspar and pegmatite veins in clusters with few infilled joints. The remaining 50% of the rock mass comprises closely to moderately spaced foliation fractures and joints with frequent pegmatite and quartz veins and few infilled joints. The essential minerals are quartz, feldspar and mica with accessory to trace augite, sillimanite, staurolite, andalusite and kyanite. The amphibolite is essentially hornblende, quartz and feldspar.

The average depth of the tunnels below GCT in this geologic zone is 59 feet. The anticipated typical range of rock mass properties and rock mass classification values along the tunnel alignment for this geologic zone are as follows:

RQD Range:	75% to 100%; Weighted Average RQD: 97%
Q-value Range:	1.5 to 90
RMR Range:	53 to 79.

The top 1.5 feet to 5 feet of the rock immediately under the GCT is fractured with RQD's tending to 75% to 80% (in comparison, the rock underlying the fractured top of rock is typically 90% to 100%). This is possibly due to the blasting effects of the construction of the GCT terminal itself and the excavations for the building footings in the area.

9.7.8 STA L402 0+75(±) to STA T402 18+50(±)

There is no soil cover in this geologic zone.

The dominant rock types are garnetiferous schistose gneiss and gneiss with widely spaced thin quartz, feldspar and pegmatite veins. The rock mass comprises moderately to very widely spaced foliation fractures and widely spaced joints, with widely spaced clusters of very closely to closely spaced joints. The essential minerals are interlocking quartz, feldspar and mica with accessory to trace augite, sillimanite, staurolite, andalusite, tourmaline and kyanite. The amphibolite is essentially hornblende, quartz and feldspar.

The average depth of the tunnels below GCT in this geologic zone is 55 feet and 123 feet below street level. The anticipated typical range of rock mass properties and rock mass classification values for this geologic zone along the tunnel alignment are as follows:

RQD Range:	65% to 100%; Weighted Average RQD: 95%
Q-value Range:	1.5 to 40
RMR Range:	53 to 74.

The condition of the rock immediately below the GCT lower level exhibits conditions described in the previous section.

10. CONSTRUCTION CONSIDERATIONS

This Chapter describes the anticipated rock mass behavior and ground water conditions during the construction of the tunnels under the CM009 Contract. The anticipated rock mass behavior in each of the defined geologic zones (described in Chapter 9) has been described separately. It is emphasized that the boundaries of the rock mass within geologic zones are approximate and have been used for simplicity in presentation. The expected quantities of ground water inflow in each geologic zone (identified in Chapter 9) are given. The types of rock mass failure modes as well as the types of initial support required are described.

10.1 Groundwater Inflow and Control

This section discusses anticipated groundwater inflows and groundwater control measures to be instituted along the alignment, both for tunnel boring machine operations and drill-and-blast operations.

Construction experience in New York and the results of the geotechnical investigation program undertaken on this Project indicate that the rock mass along the alignment generates moderate amounts of water. Permeability values are given in the GDR and Chapter 9 of this GBR. Presence of buried stream channels have been identified from the historic Viele Map (given in the GDR) in the vicinity of 45th Street, 54th to 55th Streets, 58th to 59th Street and between 61st and 62nd Street, and have been confirmed by geotechnical investigations (referenced in Chapter 4, 5 and 9 of this GBR). These locations are expected to be sources of groundwater inflow, because the streams are assumed to have developed in locations containing intensely fractured rock. In addition, shear zones identified in Chapter 9, and other unknown zones are expected to be sources of significant groundwater flow.

10.1.1 Sustained Groundwater Flow

The estimate of total groundwater inflow into the tunnels is based upon packer test results and the intensity of fracturing. It is assumed that the probability distribution of permeability measurements in boreholes is indicative of the permeability along the excavation alignment. Sustained groundwater inflows in each of the four tunnels along the alignment are anticipated to vary from 8 gpm to 80 gpm per 100 linear feet of tunnel length.

Anticipated total sustained groundwater flows into the tunnels for each zone along the alignment, in the absence of grouting or other water control measures, (as defined in Chapter 9) is given in Table 10-1.

10.1.2 Local Instantaneous Flow (Flush Flow)

Local instantaneous inflows of water (flush flows) in sufficient amounts to affect tunnel boring machine operations or the placement of shotcrete from discrete, persistent open joints, closely spaced joint clusters and shear zones are anticipated. Interception and diversion of water will be necessary in such areas. It is assumed that the local inflow (flush flow) is largely fracture flow and the groundwater reservoir is limited. The Contractor shall be capable of controlling local instantaneous inflows of 1000 gpm at the heading during excavation operations. The Contractor shall design his pumping and water control system to handle this instantaneous inflow in addition to all other inflows and his own service water along the entire alignment for all excavations.

Table 10-1: Estimates of Water Inflow Rates

Geologic Zones (Identified by Tunnel Reaches) **(Note: STA T402 34+78.06 = STA EB2 1045+37.02 STA T402 17+52.50 = STA L402 17+52.50)**	**Linear Feet of Tunnel**	**Expected Maximum Inflow GPM / 100LF of Tunnel**
Tunnels:		
STA EB2 1076+50(±) to STA EB2 1084+00(±)	750	12
STA EB2 1066+00(±) to STA EB2 1076+50(±)	1050	36
STA EB2 1063+00(±) to STA EB2 1066+00(±)	300	80
STA EB2 1054+00(±) to STA EB2 1063+00(±)	900	12
STA EB2 1052+00(±) to STA EB2 1054+00(±)	200	80
STA T402 31+00(±) to STA EB2 1052+00(±)	1041	30
STA T402 18+50(±)* to STA T402 31+00(±)	1250	8
STA L402 0+75(±) to STA T402 18+50(±)	1775	12

10.1.3 Face Inflow Incidental to Tunnel Boring

The Contractor's plant should incorporate the capability of handling groundwater inflow of up to 100 gpm in the heading without requiring the tunnel boring or drill and blast operations to be delayed or shutdown. Such small inflows are considered incidental to the excavation operations.

10.1.4 Grouting

The Contractor is required to conduct pre-grouting and post-grouting operations in the tunnels and cavern enlargements, as specified in Sections 02406. Grouting criteria and procedures are specified in Section 03605 of the Specifications.

Pre-excavation grouting is defined as grouting conducted in advance of a tunnel face (in front of the TBM cutterhead) from within the tunnel being mined as per criteria defined in Section 03605, and grouting conducted from a completed section of one tunnel to an area in advance of the tunnel face (in front of the TBM cutterhead) of an adjacent tunnel that is being or will be mined. Post-excavation grouting or cut-off grouting is defined as grouting conducted in the excavated tunnels (behind the TBMs, or after cavern enlargements) in the event that sustained groundwater inflows exceed criteria defined in Section 03605. The Contractor is expected to conduct preemptive grouting operations (either pre-excavation grouting or post-excavation grouting or both) from the tunnels excavated first, such that the incidence of water inflows are reduced during subsequent tunnel drives and cavern enlargements.

Two sets of criteria for the total allowable amount of water inflow from all new completed excavations are established, based on the type of final liner selected by the contractor:

- For the precast segmented concrete liner alternative, the total inflow from the new tunnels, caverns and intersecting structures, prior to the installation of the remaining cast-in-place concrete liner, shall not exceed 600 gpm, in addition to the flow from the existing tunnels.
- For the cast-in-place concrete liner alternative, the total amount of water inflow from all new excavations, prior to installation of the cast-in-place concrete liner, shall not exceed 1000 gpm, in addition to the flow from the existing tunnels.

Further, for both alternatives, the total amount of water inflow, measured over any 50 linear feet of excavations before installation of a concrete liner, shall not exceed 50 gpm. These final inflow requirements are also specified in Section 03605.

10.2 Excavation Support

CM009 Contract includes both TBM and drill-and-blast construction methods and installation of initial support consists of rock bolts and dowels, , welded wire fabric, channels, mine straps, steel ribs , steel mat lagging, and reinforced shotcrete, as shown on Contract Drawings and as required by Specification Section 02270. Permanent liners will be installed under this Contract at the locations shown on the plans.

Initial support selection is primarily based on geotechnical conditions, size and configuration of the underground openings, proximity to existing tunnels and structures, and methods of excavation. The initial support classes are shown on the Contract Drawings. Further discussion of initial support installation with respect to expected rock mass behavior at each geologic zone can be found in Sections 10.3 and 10.4 below. Expected rock mass characteristics along the alignment are discussed in Chapters 8 and 9 of this GBR. The Contract Documents make no representation regarding the type of TBMs to be used to excavate the tunnels. Hence, the discussion on rock behavior in Sections 10.3 and 10.4 assumes that the initial support shown on the Drawings will need to be installed.

Tunnel stations in the Contract Drawings showing initial support class locations are only approximations and are based upon available geotechnical data as well as existing tunnels and other structures. Support class types and their location will vary during construction based on observed geologic conditions in the excavated tunnel.

Initial support must be installed after each blast round and/or after each TBM stroke, as shown on the Contract Drawings, in order to reinforce the in-situ rock mass and minimize disturbance. If the precast concrete segment liner alternative is chosen by the Contractor, then, the type of TBM selected will determine the need for installation of the minimum initial support shown on the Contract Drawings, with the proviso that any rock exposed by the advance of the TBM shall be supported at all times. In addition, initial support, as shown on the drawings must be installed in the TBM driven tunnels, irrespective of the type of TBM selected, in areas that are to be enlarged in either this Construction Contract or other Construction Contracts. Round lengths are shown on the Contract Drawings. Blast round lengths are as shown on the Contract Drawings and are based upon controlled blasting procedures to minimize noise and vibration as well as to reduce overbreak and disturbance of the rock mass adjacent to existing tunnels and structures as required by Specification Sections 02414 and 02407. TBM stroke lengths have been assumed to be 6 feet.

Provisions for the installation of additional initial support over and above those shown on the Contract Drawings are included in the Specifications. The anticipated amount of additional initial support required is discussed in Section 10.3.1 of this GBR and will depend upon the actual rock mass conditions encountered or as directed by the Resident Engineer.

10.2.1 Approach Tunnel Initial Support

Initial support classes for the approach tunnels, excavated by drill-and-blast methods, are shown on the Contract Drawings and are based upon anticipated rock mass conditions, suggested excavation sequence and proximity to existing structures. The initial support includes rock dowels, reinforced shotcrete lining, and welded wire fabric. The actual initial support will be adjusted based on actual rock mass conditions encountered, or as directed by the Resident Engineer.

10.2.2 Assembly Chamber Initial Support

Initial support for the suggested assembly chamber, excavated by drill-and-blast methods, are shown on the Contract Drawings and are also based upon anticipated rock mass conditions and proximity to NYCT structures. The initial support includes rock bolts and rock dowels, reinforced shotcrete lining,, and welded wire fabric . The actual initial support will be adjusted based on actual rock mass conditions encountered.

10.2.3 Starter Tunnel Initial Support

Initial support classes for the starter tunnels, excavated by drill-and-blast methods, are shown on the Contract Drawings and are based upon anticipated rock mass conditions, suggested excavation sequence and proximity to existing structures. The initial support includes rock dowels, reinforced shotcrete lining, and welded wire fabric. The actual initial support will be adjusted based on actual rock mass conditions encountered.

10.2.4 Wye Cavern Initial Support

Initial support classes for the GCT 3 and 5 wye caverns , enlarged by drill-and-blast methods after initial TBM drives, are shown on the Contract Drawings and are also based upon anticipated rock mass conditions and proximity to NYCT structures. The initial support includes rock bolts and dowels, reinforced shotcrete lining, and welded wire fabric. The actual initial support will be adjusted based on actual rock mass conditions encountered

10.2.5 TBM Tunnel Initial Support

Initial support classes for the TBM tunnels are shown on the Contract Drawings. They are divided into five support classes, based upon the anticipated rock mass conditions. Prescribed support in areas of future enlargement has been given the support class designations SC I E TBM and SC II E TBM. These classes are shown in Table 10-2. The actual initial support will be adjusted based on actual rock mass conditions encountered. In the event that a precast concrete segment final liner is installed in the TBM driven tunnels, then the machine design will determine the need for installation of initial support. In no case shall any excavated rock surface be left unsupported. Cavern enlargement areas will not receive precast concrete final liners and the appropriate initial support (as shown on the Drawings) and additional initial support must be installed in these areas to the limits shown on the Contract Drawings.

10.2.6 Intersecting Structures Initial Support

Initial support for the excavation of intersecting structures, including cross passages, adits, sump pump chamber, Central Instrument Room, and cross flue shall be as shown on the

Drawings. Additional initial support must be installed as required by the actual ground conditions encountered. If the Contractor elects to install a precast concrete segment liner in the TBM tunnels, then the Contractor has the option to install precast segments only in the tunnel areas where intersecting cross passages are to be excavated later, as shown on the Contract Drawings. In such a case, the contractor shall submit for the Resident Engineer's review: the contractor's method of breaking out the precast concrete segmented lining; design and construction procedures for the support of partial precast concrete rings; cross passages excavation method; protection of adjacent precast concrete segments and structural and waterproofing details for the joints between the precast tunnel lining and the cast-in-place cross passage lining. On the other hand, if the TBM driven tunnels at the cross passages do not receive precast concrete final liner, or if the cast-in-place concrete final liner alternative is chosen by the Contractor, then the appropriate initial support (as shown on the Drawings) and additional initial support must be installed in the tunnels at the intersecting structure areas, to the limits shown on the Contract Drawings.

Table 10-2: Initial Support for TBM Tunnels

Support Class	Dowel Pattern ;(No.) x ft	Length of Rock Dowels, (ft)		Support
		#8 Steel	GRP	
SC I TBM	4 dowels at 6' longitudinally	10'		Mine Straps and WWF as required
SC II TBM	4 dowels at 6' longitudinally	10'		Channels at 6' longitudinally & WWF
SC III TBM				Ribs W6X25 at 5' longitudinally with steel mat lagging
SC I E TBM	4 GRP dowels at 4' longitudinally		10'	Mine straps and WWF as required
SC II E TBM	4 GRP dowels at 4' longitudinally		10'	Channels at 4' longitudinally & WWF

10.3 Running Tunnel Excavation

This Section describes the anticipated rock mass behavior during tunneling operations on this Contract.

The approach tunnels, starter tunnels, assembly chamber, enlargement of the running tunnels at the GCT 3 and 5 wye cavern locations, central instrument room, cross flue and cross passages will be by drill-and-blast methods. Remaining tunnels will be excavated by TBM.

10.3.1 Rock Mass Behavior

All tunnels will be excavated within the geologic zones as defined in Chapter 9, which exhibit varying strength and stability characteristics. Expected rock mass characteristics are presented in Chapter 8 of this GBR and rock mass conditions including jointing intensity for each approximate geologic zone are described in Chapter 9 of this GBR. Definitions for joint spacings, such as close, moderate, etc., are shown in Figure 6. Tunnel stations showing the transition between different geologic zones are estimates based upon the available geotechnical data and are not necessarily coincident with support class boundaries shown on Contract Drawings.

The TBM shall be designed to be able to excavate efficiently within this rock formation which exhibits variable strengths and will be capable of installing a combination of rock dowels (steel or GRP, as specified), welded wire fabric, mine straps, channels, steel ribs, and steel mat lagging, or a combination thereof, as per Specification Sections 02270 and 02406, and shown on the Contract Drawings.

The drill-and-blast excavations are expected to be carried out with sufficient care taken in the drilling and blasting operations to ensure that the disturbed rock zone around the excavation is kept to a minimum with initial support, consisting of rock bolts or rock dowels, welded wire fabric, reinforced shotcrete lining, and additional initial support, installed as required by Specification Sections 02270 and 02407.

Rock mass behavior during tunneling will be driven by the characteristics of the rock mass including joint intensity, their orientation with respect to the tunnel orientation and spacing relative to the tunnel diameter, and water inflow conditions. The degree of difficulty that the Contractor will face in excavating these tunnels will also be dependent upon the method and type of construction, e.g., TBM or drill-and-blast, and muck handling systems employed.

Geotechnical investigations have identified several joint sets along the alignment. For the purposes of this Contract, a pervasive three joint set system is assumed at a minimum. A combination of the joint sets identified in Chapter 9 of this GBR will divide the rock mass into prismatic blocks, depending upon the orientation of the excavation relative to the joint sets, and their spacing relative to the size of the excavation. Failure is generally expected to be gravity driven and controlled by the degree of jointing intensity.

Blocks formed by joint surfaces are prone to fallout when they are oriented adversely relative to the excavation orientation; joint surfaces are open or contain mineral coatings or gouge material. The probability for fallout will be high when the joints are persistent and closely to moderately spaced, especially in shattered or shear zones. These blocks will tend to fall out of the crown and sidewalls unless promptly supported during excavation. Block fallouts can also occur in blocky and seamy rock (as defined by Cording and Mahar, 1974) due to the interaction between foliation shear zones, conjugate shear zones, and joints oriented across foliation. The fallouts occur due to the presence of very closely to closely spaced seams of gouge and slickensided joints along the shear zones and tend to increase in propensity when such zones strike within 25º of the tunnel axis. If the precast concrete segment liner alternative is chosen by the Contractor, then special care must be exercised in the proper installation of the precast liner and the backfilling and contact grouting of the liner in areas where such blocks do fall out of the crown and sidewalls of the tunnels.

Blocky rock is defined by the U.S. National Committee on Tunneling Technology as "*rock having joints or cleavage spaced and oriented in a manner such that it readily breaks into loose blocks under excavation conditions*" (citation: "Geotechnical Site Investigations for Underground Projects", Volume 1, Subcommittee on Geotechnical Site Investigations, U.S.N.C.T.T., Commission on Engineering and Technical Systems, National Research Council, National Academic Press, Washington, D.C., 1984). Blocky rock conditions are expected along the CM009 alignment and will be created by the presence of two or more persistent joint sets at close to moderate spacings, especially when the joints are open or have weak mineral coatings or gouge material on their surfaces. Blocky rock conditions can occur in the crown, sidewalls and the tunnel face (definitions for joint spacings are given in Figure 6).

The main types of block fallouts from the crown and sidewalls and the face of the tunnels expected are as follows:

- Wedge-shaped fallout: This type of fallout is generally characterized by blocks bounded by three or more intersecting joints. In general these occur due to the presence of steeply dipping joints intersecting the tunnel combined with shallow dipping foliation joints. Such instabilities can occur both during excavation and also at any time after the tunnel has been excavated and can occur both in the crown and sidewalls of the tunnel, depending upon their relative orientations relative to the tunnel axis.

- Slab fallout: This type of fall out can occur at the intersection between the schistose gneiss and other rock types, such as pegmatite and amphibolite, or at intersections with shear zones. It can also occur due to the presence of a combination of closely spaced shallow foliation joints or gouge seams (shear zones) and one or more moderately to widely spaced steeply dipping joints.

- Face Fallout (Blocky Face Condition): Fallouts from the face during TBM excavation can occur due to the presence of closely to moderately spaced persistent joints or joint clusters adversely oriented relative to the tunnel face, especially where joints are open or contain gouge material, microshear zones and major shear zones. The loss of confinement created at the tunnel face by the tunnel boring operation coupled with the combination of persistent joint sets creates a blocky face condition. The blocks can take the form of wedge or slab fallouts (as defined above). Such fallouts can cause cutter and cutterhead damage and muck handling problems. Blocky face conditions can contribute to overbreak in the crown and sidewalls of the tunnel.

The major types of failure modes in the excavation that can be expected are presented below:

- Progressive failure by gradual loosening and fallout of small blocks (up to 3 feet in depth) of rock. This failure mode is likely to occur when initial support is not installed immediately after the tunnel is excavated contrary to the Contract Specification requirements. Of special note is the fact that in case of the tunnels excavated by TBM, potential blocks that could fall out are not readily apparent at the time of excavation and are likely to fall out behind the TBM. In drill-and-blast operations, such blocks are more likely to fall out with the blast or during scaling operations. The Contractor should have provisions for installation of additional initial support behind the TBM and trailing gear.

- Failure of large blocks (up to 10 feet in depth) bounded by persistent discontinuities. This failure mode is generally dependent upon the persistence of the discontinuities. Following specified excavation sequences and early installation of initial support can mostly prevent large block failures.

- Immediate failure of blocks at the face due to the loss of confinement caused by the tunnel boring action, due to the presence of several persistent joint sets at close to moderate spacings containing open joints or joints containing gouge material, and in shear zones. The TBM design shall have provisions to handle this type of failure.

The initial support system is designed to prevent failure of blocks from the crown and sidewalls of the tunnels. In cases where the rock mass conditions dictate the need for additional initial support over and above the support class shown on the Contract Drawings, such support must be installed to maintain a stable rock mass. However, when the actual rock mass conditions encountered indicate a different rock support class from that shown on the Contract Drawings, then the specified initial support for that class will be installed along with additional initial support appropriate for that class, if required.

The degree of additional initial support required will depend upon the rock mass conditions encountered relative to the rock support class shown on the Contract Drawings. In general, the following types of additional initial support will likely be necessary for each of the specified support classes:

- Locations shown on the Contract Drawings as requiring SC I TBM support:
  Occasional installation of one or more dowels in combination with mine straps or channels and local installation of welded wire fabric (welded wire fabric installation is incidental to SC I Support Class).

- Locations shown on the Contract Drawings as requiring SC II TBM support:
  Pattern rows of rock dowels in combination with welded wire fabric, mine straps or channels, occasionally with timber lagging.

- Locations shown on the Contract Drawings as requiring SC III TBM support:
  Steel ribs installed midway between the specified rib spacing, with steel mat lagging, and possibly a combination of the above additional support types.

- Locations shown on Contract Drawings as requiring SC I E TBM or SC II E TBM support:
  The additional support for these areas will generally follow the guidelines given for the above three conditions depending upon the rock mass conditions encountered.

Encountering poor quality rock mass conditions that require additional initial support is normally readily evident during TBM boring (in most cases immediately behind the cutterhead). However, the transition boundary from poor quality rock that requires additional initial support, to good quality rock where the specified initial support is sufficient, is not readily apparent. Therefore, it is expected that some additional initial support will be installed although the rock mass conditions may not require it. This characteristic of a TBM bore will play a role in determining the transitions between the specified initial support class boundaries. The procedures for making the transitions between initial support classes will be in accordance with Specification 02270. In addition, as mentioned above, occasional installation of additional initial support is likely to be required behind the TBM. This is especially important, since the final liner of these tunnels will be installed in a future construction contract.

Blocky rock conditions, blocky and seamy rock conditions, shear zones, and faulted zones are anticipated along the CM009 alignment and are anticipated to affect tunnel boring machine operations in terms of advance rate, initial support installation, groundwater control and grouting, and requirements for additional initial support.

Table 10.3 gives the anticipated percentages of rock mass conditions along the tunnel drives. These conditions are averaged over the total linear feet of all TBM tunnels, caverns and starter tunnels within each geologic zone. Higher percentages of these conditions than those indicated in Table 10.3 will be encountered locally in the areas identified above as shear zones and fault zones.

Details of rock mass behavior expected in each of the geologic zones, identified by tunnel reaches with approximate Station numbers, are discussed in the following sections.

Table 10.3 Estimates of Rock Conditions

Geologic Zones (Identified by Tunnel Reaches) **(Note: T402 34+78.06 = EB2 1045+37.02** **T402 17+52.50 = L402 17+52.50)**	**Linear Feet of Tunnel**	**Blocky Rock Zones including Minor Shear Zones**	**Major Shear Zones and Faulted Zones**	**Rock Mass Zones not containing shears, faults, or exhibiting blocky character**
STA EB2 1076+50(±) to STA EB2 1084+00(±)	750	30%		70%
STA EB2 1066+00(±) to STA EB2 1076+50(±)	1050	60%		40%
STA EB2 1063+00(±) to STA EB2 1066+00(±)	300		100%	0%
STA EB2 1054+00(±) to STA EB2 1063+00(±)	900	30%		70%
STA EB2 1052+00(±) to STA EB2 1054+00(±)	200		100%	0%
STA T402 31+00(±) to STA EB2 1052+00(±)	1041	26%	49%	25%
STA T402 18+50(±) to STA T402 31+00(±)	1250	20%		80%
STA L402 0+75(±) to STA T402 18+50(±)	1775	30%		70%

10.3.1.1 STA EB2 1076+50(±) to STA EB2 1084+00(±)

The rock mass conditions at STA EB2 1084+00 is anticipated to be good by both Q and RMR classifications and grades down to poor according to Q classifications and fair according to RMR classification at STA EB2 1076+50. The rock mass is complexly folded with easterly dipping foliation jointing at STA EB2 1084+00 to a westerly dip at STA EB2 1076+50, as shown in the stereographic pole plots and rose diagrams in Figures 4 and 5. Further details are provided in the reference documents entitled Appendices A-1 and A-3 (attached to this GBR). Joint spacings are wide at STA EB2 1084+00 and become moderate to close at STA EB2 1076+50 (definitions of spacing terms are given in Figure 6). Widely spaced steeply dipping jointing and widely spaced clusters of closely spaced joints are also observed in this geologic zone, with spacing becoming moderately spaced closer to STA EB2 1076+50.

Occasional wedge and slab type block fallouts are anticipated at the crown of the tunnels. Occasional wedge and slab type block fallouts are anticipated on the northerly sidewall of the tunnel closer to STA EB2 1084+00 and on the southerly sidewall closer to STA EB2 1076+50, during boring. A larger percentage of block fallouts are anticipated in the crown and sidewalls between STA EB2 1078+50 and STA EB2 1076+50 because joint orientations show a high degree of scatter as a consequence of folding, as exemplified in the rose diagrams shown in Figure 5. In addition, areas within the 10-foot fault zone (as described in Chapter 9) will cause additional wedge and slab type failures.

Blocky face conditions with a propensity for fallout are anticipated to be encountered in areas where closely spaced clusters of joints are present, and the probability of encountering such conditions will increase as STA EB2 1076+50 is approached, due to the progressive change in foliation direction, large scatter in joint orientations, and the presence of alteration minerals on the joint surfaces. It is anticipated that up to 30% of this geologic zone will encounter blocky rock conditions at the face, which will be prone to fallout.

In general, Support Class SC I TBM is anticipated to be required in this geologic zone with some requirements for SC III TBM near STA 1077+00 due to blocky rock conditions. Additional initial support, compatible with SC I TBM support class, will be required in areas where block fallouts occur, the degree of which will be determined by actual ground conditions encountered or as directed by the Resident Engineer.

The tunnel reach between STA EB2 1082+24 to STA EB2 1081+04 contains the starter tunnels and the assembly chamber, to be built using drill-and-blast methods. Initial support requirements for these are discussed in Section 10.4.

10.3.1.2 STA EB2 1066+00(±) to STA EB2 1076+50(±)

The rock mass conditions in this geologic zone are anticipated to be very poor to good according to the Q classification system and poor to good according to the RMR classification system.

Joints are closely to moderately spaced over this geologic zone and contain alteration minerals on their surfaces. Both shallow and steeply dipping joints have been encountered. Due to the folding in this area, the major foliation jointing dips in an easterly direction east of Lexington Avenue and in a westerly direction west of Lexington Avenue, and the jointing orientations show a high degree of scatter as shown in the stereographic pole plots and rose diagrams in Figures 4 and 5. Further details are provided in the reference documents entitled Appendices A-1 and A-3 (attached to this GBR).

Zones of pegmatite and amphibolite are anticipated to cause slab type failures in the crown and sidewalls of the tunnels. A friable and decomposed amphibolite, about 3 feet thick, has been encountered above the tunnel elevation at approximately STA EB2 1066+00. Wedge and slab type block failures are anticipated in the crown and sidewalls over the entire length of this geologic zone due to the jointing conditions, with the EB2 tunnel experiencing a higher percentage of failures than the WB1 tunnel. The blocky character is anticipated to increase toward STA EB2 1066+00 due to the proximity of a shear zone (described in the next Section). In addition, a larger percentage of sidewall failures are anticipated to occur along the southerly sidewalls of the tunnels.

Blocky face conditions with a propensity for fallout are anticipated to be encountered in this geologic zone due to the presence of closely to moderately spaced joints with alteration minerals on their surfaces, progressive change in foliation direction and the large scatter in joint orientations. It is anticipated that up to 60% of this geologic zone will encounter blocky rock conditions at the face which will be prone to fallout. The blocky and seamy character will become more pronounced as STA EB2 1066+00 is approached, due to the proximity of the shear zone.

Support Class SC II TBM is anticipated to be required in this geologic zone due to the jointing character and alteration products on the joint surfaces. Due to the excavation of the wye cavern between STA EB2 1066+00 to STA EB2 1069+01, the Specifications require support class SC I E TBM to be installed in the EB2 and WB1 tunnels. Additional initial support, compatible with SC II TBM support class, will be required in areas where block fallouts occur, the degree of which will be determined by actual ground conditions encountered or as directed by the Resident Engineer.

Support requirements for the GCT 5 wye caverns, cross flue and the central instrument room, to be built using drill-and-blast methods, are discussed in Section 10.4. The NYCT 60th Street Subway Line crosses the alignment at STA 1071+00 at a distance of 62 feet; however, Support Class SC II is anticipated to be sufficient in this area. Additional initial support in this area, if required, will be compatible with SC II TBM support class.

10.3.1.3 STA EB2 1063+00(±) to STA EB2 1066+00(±)

The rock mass conditions in this geologic zone are anticipated to be extremely poor to very poor according to the Q classification and poor to fair according to the RMR classification because this geologic zone has been identified as a major shear zone with a NNW trend.

The jointing is complex and variable and is closely to moderately spaced with joint orientations and dip angles showing a high degree of scatter, as shown in the stereographic pole plots and rose diagrams in Figures 4 and 5. Further details are provided in the reference documents entitled Appendices A-1 and A-3 (attached to this GBR). Steeply dipping joints are open. Groundwater inflows are expected. Wedge and slab type block failures are anticipated in the crown and sidewalls over the entire length of this geologic zone due to the jointing intensity, and weathering and alteration along joint surfaces.

Blocky face conditions and blocky and seamy conditions, with propensity for fallout, are anticipated to be encountered throughout this geologic zone due to the presence of the shear zone with open joints and weathering and alteration products on the joint surfaces and the presence of groundwater. It is anticipated that up to 100% of this geologic zone will encounter blocky rock conditions at the face, which will be prone to fallout.

Since this is a shear zone, Support Class SC III TBM is anticipated to be required in this geologic zone. Additional initial support, compatible with SC III TBM support class, will be required in areas where the wedge or slab type failures are extensive, the degree of which will be determined by actual conditions encountered during construction.

The tunnel reach between STA EB2 1066+00 to STA EB2 1063+75 contains a part of the GCT 5 wye cavern, to be built using drill and blast methods. Support requirements for these are discussed in Section 10.4.

10.3.1.4 STA EB2 1054+00(±) to STA EB2 1063+00(±)

The rock mass conditions in this geologic zone are anticipated to be very poor to very good according to the Q classification and fair to good according to the RMR classification, with the EB2 and EB4 tunnels tending to be in the poorer rock, and WB1 and WB3 tunnels in good rock.

It is anticipated that the effects of the shear zone will be experienced to approximately STA EB2 1062+00(±). Foliation joints show a westerly shallow dip and steeply dipping joints generally show an easterly dip, as shown in the stereographic pole plots and rose diagrams in Figures 4 and 5. Further details are provided in the reference documents entitled Appendices A-1 and A-3 (attached to this GBR). Joints are closely to moderately spaced with some alteration products on joint surfaces. Widely spaced clusters of closely spaced joints also occur. Wedge type block fallouts are anticipated in the crown due to a combination of the shallow dipping foliation joints and steeply dipping joints. Occasional wedge type fallouts are anticipated along the northerly sidewalls. A larger percentage of wedges are anticipated in the crown and sidewalls in the EB2 and EB4 tunnels as compared to WB1 and WB4 tunnels. Slab type fallouts are anticipated in the vicinity of the pegmatite zone and the amphibolite (approximately STA EB2 1055+50(±)) zones in all tunnels.

Blocky face conditions and blocky and seamy rock conditions, with propensity for fallout, are anticipated to be encountered in areas affected by the proximity to the shear zone (described in the previous Section) and also due to the presence of a brecciated zone as STA EB2 1054+00 is approached (described in the following Section). It is anticipated that up to 30% of this geologic zone will encounter blocky rock conditions at the face which will be prone to fallout.

Due to the proximity of the shear zone and the brecciated zone, it is anticipated that some areas will require Support Class SC III TBM; however, the majority of this geologic zone will require Support Class SC I TBM. Additional initial support, compatible with SC II TBM and SC III TBM support classes, will be required near the shear zone and the brecciated zone, the degree of which will be determined by actual conditions encountered during construction, or as directed by the Resident Engineer.

The reach between approximately STA EB2 1056+00(±) to STA EB2 1055+00(±) contains the 55th Street Ventilation Plant enlargement, to be built using drill-and-blast methods under future Contracts. The initial support for this reach is prescribed to be Support Class SC I E TBM for the upper two tunnels. Additional initial support in this area, if required, will be compatible with SC I TBM or SC III TBM support class, depending upon the actual rock mass conditions encountered.

10.3.1.5 STA EB2 1052+00(±) to STA EB2 1054+00(±)

The rock mass conditions in this geologic zone are anticipated to be extremely poor to poor according to the Q classification and very poor to fair according to the RMR classification, due to the presence of an E-W trending fault in this area.

It is anticipated that the EB2 and EB4 tunnels will experience poorer rock as compared to the WB1 and WB3 tunnels. The major jointing shows a westerly dip, as shown in the stereographic pole plots and rose diagrams in Figures 4 and 5. Further details are provided in the reference documents entitled Appendices A-1 and A-3 (attached to this GBR). The jointing is closely to moderately spaced with slickensides on joint surfaces. Clusters of broken rock and breccia, up to 10 feet thick, have been identified by the geotechnical investigation program. Wedge type fallouts are anticipated in the crown and sidewalls with the EB2 and EB4 tunnels experiencing a larger percentage of fallouts as compared to WB1 and WB3 tunnels. At the brecciated zones, the rock will exhibit blocky and seamy conditions and both wedge type and slab type failures are anticipated.

Blocky face conditions with propensity for fallout are anticipated to be encountered due to the presence of the brecciated zone. It is anticipated that up to 50% of this geologic zone will encounter blocky rock conditions at the face which will be prone to fallout.

Due to the presence of the brecciated zone, it is anticipated that Support Class SC II TBM will be required in this geologic zone. Additional initial support, compatible with SC II TBM support class, will be required in areas where the wedge or slab type failures are extensive, the degree of which will be determined by actual conditions encountered during construction, or as directed by the Resident Engineer.

10.3.1.6 STA T402 31+00(±) to STA EB2 1052+00(±)

The rock mass conditions in this geologic zone are anticipated to range from extremely poor to very good according to the Q classification and poor to good according to the RMR classification.

It is anticipated that the WB1(T403-L403) and WB3 (T303-L303) tunnels will encounter poorer rock mass conditions than the EB2 and EB4 tunnels due to the presence of a heavily fractured rock mass, interpreted to be a fault, lying west of the tunnels. The rock quality in the EB2 (T402-L402) and EB4 (T302-L302) tunnels is anticipated to be good quality rock with the Q values ranging from good to very good and RMR values are good. In general, foliation joints dip in a westerly to a southerly direction, as shown in the stereographic pole plots and rose diagrams in Figures 4 and 5. Further details are provided in the reference documents entitled Appendices A-1 and A-3 (attached to this GBR).

Discontinuities in the area of EB2 and EB4 tunnels include foliation joints and occasional low angle and persistent high angle joints. Joints are generally tight, are occasionally slickensided, and contain alteration products and rare mineralization on the surfaces. Joints are closely to widely spaced, with widely spaced clusters of closely spaced foliation joints intersected by occasional high angle to vertical joints. Toward the west side of the alignment, in the WB1 and WB3 tunnels, discontinuities are tight to open, frequently slickensided, and are infilled with alteration products and mineralization. Joint spacings are close to moderate with closely spaced clusters and numerous persistent steeply dipping fractures. Both wedge type and slab type fallouts are anticipated in the crown and sidewalls of the tunnels with a larger percentage in the WB1 and WB3 tunnels, due to the combination of shallow dipping and steeply dipping joints and a high degree of scatter in the orientation of steeply dipping joints, especially between STA T402 34+00(±) to STA EB2 1048+00(±).

The rock pillars in the upper level tunnels, at approximately T402 32+50 to T402 33+00, and in the lower level tunnels, at approximately STA T402 34+00 to STA EB2 1045+60, are expected to be influenced by the near presence of the fault zone on the west side Park Avenue. In general, rock mass quality is anticipated to be good, with Q values in the range of 10 to 40. Joints are anticipated to be closely to widely spaced. However, occasional thin to thick clusters of extremely top closely fractured rock with altered joint surfaces and occasional slickensides will be encountered. Clusters are anticipated to comprise numerous foliation joints and occasional low to medium angle joints intersected by high angle to vertical joints.

Blocky face conditions, with propensity for fallout, are anticipated to be encountered due to the proximity to the fault zone and a combination of foliation and persistent steeply dipping joints and close to moderate spacings. It is anticipated that up to 50% of this geologic zone will encounter blocky rock conditions at the face, which will be prone to fallout.

Due to the proximity to the fault zone and the joint characteristics, it is anticipated that, in general, Support Class SC II TBM will be required in this geologic zone. Additional initial support, compatible with SC II TBM support class, will be required in areas where the wedge or slab type failures are extensive, the degree of which will be determined by actual conditions encountered during construction, or as directed by the Resident Engineer.

The NYCT 53rd Street Subway Line crosses above the alignment at STA EB2 1050+50(±) at a distance of 12 feet. Support Class SC III TBM is prescribed for this area. The tunnel reach between approximately STA T402 29+50(±) to STA EB2 1049+40(±) contains the GCT 3 wye cavern and crossover structure and associated starter tunnels, to be built using drill and blast methods (further discussion in Section 10.4). The initial support for the TBM tunnels in the GCT 3 wye cavern and crossover area is prescribed to be Support Class SC II E TBM, for the upper two tunnels. The lower two tunnels will require SC II TBM support class. Additional initial support in this area, if required, will be compatible with SC II TBM support class. Pillar reinforcement will be required in the starter tunnel area.

10.3.1.7 STA T402 18+50(±) to STA T402 31+00(±)

The rock mass conditions in this geologic zone are anticipated to be poor to very good according to the Q classification and fair to good according to the RMR classification.

Some effects of the faulting on the west side of the excavations are anticipated to persist in the WB1 and WB3 tunnels from approximately STA T402 31+00(±) to about STA T402 29+00(±). In general, the joints dip in a westerly to a southerly direction as shown in the stereographic pole plots and rose diagrams in Figures 4 and 5. Further details are provided in the reference documents entitled Appendices A-1 and A-3 (attached to this GBR). Occasional steeply dipping joints are present. About 50% of this geologic zone contains joints at a close to moderate spacing and the rest is moderately to widely spaced. Occasional wedge and slab type block fallouts are anticipated to occur at the crown and sidewalls of the tunnels due to the combination of steeply dipping and shallow dipping joints, with a larger percentage anticipated on the easterly sidewalls of the tunnels.

Blocky face conditions, with propensity for fallout, are anticipated to be encountered due to the proximity to the fault zone and where clusters of closely spaced joints and steeply dipping joints occur. It is anticipated that up to 20% of this geologic zone will encounter blocky rock conditions at the face which will be prone to fallout.

Since the rock in this geologic zone is generally good, it is anticipated that Support Class SC I TBM will be required in this area. Additional initial support, compatible with SC I TBM support class, will be required where wedge or slab type block fallouts occur, the degree of which will be determined by actual conditions encountered during construction, or as directed by the Resident Engineer.

The tunnel reaches between approximately STA T402 29+50(±) to STA T402 31+00(±) contains a portion of the GCT 3 cavern and starter tunnel, to be built using drill and blast methods. The tunnel reach between approximately STA T402 28+91(±) to STA L402 17+26(±) contains the Station caverns and approach structures, to be built using drill and blast methods under future Contracts. Initial support for all these areas is Support Class SC I E TBM for the upper two tunnels. The lower tunnels in this area will require SC I TBM support class. Additional initial support in this area, if required, will be compatible with SC I TBM support class. Pillar reinforcement will be required in the starter tunnel area.

10.3.1.8 STA L402 0+75(±) to STA T402 18+50(±)

The rock mass conditions in this geologic zone are anticipated to be poor to good according to the Q classification and fair to good according to the RMR classification.

In general, it is anticipated that the westerly tunnels will remain in good to very good rock, whereas the easterly tunnels will be in good rock. The joints dip in a westerly to a southerly direction as shown in the stereographic pole plots and rose diagrams in Figures 4 and 5. Further details are provided in the reference documents entitled Appendices A-1 and A-3 (attached to this GBR). Occasional steeply dipping joints are present. Joints are closely to moderately spaced, and clusters of closely spaced joints occur at very wide spacings. Occasional wedge and slab type block fallouts are anticipated to occur at the crown and sidewalls of the tunnels due to the combination of steeply dipping and shallow dipping joints, with a larger percentage anticipated in the easterly sidewalls. Blocky and seamy rock conditions are anticipated between STA L402 14+00 to STA L402 15+50. Blocky face conditions, with propensity for fallout, are anticipated to be encountered in areas where closely spaced clusters of joints and steeply dipping joints occur. It is anticipated that up to 30% of this geologic zone will encounter blocky rock conditions at the face, which will be prone to fallout.

Due to the generally good rock conditions, it is anticipated that Support Class SC I TBM will be required in this geologic zone. Additional initial support, compatible with SC I TBM support class, will be required where wedge or slab type block fallouts occur, the degree of which will be determined by actual conditions encountered during construction. Of special note is the fact that a portion of this reach of tunnels lies directly below the great hall of the GCT and Support Class SC I E TBM is prescribed for this area for the upper two tunnels. The lower two tunnels are anticipated to require SC I TBM support class. The boring information in this area is sparse compared to the remainder of the alignment, and unanticipated poor quality rock mass conditions should be anticipated by the Contractor. Additional initial support for this area is anticipated to be compatible with SC I TBM or SC II TBM support class depending upon the actual rock mass conditions encountered, or as directed by the Resident Engineer.

The NYCT Street Flushing Subway Line crosses the alignment at STA L402 11+00 at a distance of 20 feet and SC III-TBM support class is prescribed for this area. The 38th-41st Street NYCT Lexington Avenue Subway Line is adjacent to the alignment between STA L402 2+00 to STA L402 9+50 at a distance of 60 feet, however, Support Class SC I is anticipated to be sufficient in this area. Additional initial support in these areas, if required, will be compatible with SC I TBM support class. The area between approximately STA L402 15+31(±) and STA L402 11+92(±) contains the Tail Track caverns to be built using drill and blast methods under future construction contracts. The initial support for these tunnel reaches is Support Class SC I E TBM for the upper two tunnels. The lower two tunnels is anticipated to require SC I TBM support class. Additional initial support in this area, if required (especially between STA L402 14+00 to STA L402 15+50), will be compatible with SC I TBM or SC II TBM support class depending upon the actual rock mass conditions encountered, or as directed by the Resident Engineer.

10.3.2 Tunnel Boring Machine Excavation

The tunnel boring machine requirements are given in Specification Section 02413. Anticipated excavation conditions with respect to the tunnel boring machine operations are discussed below.

10.3.2.1 Rock Mass Parameters

The TBMs must be selected and designed such that they are capable of excavating rock with properties ranging from 90% of the Minimum Tested Values to 110% of the Maximum Tested Values of strength, abrasivity, hard mineral content, quartz content, garnet/almandine content, drilling indices, and cutter wear indices as delineated in Chapter 12 of this GBR, as well as 90% of other applicable minimums and 110% of other applicable maximums of parameters or conditions. For the purposes of this Contract, the baselines in the GBR; and, to the extent not inconsistent with the baselines, the Contract indications in this GBR and the GDR, including but not limited to rock mass characteristics and the mechanical properties as given in Chapter 8 are indications for TBM production. Actual excavation rates will be affected by the rock mass properties (as described earlier), the degree of jointing intensity actually encountered and their orientation relative to the excavation orientation, and actual groundwater conditions.

The TBM and muck handling system must be designed to excavate the tunnel, install appropriate initial support, handle and control groundwater inflows, and remove muck under blocky and seamy rock conditions, as discussed in the previous Section. It is anticipated that in some cases, tunnel excavation operations will require to be suspended for the installation of initial support and additional initial support immediately behind the cutterhead support or for grouting operations.

10.3.2.2 Gripper Pressure

During the selection of TBMs with side grippers, consideration must be given to the gripper bearing pad surface area to minimize local overstressing of rock. For the purposes of the CM009 Contract, an unconfined compressive strength of the rock of 2000 psi can be assumed for the design of gripper pads. If the gripper bearing pads are designed on the basis of higher rock strength, then the grippers will be unable to generate sufficient thrust to advance the TBM, and will overstress the rock. Gripper problems are anticipated along shear zones identified in this GBR and those that are likely to be found during construction.

10.3.2.3 Pillar Maintenance

Special consideration must be given to the stability of the pillar between adjacent TBM runs. Locations along the alignment where the Contract Drawings show pillar widths less than 12 feet between adjacent TBM runs will require special reinforcement of the pillar. Special reinforcement requirements are shown on the Contract Drawings.

10.4 Drill and Blast Excavation

This Contract incorporates drill-and-blast excavation in the approach tunnels, the TBM assembly chamber and adjoining starter tunnels, GCT 5 wye caverns and adjoining starter tunnels, GCT 3 wye caverns, cross passages, central instrument room, sump pump chamber, and the cross flue. Excavation sequences and round lengths are based upon rock mass stability requirements, stability of adjacent structures, and the requirement to maintain ground vibration and air blast effects of blasting within allowable prescribed limits, as given in the controlled blasting specifications, Section 02414, of this Contract. The Contractor shall use controlled blasting techniques, such as smoothwall blasting, or line drilling techniques to maintain the prescribed limitations in ground vibration and stability of adjacent structures. The Contractor shall conduct, in accordance with the Specifications, a series of test blasts to demonstrate the effectiveness of his excavation technique.

Limits on vibration, noise limits and working hours are imposed upon drilling and blasting operations at certain specified locations (see Specification Section 01572 and 02414). The Contractor shall choose his means and methods to comply with these restrictions. Blasting adjacent to existing NYCT, MNR tunnels, structures, facilities and utilities will have special restrictions as required by the Specifications.

Ground conditions in areas excavated by drill-and-blast are controlled by the degree of jointing intensity, their orientation relative to the excavation orientation, and the effects of the drill and blast operation. Incipient joints tend to remain incipient during TBM excavation, however they have a propensity to open and propagate in drill and blast operations. Therefore, in a given area, the degree of wedge or slab type failures is anticipated to be higher in drill-and-blast operations as compared to TBM operations. The Contractor shall modify his excavation sequence to minimize potential overbreak.

Initial support requirements for each type of excavation are shown on the Contract Drawings. Geotechnical instrumentation will be used to monitor ground movements due to the Contractor's work and remedial measures will be required if ground movement trends are deemed unsatisfactory.

Details of suggested excavation sequences, anticipated round lengths and anticipated initial support requirements at each blasting area of this Contract are discussed below.

10.4.1 Approach Tunnels

Two approach tunnels to the assembly chamber will be constructed from the existing 63rd Street tunnels between approximately STA EB2 1084+3.56(±) to approximately STA EB2 1082+30(±).The EB2 tunnel is approximately 176 LF in length and the WB1 tunnel is approximately 150 LF in length. Parts of these tunnels have been excavated under the previous CM016 Contract using a roadheader. Further information on these excavations can be found in the reference documents for the CM009 Contract. Of special note is the fact that the approach tunnels, especially WB1 lies in close proximity to the 63rd Street NYCTA tunnel with the smallest separation distance being 6.5 feet at STA EB2 1084+50.

10.4.1.1 Rock Mass Conditions

The approach tunnels will be constructed through rock mass conditions described in Chapter 9 of this Report. For the purposes of this Contract, the GBR baselines, and to the extent not inconsistent with those baselines, observed mechanical properties of the rock (Table 8-2 of this GBR), RQD, and a pervasive 3 joint set system, as described in Chapter 8 and 9 are indicated.

Rock mass conditions for the excavation of the assembly chamber are described in Section 10.3.1.1. for TBM operations. Wedge and slab type block fallouts are anticipated to occur at the crown and sidewalls in areas where clusters of closely to moderately spaced joints are present. The northern sidewall is anticipated to experience larger amount of fallouts than the southern sidewall.

10.4.1.2 Excavation Sequence and Initial Support

The major issue with respect to the construction of these excavations is the necessity to control overbreak and to minimize the damage to the surrounding rock, as well as to limit ground vibrations within specified limits. Due to the proximity of the NYCT tunnel and the sensitive residential area nearby, the assembly chamber is to be constructed using top heading and bench methods, as shown on the Contract Drawings. Restrictions on round lengths for both the top heading and bench excavations are shown on the Contract Drawings and may be modified based on rock mass conditions actually encountered and the ground vibration limitations.

Initial supports for these tunnels are as shown in the Contract Drawings. The support classes for the starter tunnels (I-A, I-B, and I-C) are also given in Section 10.2. It is required by the Specifications that all initial support, consisting of rock dowels at prescribed patterns, welded wire fabric, and reinforced shotcrete lining of prescribed thickness, is to be installed after blasting each round, in order to ensure that the wedge or slab type block failures described in Section 10.3.1.1 is prevented and the disturbed rock zone around the excavation is kept to a minimum. Additional initial support will be installed as required by actual ground conditions encountered or as directed by the Resident Engineer.

10.4.2 TBM Assembly Chamber

The assembly chamber for erection of the TBM and ancillary equipment is suggested to be constructed between STA EB2 1082+24(±) and STA EB2 1081+44(±). The dimensions of the assembly chamber, as shown in the Contract Drawings, are based upon due consideration given to the presence of the NYCT 63rd Street Subway tunnel located nearby (at a distance of 20 feet at STA EB2 1082+25). The final dimensions will be determined by the Contractor based upon the TBM chosen and manufacturer recommendations. However, a minimum separation distance of 20 feet must be maintained between the extrados of the assembly chamber and the NYCT structure. Another limiting factor in the excavation of this chamber is that it is located near a very sensitive residential area, known as Treadwell Farms. The Contractor's excavation sequence and blasting procedures must be such that the vibration thresholds given in the General Requirements of the Contract (Section 01571) for this area are not exceeded.

10.4.2.1 Rock Mass Conditions

The rock mass conditions are generally the same as for the approach tunnels, as described above in Section 10.4.1.1. The possible 10-foot thick fault zone as described in Section 10.3.1.1 (from borings taken in Contract CM016) will cause blocky rock conditions in the walls of the assembly chamber.

10.4.2.2 Excavation Sequence and Initial Support

All blasting and construction restrictions applicable to the approach tunnels, as described in Section 10.4.1.2, apply here as well due to the presence of the 63rd Street NYCTA tunnel and aboveground residential structures.

It is required by the Specifications that all initial support, consisting of rock bolts and rock dowels at prescribed patterns, welded wire fabric, and reinforced shotcrete lining of prescribed thickness, is to be installed after blasting each round, in order to ensure that the wedge or slab type block failures described in Section 10.3.1.1 and 10.4.1.1 is prevented and the disturbed rock zone around the excavation is kept to a minimum.

The initial support for the assembly chamber is shown in Section 10.2, and is considered to be the minimum required. Additional initial support, will be installed as required by actual ground conditions encountered or as directed by the Resident Engineer.

Ground vibrations and airblast will be monitored, as well as the structural integrity of the NYCT tunnel. Alternate excavation methods will be required in case monitoring of the NYCT tunnels show deviation from Specification requirements. Plans for any alternate methods of construction must be submitted by the Contractor for review by the Resident Engineer prior to undertaking such methods. In addition, other operational restrictions (or, blackout periods) will be imposed on drilling and blasting operations by the NYCT, MNR, and surrounding community, as prescribed in Specification Section 02414.

10.4.3 Starter Tunnels

Two starter tunnels will be constructed between STA EB2 1081+44(±) to STA EB2 1081+04(±). Actual location of the starter tunnels will depend upon the Contractor’s design of the assembly chamber and the requirements of the TBMs employed.

10.4.3.1 Rock Mass Conditions

The rock mass conditions are generally the same as for the assembly chamber, as described above in Section 10.4.1.1.

10.4.3.2 Excavation Sequence and Initial Support

All blasting and construction restrictions applicable to the assembly chamber, as described in Section 10.4.1.2, apply here as well due to the presence of the NYCT 63rd Street Subway tunnel and aboveground residential structures.

Restrictions on round lengths are shown on the Contract Drawings and may be modified based on rock mass conditions actually encountered and the ground vibration limitations.

Initial supports for these tunnels are as shown in the Contract Drawings. The support classes for the starter tunnels (SC I and SC II) are also given in Section 10.2. It is required by the Specifications that all initial support, consisting of rock dowels at prescribed patterns, welded wire fabric, and reinforced shotcrete lining of prescribed thickness, is to be installed after blasting each round, in order to ensure that the wedge or slab type block failures described in Section 10.3.1.1 and 10.4.1.1 is prevented and the disturbed rock zone around the excavation is kept to a minimum. In addition, the stability of the pillar between the starter tunnels must be maintained. Additional initial support will be installed as required by actual ground conditions encountered or as directed by the Resident Engineer.

10.4.4 GCT 5 Wye Caverns and Starter Tunnels

The GCT 5 wye caverns located between STA EB2 1069+ 31(±) and STA EB2 1064+ 19(±) will serve as chambers where partially disassembled TBMs will be reassembled to drive two of the running tunnels. Each wye cavern will be enlarged from a TBM driven pilot bore to its final configuration.

10.4.4.1 Rock Mass Conditions

The GCT 5 wye caverns will be constructed through rock mass conditions, as described in Chapter 9 of this GBR, as being within a shear zone, with varying rock types. For the purposes of this Contract, the GBR baselines (Chapter 12), and to the extent not inconsistent with those baselines, observed mechanical properties of the rock, RQD, and a pervasive three joint set system, as described in Chapter 8 and 9 are indicated. Higher rates of groundwater inflow than that indicated by packer tests are anticipated, as described in Chapter 9 of this GBR, and baselined in the GBR.

The ground conditions will be as baselined in the GBR, and to the extent not inconsistent with those baselines, as described in Sections 10.3.1.2 and 10.3.1.3, with the added factor of ground disturbance due to drill and blast excavation. In addition, enlargement operations will contribute to the damage to the rock. Wedge and slab type block failures are anticipated in the crown and sidewalls over the entire length of this reach of tunnel due to the jointing conditions. It is anticipated that the EB2 enlargement of the TBM tunnel will experience a higher percentage of failures than the WB1 enlargement.

10.4.4.2 Excavation Sequence and Initial Support

The GCT 5 wye caverns are to be enlarged from the initial TBM bores to their final configurations using top heading and bench methods, as shown in the Contract Drawings. Consideration is to be given to the presence of the NYCT 59th Street Lexington Avenue Subway line that crosses the alignment at STA EB2 1068+00 at a distance of 32 feet. Restrictions on round lengths for both the top heading and bench excavations are shown on the Contract Drawings and may be modified based on rock mass conditions actually encountered and the ground vibration limitations.

Construction sequences, as shown on the Contract Drawings, are suggested, except at the shear zone, where the sequence shall be as shown on the Contract Drawings.

It is required by Specification Section 02407 that all initial support, consisting of rock dowels at prescribed patterns, welded wire fabric, lattice girders and shotcrete of prescribed thickness, will be installed after blasting each round, in order to ensure that the wedge or slab type block failures described in Section 10.3 are prevented and the disturbed rock zone around the excavation is kept to a minimum. Ground vibrations and airblast will be monitored. Minimal effects are anticipated at the Metro-North Railroad (MNR) tunnel due to this blasting work. Additional initial support will be installed as required by actual ground conditions encountered or as directed by the Resident Engineer. Restrictions regarding hours of work will be imposed on drilling and blasting operations, as prescribed in Specification Section 02414.

In addition, the stability of the pillar between the branches of the tunnels starting from the wye caverns must be maintained**.** In order to monitor the stability of the pillar against gripper pressure, additional reinforcement of the pillar is necessary from the TBM bore prior to excavation of the branch starter tunnel, until a minimum pillar width of 12 feet has been achieved, as shown on the Contract Drawings and as discussed earlier in Sections 10.3.2.3 and 10.3.2.4. Additional initial support will be installed as required by actual ground conditions encountered or as directed by the Resident Engineer.

10.4.5 GCT 3 Wye Caverns

The GCT 3 wye caverns are located between approximately STA EB4 1043+59(±) and STA T302 29+ 73(±). Each cavern will be enlarged from either one or two TBM driven pilot bore to its final configuration. As given in the description of work, this cavern enlargement will have single TBM driven tunnels underlying them at varying vertical and horizontal distances.

10.4.5.1 Rock Mass Conditions

The GCT 3 wye caverns will be constructed through rock mass conditions, as described in Chapter 9 of this GBR, as being adjacent to a fault zone, with varying rock types. For the purposes of this Contract, the GBR baselines (Chapter 12), and to the extent not inconsistent with those baselines, observed mechanical properties of the rock, RQD, and a pervasive three joint set system, as described in Chapter 8 and 9 are indicated. Higher rates of groundwater inflow than that indicated by packer tests are anticipated, as described in Chapter 9 of this GBR, and baselined in the GBR.

The ground conditions will be as baselined in the GBR, and to the extent not inconsistent with those baselines, as described in Sections 10.3.1.6, with the added factor of ground disturbance due to drill and blast excavation and multiple openings. In addition, enlargement operations will contribute to the damage to the rock. Wedge and slab type block failures are anticipated in the crown and sidewalls over the entire length of this reach of tunnel due to the jointing conditions. It is anticipated that the western boundaries of the caverns will experience a higher percentage of failures due to the presence of a fault zone alongside the western boundary of the cavern and tunnel excavations.

10.4.5.2 Excavation Sequence and Initial Support

The GCT 3 wye caverns are to be enlarged from the initial TBM bores to their final configurations using top heading and bench methods, as shown in the Contract Drawings. Restrictions on round lengths for both the top heading and bench excavations are shown on the Contract Drawings and may be modified based on rock mass conditions actually encountered and the ground vibration limitations. Construction sequences as shown on the Contract Drawings are suggested.

It is required by Specification Section 02407 that all initial support, consisting of rock dowels at prescribed patterns, welded wire fabric, and reinforced shotcrete lining of prescribed thickness, will be installed after blasting each round, in order to ensure that the wedge or slab type block failures described in Section 10.3 are prevented and the disturbed rock zone around the excavation is kept to a minimum. Ground vibrations and airblast will be monitored. Additional initial support will be installed as required by actual conditions encountered or as directed by the Resident Engineer. Restrictions regarding hours of work will be imposed on drilling and blasting operations, as prescribed in Specification Section 02414.

10.4.6 Cross Flue and Central Instrument Room

The cross flue cavern connects the EB2 and WB1 tunnels. The limits of the excavation in EB2 tunnels extend from STA EB2 1072+53(±) to STA EB2 1071+93(±), and in WB1 tunnels, from STA WB1 1072+36.5(±) to STA WB1 1071+76(±). The central instrument room is located between the EB2 and WB1 tunnels at approximately STA EB2 1068+00(±). Both caverns will be excavated from either or both of the EB2 and WB1 tunnels that will have been excavated in this Contract.

10.4.6.1 Rock Mass Conditions

Both caverns will be constructed through rock mass conditions, as described in Chapter 9 of this GBR, as being adjacent to a fault zone, with varying rock types. For the purposes of this Contract, the GBR baselines (Chapter 12), and to the extent not inconsistent with those baselines, observed mechanical properties of the rock, RQD, and a pervasive three joint set system, as described in Chapter 8 and 9 are indicated. Higher rates of groundwater inflow than that indicated by packer tests are anticipated, as described in Chapter 9 of this GBR, and baselined in the GBR.

The rock mass conditions in this specific area are anticipated to be poor to fair according to the Q classification system and fair according to the RMR classification system.

Joints are closely to moderately spaced and contain alteration minerals on their surfaces. Both shallow and steeply dipping joints have been encountered. Due to the folding in this area, the major foliation jointing appears to dip from an easterly direction to a westerly direction across the cavern, and the jointing orientations show a high degree of scatter as shown in the stereographic pole plots and rose diagrams in Figures 4 and 5. Further details are provided in the reference documents entitled Appendices A-1 and A-3 (attached to this GBR).

Zones of pegmatite and amphibolite are anticipated to cause slab type failures in the crown and sidewalls of the tunnels. A friable and decomposed amphibolite, about 3 feet thick, has been encountered above the tunnel elevation at approximately STA EB2 1066+00 and may extend into the cavern limits. Wedge and slab type block failures are anticipated in the crown and sidewalls over the entire length of this cavern due to the jointing conditions, with the easterly walls experiencing a higher percentage of failures than the westerly wall. The blocky character is anticipated to be present throughout the cavern length due to the proximity of the shear zone.

Blocky face conditions with a propensity for fallout are anticipated to be encountered in this cavern due to the presence of closely to moderately spaced joints with alteration minerals on their surfaces, progressive change in foliation direction and the large scatter in joint orientations.

10.4.6.2 Excavation sequence and Initial Support

The caverns are to be excavated from the initial TBM bores to their final configurations using top heading and bench methods, as shown in the Contract Drawings. Consideration is to be given to the presence of the NYCT 59th Street Lexington Avenue Subway line that crosses the alignment at STA EB2 1068+00 at a distance of 32 feet. Restrictions on round lengths for both the top heading and bench excavations are shown on the Contract Drawings and may be modified based on rock mass conditions actually encountered and the ground vibration limitations. Construction sequences, as shown on the Contract Drawings, are suggested.

It is required by Specification Section 02407 that all initial support, consisting of rock dowels at prescribed patterns, welded wire fabric, lattice girders and shotcrete of prescribed thickness, will be installed after blasting each round, in order to ensure that the wedge or slab type block failures described in Section 10.3 are prevented and the disturbed rock zone around the excavation is kept to a minimum. Ground vibrations and airblast will be monitored. Additional initial support will be installed as required by actual ground conditions encountered or as directed by the Resident Engineer. Restrictions regarding hours of work will be imposed on drilling and blasting operations, as prescribed in Specification Section 02414. In addition, in order to maintain the long term stability of the pillars between the TBM driven tunnels and the cross flue cavern, permanent double corrosion protected rock anchors will need to be installed, as shown on the Contract Drawings..

10.4.7 Intersecting Structures

Nine intersecting cross passages and a sump pump chamber are to be constructed using the drill-and-blast method. The intersecting structures are as follows:

Tail Track Tunnels:

- Upper Cross Passage No. 2: STA L302 5+85
- Upper Cross Passage No. 3: STA L302 10+30
- Lower Cross Passage No. 2: STA L402 5+85
- Lower Cross Passage No. 3: STA L402 10+30

GCT Cavern Approach Tunnels:

- Cross Passage No. 2: STA EB2 1048+70
- Cross Passage No. 4: STA WB3 1063+07.26 (Inclined)
- Cross Passage No. 5: STA EB4 1062+95.81 (Inclined)
- Cross Passage No. 6: STA EB2 1070+10
- Cross Passage No. 7: STA EB2 1077+90
- Sump Pump Chamber: STA EB2 1050+81.83

10.4.7.1 Rock Mass Conditions

Rock mass conditions for the No. 2 and No. 3 cross passages in the tail track tunnels will be as described in Section 10.3.1.8. In general, it is anticipated that the rock in these areas is in the range of good to very good rock. The joints dip in a westerly to a southerly direction. Occasional steeply dipping joints are present. Joints are closely to moderately spaced, and clusters of closely spaced joints occur at very wide spacings. Occasional wedge and slab type block fallouts are anticipated to occur at the crown and sidewalls (a larger percentage in the northern sidewalls) of the excavations due to the combination of steeply dipping and shallow dipping joints, with a larger percentage anticipated in the easterly sidewalls.

Rock mass conditions for the No. 2 cross passage in the GCT Cavern Approach Tunnels will be as described in Section 10.3.1.6. The rock quality is anticipated to be good. In general, foliation joints dip in a westerly to a southerly direction. Discontinuities also include occasional low angle and persistent high angle joints. Joints are generally tight, are occasionally slickensided, and contain alteration products and rare mineralization on the surfaces. Toward the western end of the cross passage, discontinuities range from tight to open, frequently slickensided, and are infilled with alteration products and mineralization, possibly due to the presence of a fault to the west of the area. Wedge type and slab type fallouts are anticipated in the crown and sidewalls of the excavations due to the combination of shallow dipping and steeply dipping joints and a high degree of scatter in the orientation of steeply dipping joints and a fault located to the west of the area. Both wedge type and slab type fallouts are anticipated in the crown and sidewalls of the tunnel due to the combination of shallow dipping and steeply dipping joints and a high degree of scatter in the orientation of steeply dipping joints and a fault located to the west of the area.

Rock mass conditions for the No. 4 cross passage in the GCT Cavern Approach Tunnels will be as described in Section 10.3.1.3. The rock mass conditions are anticipated to be extremely poor to very poor because this area has been identified as a major shear zone with a NNW trend. The jointing is complex and variable and is closely to moderately spaced, with joint orientations and dip angles showing a high degree of scatter. Steeply dipping joints are open. Groundwater inflows are expected to be similar to inflows in the approach tunnels that intersect this major shear zone. Blocky face and blocky and seamy conditions, and wedge and slab type block failures are anticipated in the crown and sidewalls over the entire length of this cross passage due to the jointing intensity, and weathering and alteration along joint surfaces.

Rock mass conditions for the No. 5 cross passage in the GCT Cavern Approach Tunnels will be as described in Sections 10.3.1.3 and 10.3.1.4. The rock mass conditions are anticipated to be very poorer near the EB2 and EB4 tunnels and fair to good near the WB1 and WB3 tunnels. It is anticipated that the effects of the shear zone will be experienced. Foliation joints show a westerly shallow dip and steeply dipping joints generally show an easterly dip. Joints are closely to moderately spaced with some alteration products on joint surfaces. Widely spaced clusters of closely spaced joints also occur. Wedge type block fallouts are anticipated in the crown due to a combination of the shallow dipping foliation joints and steeply dipping joints. Occasional wedge type fallouts are anticipated along the northerly sidewalls. Blocky face conditions and blocky and seamy rock conditions, with propensity for fallout, are anticipated.

Rock mass conditions for the No. 6 cross passage in the GCT Cavern Approach Tunnels will be as described in Section 10.3.1.2 and similar to the cross flue excavation described in Section 10.4.6.1 for the cross flue excavation. The rock mass conditions in this area are anticipated to be very poor. Joints are closely to moderately spaced and contain alteration minerals on their surfaces. Both shallow and steeply dipping joints have been encountered. Due to the folding in this area, the major foliation jointing dips in an easterly direction, east of Lexington Avenue, and in a westerly direction, west of Lexington Avenue, and the jointing orientations show a high degree of scatter. Wedge and slab type block failures are anticipated in the crown and sidewalls and blocky face conditions with a propensity for fallout is also anticipated.

Rock mass conditions for the No. 7 cross passage will be as described in Section 10.3.1.1. The rock mass conditions are anticipated to be good to poor. The rock mass is complexly folded with foliation jointing exhibiting a westerly dip direction. Joint spacings are moderate to close at STA EB2 1076+50 (definitions of spacing terms are given in Figure 6). Widely spaced steeply dipping jointing and widely spaced clusters of closely spaced joints are also observed. Blocky rock conditions with a propensity for fallout are anticipated to be encountered in this tunnel due to closely spaced clusters of joints and the progressive change in foliation direction, large scatter in joint orientations, and the presence of alteration minerals on the joint surfaces.

Rock mass conditions for the Sump Pump Chamber in the GCT Cavern Approach Tunnels will be as described in Section 10.3.1.6 and similar to that described for cross passage No. 2 above. The rock quality is anticipated to be good. In general, foliation joints dip in a westerly to a southerly direction. Discontinuities also include occasional low angle and persistent high angle joints. Joints are generally tight, are occasionally slickensided, and contain alteration products and rare mineralization on the surfaces. Toward the western end, discontinuities are tight to open, frequently slickensided, and are infilled with alteration products and mineralization, possibly due to the presence of a fault to the west of the area. Wedge type and slab type fallouts are anticipated in the crown and sidewalls of the tunnel due to the combination of shallow dipping and steeply dipping joints and a high degree of scatter in the orientation of steeply dipping joints and a fault located to the west of the area.

10.4.7.2 Excavation Sequence and Initial Support

All blasting and construction restrictions, as specified in Specification 02414 apply here as well due to the presence of NYCTA and MNR tunnels and aboveground residential structures.

It is required by the Specifications that all initial support, consisting of rock bolts and rock dowels at prescribed patterns, welded wire fabric, and reinforced shotcrete lining of prescribed thickness, is to be installed after blasting each round, in order to ensure that the wedge or slab type block failures described in Section 10.4.7.1 is prevented and the disturbed rock zone around the excavation is kept to a minimum.

The initial support shown on the Drawings is considered to be the minimum required. Additional initial support, including pre-support spiling at the breakouts, will be installed as required by actual ground conditions encountered or as directed by the Resident Engineer.

Ground vibrations and airblast will be monitored, and alternate excavation methods will be required in case monitoring shows deviation from Specification requirements. Plans for any alternate methods of construction must be submitted by the Contractor for review by the Resident Engineer prior to undertaking such methods. In addition, other operational restrictions (or, blackout periods) will be imposed on drilling and blasting operations by the NYCT, MNR, and surrounding community, as prescribed in Specification Section 02414.

The tunnel final lining at the intersections with the cross passages are shown as cast-in-place concrete in the Contract Drawings. Under the precast tunnel lining alternative, the limits between precast tunnel lining and the cast-in-place tunnel segments are approximate and can be adjusted by the contractor based on his means and methods for excavating the adjacent cross passages and caverns.

If the contractor elects to install precast concrete lining in the tunnels at these intersections for maintaining continuity of the TBM excavation, the contractor shall submit for the Resident Engineer's review: the contractor's method of breaking out the precast concrete segmented lining; design and construction procedures for the support of partial precast concrete rings; cross passages excavation method; protection of adjacent precast concrete segments and structural and waterproofing details for the joints between the precast tunnel lining and the cast-in-place cross passage lining.

10.5 Subsurface Environmental Considerations

Excavated materials from the tunnels, chamber and caverns are anticipated to be non-hazardous, non-contaminated construction and demolition (C & D) materials and are expected to require only dust control during transportation and disposal or beneficial re-use. Rock debris is to be disposed of as C & D debris, as per 6NYCRR Part 360 regulations, or beneficially re-used under 6NYCRR Part 360-1.15(b)(11).

Sediments collected at the Roosevelt Island grit chambers are expected to be classified as potentially contaminated and non-hazardous material, based on laboratory chemical results and field determination. Further testing of these sediments shall be conducted by the Contractor as required by the disposal facility. Any potentially contaminated and non-hazardous material found shall be containerized and temporarily staged at the Work Site until it has been approved by MTA for proper transportation and disposal at an off-site authorized Treatment, Storage and Disposal (TSD) facility in accordance with 6 NYCRR Part 364 and as directed in the CCMP.

Seepage water from the LIRR's tunnel drainage system is expected to be below the NYCDEP Limitations for Effluent to Sanitary/Combined Sewers.

Groundwater inflows along the CM009 tunnel alignment is expected to remain within NYCDEP limits or discharge levels, except that at or near STA EB2 1083+75, one Volatile Organic Compound (VOC), toluene, was detected in a groundwater sample at a concentration above the NYCDEP Limitations for Effluent to Sanitary or Combined Sewers. Toluene, a component of gasoline may have entered the well from street run-off through the uncapped well top during rainstorms or street cleaning operations. Therefore toluene concentrations are not expected to exceed NYCDEP limits during excavation operations.

11. INSTRUMENTATION

The CM009 Contract requires installation of instrumentation in the excavations, along the ground surface and in NYCT tunnels, as shown on the drawings. Other instrumentation (of types similar to those installed in this Contract) will be installed in the MNR tunnels and GCT structures under separate Contracts.

The alignment passes under a heavily developed urban area with a variety of low and hi-rise buildings as well as surface and underground transportation systems. Particularly sensitive facilities include historic landmark structures, a historic district of residential dwellings, sensitive businesses and houses of worship as well as heavily used commuter rails and subway tunnels. CM009 construction must keep the impact to a minimum. The impact is likely to result from deformation of rock mass around the excavations, lowering of groundwater, and vibration related to drilling and blasting. The design and Contract specifications have addressed these problems, which have been discussed in the GBR. If work is performed in accordance with the Contract document requirements, only minor impact is anticipated. However, a comprehensive and integrated instrumentation and monitoring program has been developed to provide control of and notification of impacts.

The Resident Engineer (or, others) will take readings, interpret, and evaluate the data. The data will be used to confirm design assumptions of ground behavior and closely monitor threshold levels of settlement and vibration. Instruments installed will provide measurements for several years beyond the CM009 construction. The instruments will remain at the installed locations for future construction contracts.

The instrumentation and monitoring program can be divided into the following categories:

1. Deformation of Ground: Settlement of ground surface is measured by surface settlement points in conjunction with manual optical survey. Ground deformations at depth are measured by Multiple Position Borehole Extensometers (MPBX) and In-Place Inclinometers (IP), which are real time measurement instruments. All real time instrument outputs are fed (via modems) into Contractor-provided data loggers that are compatible with the Resident Engineer's Central Data Storage System.

2. Groundwater Level: Groundwater level will be monitored by Observation Wells and Open Stand Pipe Piezometers.

3. Deformation of Existing Tunnels: Measurements are made by Liquid Level Settlement Systems (LLSS) and Automated Motorized Total Station Systems (AMTS). Both are real time instruments. LLSS measures settlements at sensor locations and integrates the data to plot settlement troughs. AMTS measure movement along X, Y and Z axes at the optical prism target locations.

4. Settlement of Buildings and Structures: Primary measurements are done by AMTS. Exact locations of instrument mounting points are not shown on Contract Drawings. AMTS theodolites and optical prisms can be mounted on building facades upon approval by the building owners.

At certain building locations where AMTS monitoring is not feasible, manual survey can be performed with portable instruments.

At certain structure columns and beams located within the GCT complex, tiltmeters are used for tilt or slope of these structural members (these are not part of Contract CM009).

Periodic manual optical survey will be performed for quality control purposes.

Where LLSS ends within the influence of construction, the ends must be checked by AMTS or manual survey referencing Deep Bench Marks.

Within the GCT complex, Total Station target prisms will be installed, but monitored as needed through the use of portable Total Station theodolites, rather than robotic units. The possibility of excessive heat build-up from idling trains running their air conditioners makes the use of real-time robotic units impractical.

Selected existing cracks in the buildings and structures, as identified during pre-construction inspection, are to be monitored by crack gauges. These are not identified on Contract Drawings and will be installed and monitored by the Resident Engineer.

5. Vibration Monitoring: A number of portable Seismographs will be used to monitor peak particle velocity during drilling, blasting and TBM operation. At the NYCT 63rd Street Subway tunnels, Accelerometers and Dynamic Strain Gauges are also used.

6. Monitoring within CM009 Tunnels: This monitoring involves the combination of two methods. In the caverns, roof sag and convergence measurements will be accomplished through the use of optical surveys, which may also include AMTS. In the running tunnels, convergence measurements will be accomplished through the use of tape extensometers stretched between anchors mounted on the walls of the excavations. Under the precast segmented tunnel liner alternative, convergence measurements of the installed liner will be made through the use of tape extensometers utilizing anchors mounted on the liner.

12. BASELINED PARAMETERS

12.1 Baseline Ranges for Discontinuity Attitudes

Baseline ranges for dip angles and dip directions of discontinuities along the alignment, categorized by tunnel stations are given in Table 12-1. The whole range of dip angles and dip directions stated in the table are baselined for the stationing indicated and must be considered in estimating rock mass behavior during TBM mining, drill and blast tunnel and cavern excavation, initial support installation and estimating rock mass instability.

Rock mass descriptions, rock mass behavior and engineering properties and baselines presented in this document apply to all TBM tunnels, starter tunnels and caverns. The EB2-T402-L302 tunnel stations are used only as reference stations to subdivide the alignment into several geologic zones for presentation of the associated geotechnical properties, rock mass descriptions, rock mass behavior and baselines. The equations for converting from tunnel stations to track stations are given in the Contract drawings (for example STA T402 34+78.06 = STA EB2 1045+37.02 and STA T402 17+52.50 = STA L402 17+52.50).

Table 12-1: Baseline Joint Dip Angles and Dip Directions (Ranges)

Joint Set Attitudes		Tunnel Stations (Note: STA T402 34+78.06 = STA EB2 1045+37.02 ; STA T402 17+52.50 = STA L402 17+52.50)							
		EB2 1076+50 to EB2 1084+00	EB2 1066+00 to EB2 1076+50	EB2 1063+00 to EB2 1066+00	EB2 1054+00 to EB2 1063+00	EB2 1052+00 to EB2 1054+00	T402 31+00 to EB2 1052+00	T402 18+50 to T402 31+00	L402 0+75 to T402 18+50
Set 1	**Dip**	**5° to 55°**	**5° to 75°**	**5° to 60°**	**5° to 55°**	**5° to 65°**	**5° to 55°**	**15° to 55°**	**15° to 60°**
	Dip Direction	**20° to 360°**	**0° to 360°**	**0° to 350°**	**45° to 310°**	Not Determined *	**110° to 340°**	**195° to 300°**	**135° to 290°**
Set 2	**Dip**	**65° to 90°**	**60° to 90°**	**60° to 80°**	**60° to 75°**	**	**65° to 90°**	**75° to 90°**	**60° to 85°**
	Dip Direction	**175° to 225°**	**105° to 220°**	**105° to 230°**	**95° to 215°**	**	**95° to 225°**	**155° to 250°**	**200° to 230°**
Set 3	**Dip**	**15° to 55°**	**15° to 60°**	**30° to 60°**	**10° to 60°**	**	**15° to 60°**	**25° to 50°**	**5° to 50°**
	Dip Direction	**30° to 345°**	**5° to 345°**	**5° to 325°**	**10° to 350°**	**	**335° to 10°**	**35° to 140°**	**10° to 130°**
Set 4 Low	**Dip**	**10° to 40°**	Not Detected***	Not Detected***	Not Detected***	**	**10° to 40°**	Not Detected***	**10° to 25°**
	Dip Direction	**335° to 10°**	Not Detected***	Not Detected***	Not Detected***	**	**265° to 285°**	Not Detected***	**300° to 360°**
Set 4 High	**Dip**	**55° to 60°**	**55° to 85°**	**60° to 80°**	**55° to 70°**	**	**65° to 85°**	**85°**	**70° to 85°**
	Dip Direction	**335° to 15°**	**245° to 15°**	**245° to 5°**	**265° to 35°**	**	**295° to 320°**	**320°**	**290° to 325°**

Notes:
* Not Determined: Joint orientation could not be determined because the borings in this reach of the tunnels were not oriented.
** Joint sets other than foliation jointing could not be determined because this reach of the tunnels lie in a shear zone.
*** Not Detected: This joint set was not detected in the borings in the geologic zones indicated.

12.2 Baseline Ranges For Engineering Properties of Rock

Engineering Property Baseline:

The baseline ranges of some of the engineering properties of the rock for the purposes of this Contract are shown in the third column of Table 12-2a. It is also expected, for the purposes of this Contract, that 85% of the engineering property values within the baseline ranges will lie within the ranges shown in the fourth column of Table 12-2a. Examination of the laboratory test results indicates that the engineering property values do not show a significant variation in range across the project alignment or between rock types. Therefore, both baseline ranges for each parameter are considered applicable to the entire project alignment. These baselines do not apply to the selection and design of the tunnel boring machines (see Table 12-2b below).

Table 12-2a: Baseline Engineering Properties of Rock Based on Laboratory Tests

Property	**Baseline Range of Rock Property Values**		
	Failure Type	**Baseline Range**	**85% of Values within Baseline Range**
Density (air-dried)		Not Baselined	
Uniaxial Compressive Strength (UCS)	Structural Failure	**4000 psi – 16000 psi**	**5000 psi – 11000 psi**
	Non-structural Failure	**7000 psi – 22000 psi**	**7500 psi – 16250 psi**
Brazilian Tensile Strength (BTS)	Structural Failure	**600 psi – 1700 psi**	**850 psi – 1500 psi**
	Non-structural Failure	**800 psi – 2300 psi**	**950 psi – 2100 psi**
Point Load Strength Index (PLSI)	Structural Failure	**100 psi – 750 psi**	**190 psi – 650 psi**
	Non-structural Failure	**150 psi – 1280 psi**	**400 psi – 1150 psi**
Static Elastic Modulus		Not Baselined	
Dynamic Elastic Modulus		Not Baselined	
P-wave velocity		Not Baselined	
S-wave velocity		Not Baselined	
Quartz content		**10% - 60%**	**20% - 53%**
Garnet/Almandine		**0% - 10%**	**0% - 5%**
Hard mineral content*		**1% - 8%**	**1% - 4%**
Cerchar Abrasivity Index		**2.7 – 5.2**	**3 – 5**
Drilling Rate Index (DRI)		**48 – 58**	**49 – 57**
Bit Wear Index (BWI)		**30 – 42**	**31 – 40**
Cutter Life Index (CLI)		**5 – 21.5**	**5.5 – 19.2**

*Minerals with Mohs' hardness equal to or greater than 7 excluding quartz, garnet/almandine

Baseline Values for TBM Selection and Design:

The TBM(s) shall be selected and designed such that the TBM(s) will be capable of excavating rock with properties ranging from 90% of the Minimum Tested Values to 110% of the Maximum Tested Values of strength, abrasivity, hard mineral content, quartz content, garnet/almandine content, drilling indices, and cutter wear indices. The baseline range of these properties for TBM selection and design are presented in Table 12-2b.

Table 12-2b: Engineering Property Values for TBM Selection and Design

Property	**Baseline Rock Property Values for TBM Selection and Design**		
	Failure Type	**90% of Minimum Test Value**	**110% of Maximum Test Value**
Density (air-dried)		**142 pcf**	**200 pcf**
Uniaxial Compressive Strength (UCS)	Structural Failure	**2480 psi**	**21660 psi**
	Non-structural Failure	**5900 psi**	**31000 psi**
Brazilian Tensile Strength (BTS)	Structural Failure	**440 psi**	**1940 psi**
	Non-structural Failure	**320 psi**	**2800 psi**
Point Load Strength Index (PLSI)	Structural Failure	**64 psi**	**1370 psi**
	Non-structural Failure	**58 psi**	**1410 psi**
Static Elastic Modulus		**1410 ksi**	**16100 ksi**
Dynamic Elastic Modulus		**2730 ksi**	**11070 ksi**
P-wave velocity		**8830 ft/sec**	**20100 ft/sec**
S-wave velocity		**5300 ft/sec**	**11440 ft/sec**
Quartz content		**3%**	**100 %**
Garnet/Almandine		**0%**	**20%**
Hard mineral content*		**0.9%**	**35%**
Cerchar Abrasivity Index		**1.5**	**5.7**
Drilling Rate Index (DRI)		**30**	**64**
Bit Wear Index (BWI)		**27**	**68**
Cutter Life Index (CLI)		**4.4**	**23.7**

*Minerals with Mohs' hardness equal to or greater than 7 excluding quartz, garnet/almandine

12.3 Baseline Estimates of Groundwater Inflow

<u>Sustained Groundwater Flow Baseline:</u>

Anticipated total sustained groundwater flows into the tunnels for each zone along the alignment, in the absence of grouting or other water control measures, is given in Table 12-3. The inflows are expressed in terms of gallons per minute per 100 linear foot of tunnel.

Table 12-3: Baseline Estimates of Water Inflow Rates

Geologic Zones (Identified by Tunnel Reaches) (Note: STA T402 34+78.06 = STA EB2 1045+37.02 STA T402 17+52.50 = STA L402 17+52.50)	**Linear Feet of Tunnel**	**Expected Maximum Inflow GPM / 100LF of Tunnel**
Tunnels:		
STA EB2 1076+50(±) to STA EB2 1084+00(±)	750	**12**
STA EB2 1066+00(±) to STA EB2 1076+50(±)	1050	**36**
STA EB2 1063+00(±) to STA EB2 1066+00(±)	300	**80**
STA EB2 1054+00(±) to STA EB2 1063+00(±)	900	**12**
STA EB2 1052+00(±) to STA EB2 1054+00(±)	200	**80**
STA T402 31+00(±) to STA EB2 1052+00(±)	1041	**30**
STA T402 18+50(±)* to STA T402 31+00(±)	1250	**8**
STA L402 0+75(±) to STA T402 18+50(±)	1775	**12**

<u>Local Instantaneous Flow (Flush flow) Baseline:</u>

For the purposes of this Contract, the Contractor shall be capable of controlling local instantaneous inflows of 1000 gpm during excavation operations.

The Contractor shall design his pumping and water control system to handle this instantaneous inflow in addition to all other inflows and his own service water along the entire alignment for all excavations, throughout the length of the Contract.

12.4 Baseline Rock Conditions

Blocky rock conditions, blocky and seamy rock conditions, shear zones, and faulted zones are anticipated along the CM009 tunnel alignment and are anticipated to affect tunnel boring machine operations in terms of advance rate, initial rock support installation, groundwater control and grouting, and requirements for additional initial support.

Table 12-4 gives the baseline percentages of rock mass conditions along the tunnel drives. These conditions are averaged over the total linear feet of all TBM tunnels, caverns and starter tunnels within each geologic zone. Higher percentages of these conditions than those indicated in Table 12-4 will be encountered locally in the areas identified as shear zones and fault zones.

Table 12-4: Baseline Estimates of Rock Conditions

Geologic Zones (Identified by Tunnel Reaches) **(Note: T402 34+78.06 = EB2 1045+37.02** **T402 17+52.50 = L402 17+52.50)**	**Linear Feet of Tunnel**	**Blocky Rock Zones including Minor Shear Zones**	**Major Shear Zones and Faulted Zones**	**Rock Mass Zones not containing shears, faults, or exhibiting blocky character**
STA EB2 1076+50(±) to STA EB2 1084+00(±)	750	**30%**		**70%**
STA EB2 1066+00(±) to STA EB2 1076+50(±)	1050	**60%**		**40%**
STA EB2 1063+00(±) to STA EB2 1066+00(±)	300		**100%**	**0%**
STA EB2 1054+00(±) to STA EB2 1063+00(±)	900	**30%**		**70%**
STA EB2 1052+00(±) to STA EB2 1054+00(±)	200		**100%**	**0%**
STA T402 31+00(±) to STA EB2 1052+00(±)	1041	**26%**	**49%**	**25%**
STA T402 18+50(±) to STA T402 31+00(±)	1250	**20%**		**80%**
STA L402 0+75(±) to STA T402 18+50(±)	1775	**30%**		**70%**

13. GLOSSARY

The following definitions are given to be consistent with the usage in this Report. The glossary is not intended to be exhaustive.

Blocky rock:

Rock having joints or cleavage spaced and oriented in a manner such that it readily breaks into loose blocks under excavation conditions. Blocky rock conditions are created by the presence of two or more persistent joint sets at close to moderate spacings, especially when the joints are open or have mineral coatings or gouge material on their surfaces. Blocky rock conditions can occur in the crown, sidewalls and the tunnel face.

Blocky and Seamy Rock:

Blocky rock conditions created by the intersection of foliation shear zones, conjugate shear zones, and joints oriented across foliation, especially when the shear zones are characterized by very closely to closely spaced seams of gouge material or slickensided joint surfaces.

Breccia:

A metamorphic rock type composed of coarse, angular broken rock debris, commonly healed with mylonite, vein quartz or calcite, generally found along fault surfaces, commonly a zone of groundwater flow.

Fault:

A fracture or fracture zone in the ground along which there has been an identifiable displacement of the two sides relative to one another, parallel to the fracture. The displacement may be measured in fractions of an inch to many miles.

Fault Zone:

A fault, instead of being a single clean fracture, may be a zone up to hundreds or thousands of feet wide. The fault zone consists of numerous interlacing small faults or zones of gouge, breccia, or mylonite.

Foliation:

General term for a planar arrangement of textural or structural features in any type of rock, especially the planar structure that results from recrystallization of the constituent minerals of a metamorphic rock.

Gouge:

Finely abraded or pulverized rock particles and claylike altered rock found between the walls or within the fractures of a fault or shear zone; the result of grinding movements that crush the affected rock.

Fissure:

An extensive crack, break, or fracture in rock. A mere joint or crack persisting only for a few inches or a few feet is not usually termed a fissure, although in a strict physical sense it is one.

Fracture:

A general term to include any kind of discontinuity in a body or rock if produced by brittle mechanical failure, whether by shear stress or tensile stress. Fractures include faults, shears, joints, and planes of fracture cleavage.

Joint:

In rock, a naturally occurring fracture or parting along which there has been no visible movement parallel to the fracture plane or surface. Generally formed by tectonic stressing. All joints are structural weaknesses, whose frequency, extent and attitude are major influences on rock mass strength.

Joint Cluster:

Several joints of similar characteristics that are spaced closely together (see spacing definition). It is a typical occurrence in rock that has undergone major tectonic episodes such as folding, faulting and intrusions.

Joint Spacing:

The distance between two immediately adjacent parallel joints along a line that is perpendicular to the joints. The spacing terminology used here is defined as follows:

- Extremely Close or crushed: < ¾ inches
- Very Close: ¾ to 2-½ inches
- Close: 2-½ to 8 inches
- Moderate: 8 inches to 2 feet
- Wide: 2 to 6 feet
- Very wide: 6 to 20 feet

Mylonite:

A metamorphic rock type, composed of sheared, fine-grained rock debris (rock flour) which has been recemented or healed subsequent to deformation.

Shear Zone:

A portion of a rock mass traversed by closely spaced fractures along which shearing has occurred resulting from relief of ground stresses. There is generally evidence of slight slipping or faulting along each fracture surface. Cording et. al. (1974) states “If the joint has a polished or slickensided surface it is termed a shear. Shears commonly contain up to ¼ inches clay gouge filling. A shear zone is a zone of fractured rock containing several parallel shears and one or more ½ to 12 inches thick gouge zones. The width of the entire shear zone typically ranges from ¼ inches to 10 ft.” The clay fraction in the gouge zones predominantly contains montmorillonite or interlayer montmorillonite-chlorite. The shear zones occur in swarms, generally 10 to 50 feet apart and are located near changes in rock type or where the foliation is pronounced.

Micro Shear

These are shear zones that have widths measurable in inches (inch scale features), with typical thicknesses less than 6 inches. They are subtle and only noticeable by a distinct zone of weak, friable and extremely fractured rock.

Minor Shear

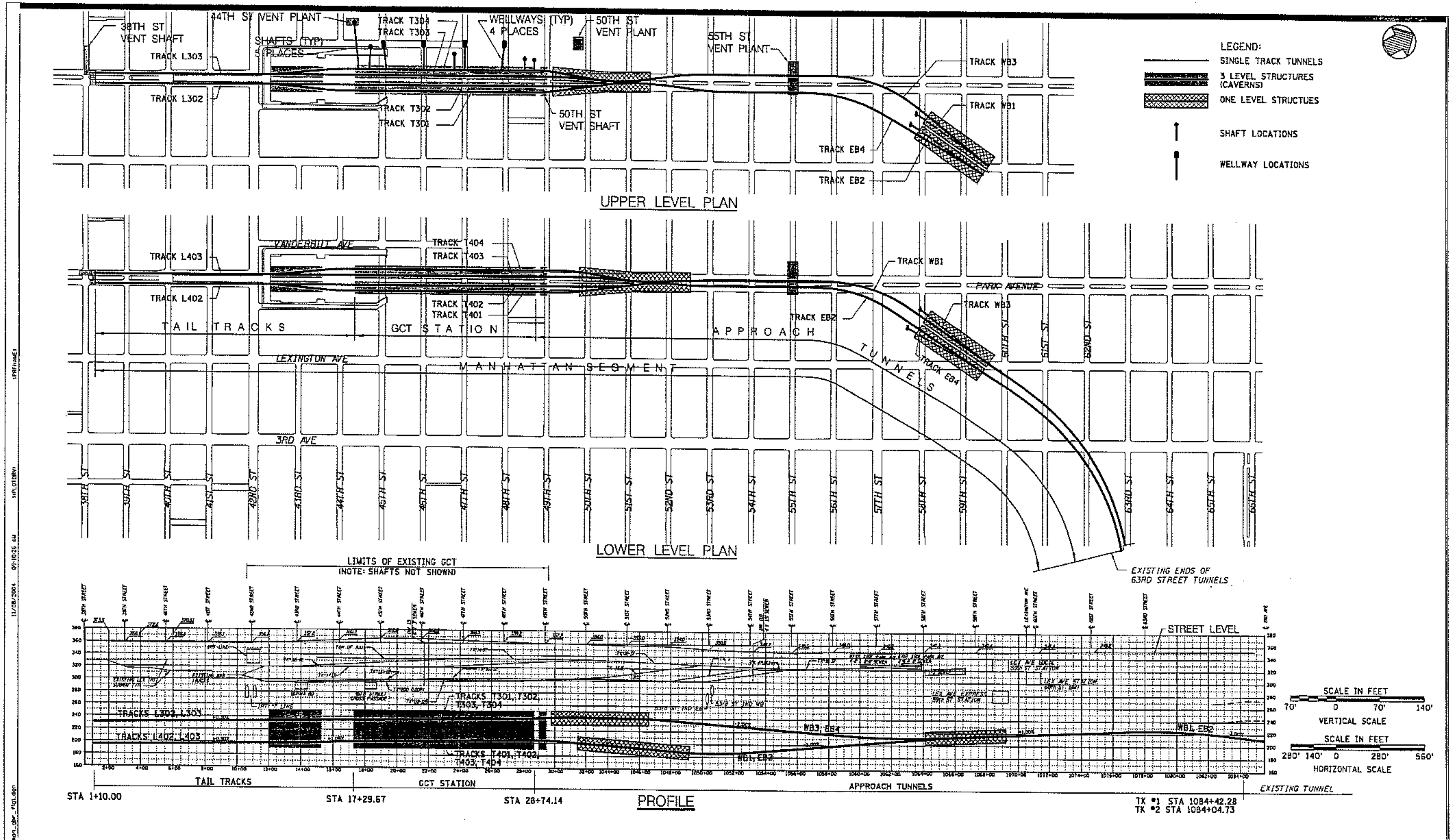
Minor shear zones are characterized by thicknesses of fractured rock of the order of a few feet (foot scale) with a zone of influence extending to tens of feet (10-foot scale) with associated clusters of infilled, stained or mineralized joints and slickensides.

Major Shear

Major shear zones are characterized by fractured rock greater than 10 feet in width (10-foot scale) with a zone of influence extending hundreds of feet (100-foot scale) with intense destructive effects. The breccia is distinct and bounded with mylonite. The fractures are healed by quartz and mylonite. The boundary of the breccia and the undamaged rock is distinctive but the zone of influence includes clusters of open infilled and mineralized joints.

Schistosity:

The foliation in schist or other coarse-grained, crystalline rock due to the parallel, planar arrangement of mineral grains of the platy, prismatic or ellipsoidal type, such as mica.



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MANHATTAN SEGMENT
FIGURE 1

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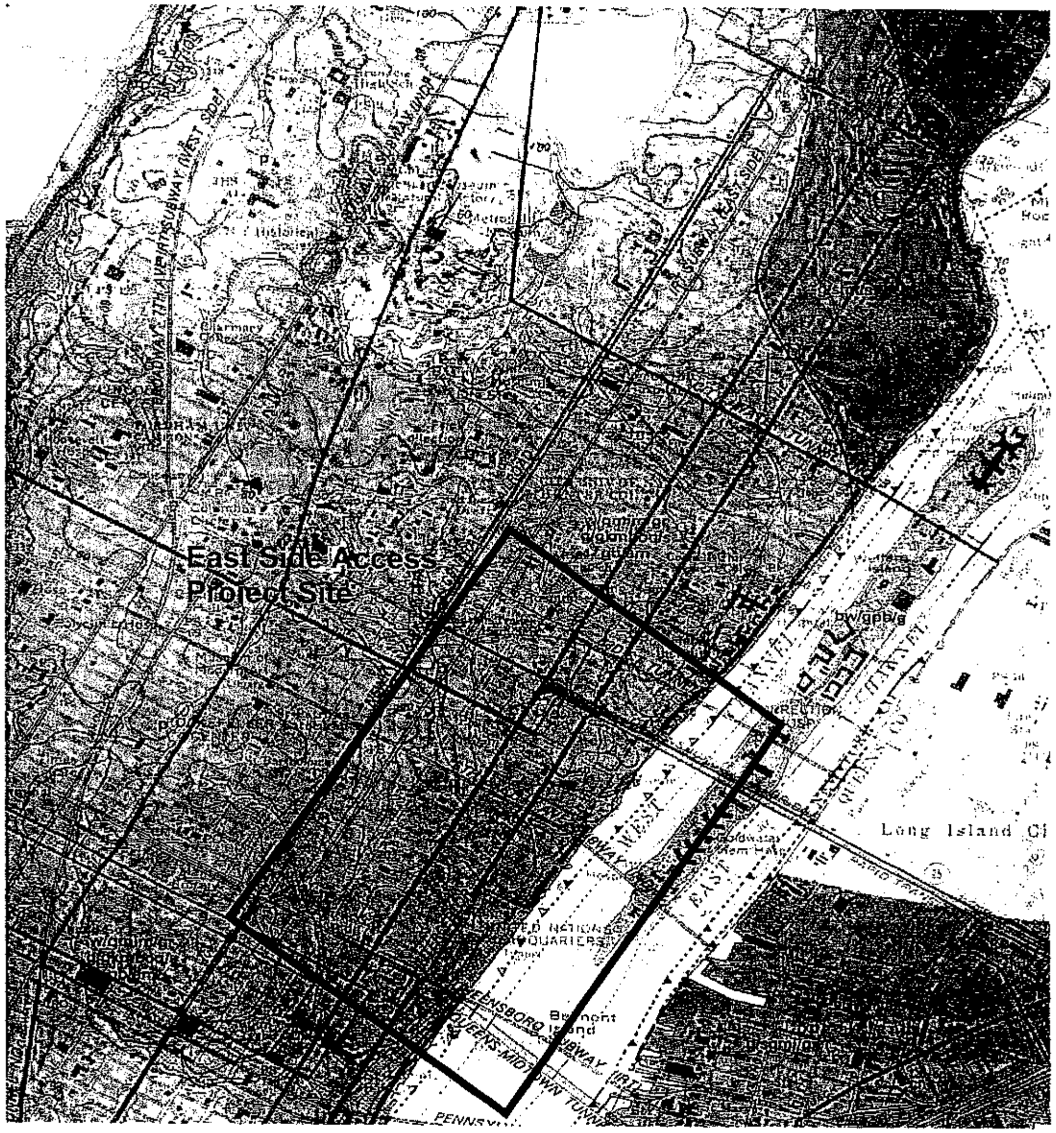

GEOLOGIC UNITS COMBINED ACCORDING TO SIMILAR ENGINEERING CHARACTERISTICS

The major common attribute of engineering significance used in the grouping of these units is similarity of rock type, which should give rise to reasonably uniform strength characteristics for intact rock (rock without faults or other discontinuities). Intact-rock strength decreases with an increase in discontinuity frequency and in weathering (Farmer 1983). Formal geologic unit names are in parentheses.

- Gray sillimanite-muscovite tourmaline schist (Manhattan Schist)
- Gray plagioclase-quartz-muscovite schist (Walloomsac Formation)

- White calcite-dolomite marble (Inwood Marble and lenses in the Hartland Formation (OChm)), and coarse-grained siliceous dolomite (Ylm)

- bw/gpb/g — Black and white garnet-plagioclase-biotite gneiss (Fordham Gneiss, member B)
- g/qbp/s — Gray quartz-biotite-plagioclase schist (Fordham Gneiss, member C)
- p/mbp/g — Pink muscovite-biotite-plagioclase gneiss (Fordham Gneiss, member A)

- White quartz-microcline-muscovite granite (Hartland Formation)
- Gray biotite-muscovite quartz schist (Hartland Formation)
- Gray garnet-kyanite-muscovite-biotite-oligoclase-quartz schist (Hartland Formation)
- Gray sillimanite-plagioclase-muscovite schist (Hartland Formation)
- wgr — White granite
- gr/sp — Green serpentinite
- gb/am — Greenish-black amphibolite (in all units except marble and Walloomsac Formation)
- am — Amphibolite (usually looks black in outcrops)
- Gray sillimanite-garnet microcline gneiss (Ravenswood Granodiorite)
- Dark-gray plagioclase augite diabase (Palisade Diabase)

- Greenish red shale and sandstone (Passaic Formation)
- Gray and black shale (Lockatong Formation)
- Gray and reddish-brown sandstone (Stockton Formation)

Reference: Baskerville, C.A., "Bedrock and Engineering Geologic Maps of New York County and Parts of Kings and Queens Counties, New York, and Parts of Bergen and Hudson Counties, New Jersey", United States Geological Survey (USGS),1994

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EXTRACT FROM PUBLISHED GEOLOGIC MAP FOR MANHATTAN BEDROCK
FIGURE 2

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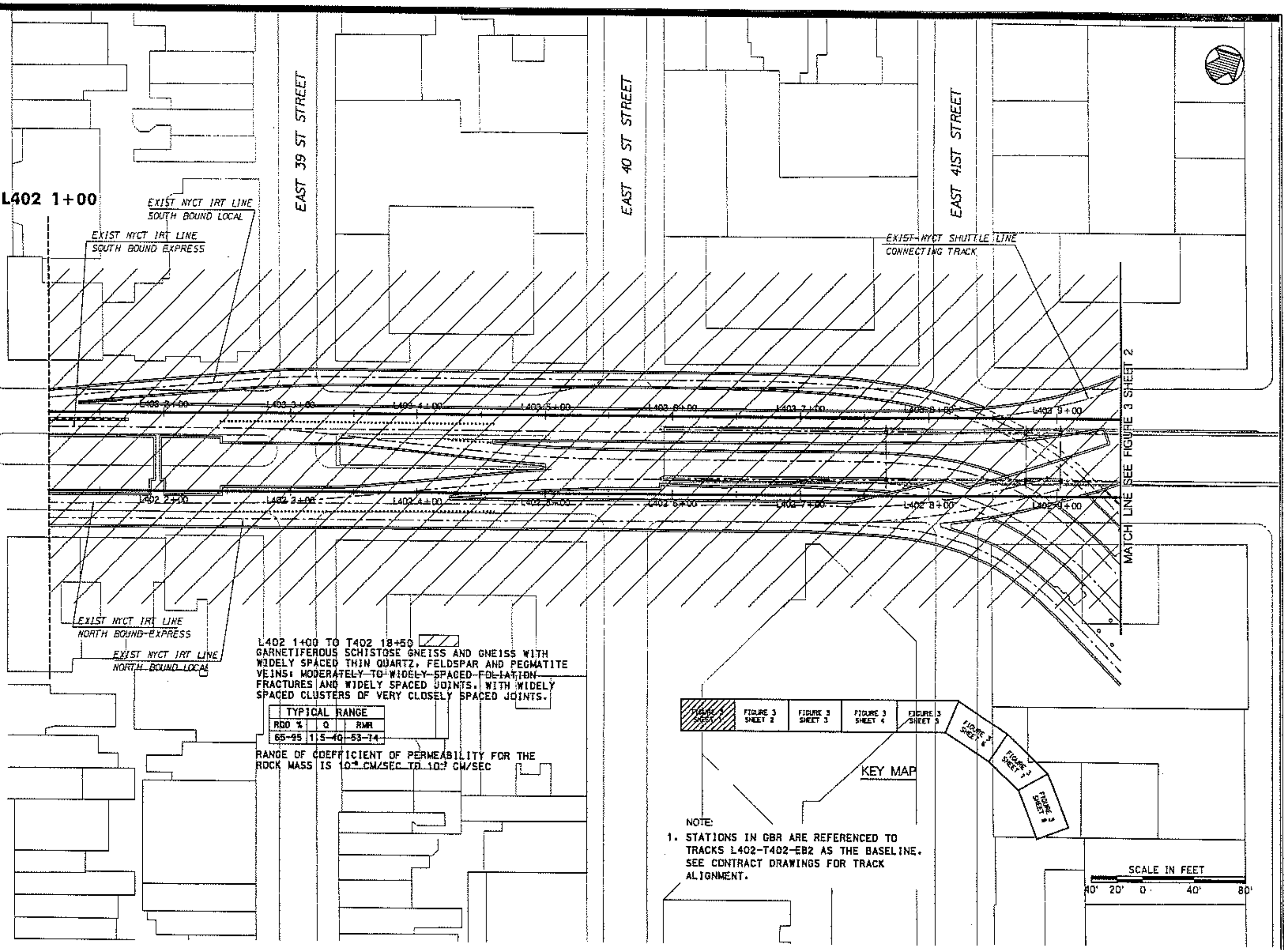

LEGEND:

- - - - - - - -	ZONE BOUNDARY
EB2 1084+00	REFERENCE STATION FOR ZONE BOUNDARY
RQD %	ROCK QUALITY DESIGNATION
Q	Q-VALUE FOR ROCK CORE AFTER BARTON ET. AL
RMR	ROCK MASS RATING AFTER BIENIAWSKI
1	GEOLOGICAL ZONE L402 1+00 TO T402 18+50
2	GEOLOGICAL ZONE T402 18+50 TO T402 31+00
3	GEOLOGICAL ZONES T402 31+00 TO EB2 1052+00, EB2 1052+00 TO EB2 1054+00, EB2 1063+00 TO EB2 1066+00
4	GEOLOGICAL ZONE T402 31+00 TO EB2 1052+00
5	GEOLOGICAL ZONE EB2 1054+00 TO EB2 1063+00
6	GEOLOGICAL ZONE EB2 1066+00 TO EB2 1076+50
7	GEOLOGICAL ZONE EB2 1076+50 TO EB2 1084+00

L402 1+00 TO T402 18+50
GARNETIFEROUS SCHISTOSE GNEISS AND GNEISS WITH WIDELY SPACED THIN QUARTZ, FELDSPAR AND PEGMATITE VEINS; MODERATELY TO WIDELY SPACED FOLIATION FRACTURES AND WIDELY SPACED JOINTS. WITH WIDELY SPACED CLUSTERS OF VERY CLOSELY SPACED JOINTS.

TYPICAL RANGE		
RQD %	Q	RMR
65-95	1.5-40	53-74

RANGE OF COEFFICIENT OF PERMEABILITY FOR THE ROCK MASS IS 10[illegible] CM/SEC TO 10[illegible] CM/SEC

NOTE:
1. STATIONS IN GBR ARE REFERENCED TO TRACKS L402-T402-EB2 AS THE BASELINE. SEE CONTRACT DRAWINGS FOR TRACK ALIGNMENT.

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MANHATTAN SEGMENT
GEOLOGIC ZONES AND SUMMARY DESCRIPTIONS
FIGURE 3 - SHEET 1 OF 8

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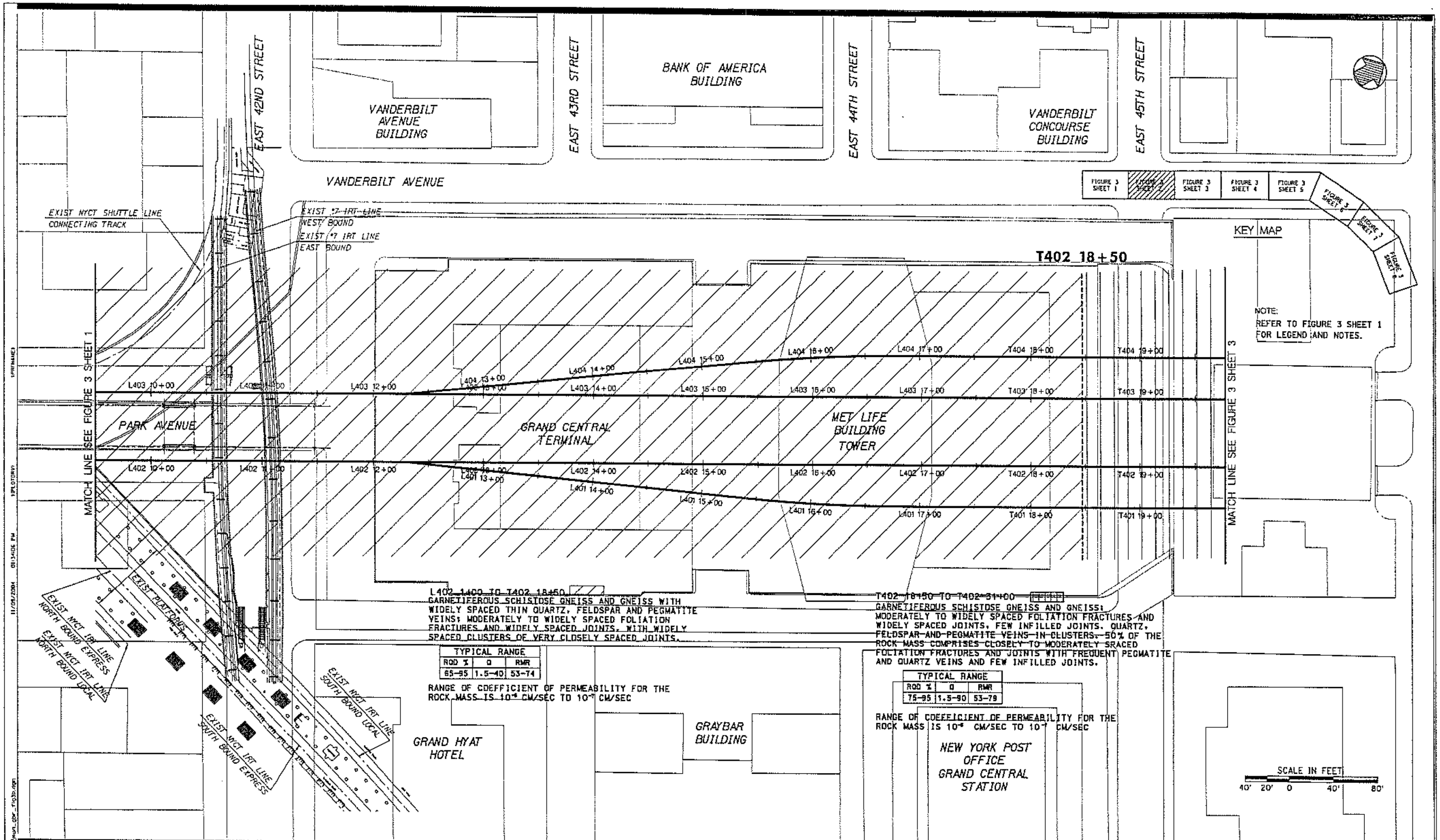

L402 14+00 TO T402 18+50

GARNETIFEROUS SCHISTOSE GNEISS AND GNEISS WITH WIDELY SPACED THIN QUARTZ, FELDSPAR AND PEGMATITE VEINS; MODERATELY TO WIDELY SPACED FOLIATION FRACTURES AND WIDELY SPACED JOINTS, WITH WIDELY SPACED CLUSTERS OF VERY CLOSELY SPACED JOINTS.

TYPICAL RANGE		
RQD %	Q	RMR
65–95	1.5–40	53–74

RANGE OF COEFFICIENT OF PERMEABILITY FOR THE ROCK MASS IS 10^{-4} CM/SEC TO 10^{-7} CM/SEC

T402 18+50 TO T402 31+00

GARNETIFEROUS SCHISTOSE GNEISS AND GNEISS; MODERATELY TO WIDELY SPACED FOLIATION FRACTURES AND WIDELY SPACED JOINTS, FEW INFILLED JOINTS. QUARTZ, FELDSPAR AND PEGMATITE VEINS IN CLUSTERS. 50% OF THE ROCK MASS COMPRISES CLOSELY TO MODERATELY SPACED FOLIATION FRACTURES AND JOINTS WITH FREQUENT PEGMATITE AND QUARTZ VEINS AND FEW INFILLED JOINTS.

TYPICAL RANGE		
RQD %	Q	RMR
75–95	1.5–90	53–79

RANGE OF COEFFICIENT OF PERMEABILITY FOR THE ROCK MASS IS 10^{-4} CM/SEC TO 10^{-7} CM/SEC

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MANHATTAN SEGMENT
GEOLOGIC ZONES AND SUMMARY DESCRIPTIONS
FIGURE 3 – SHEET 2 OF 8

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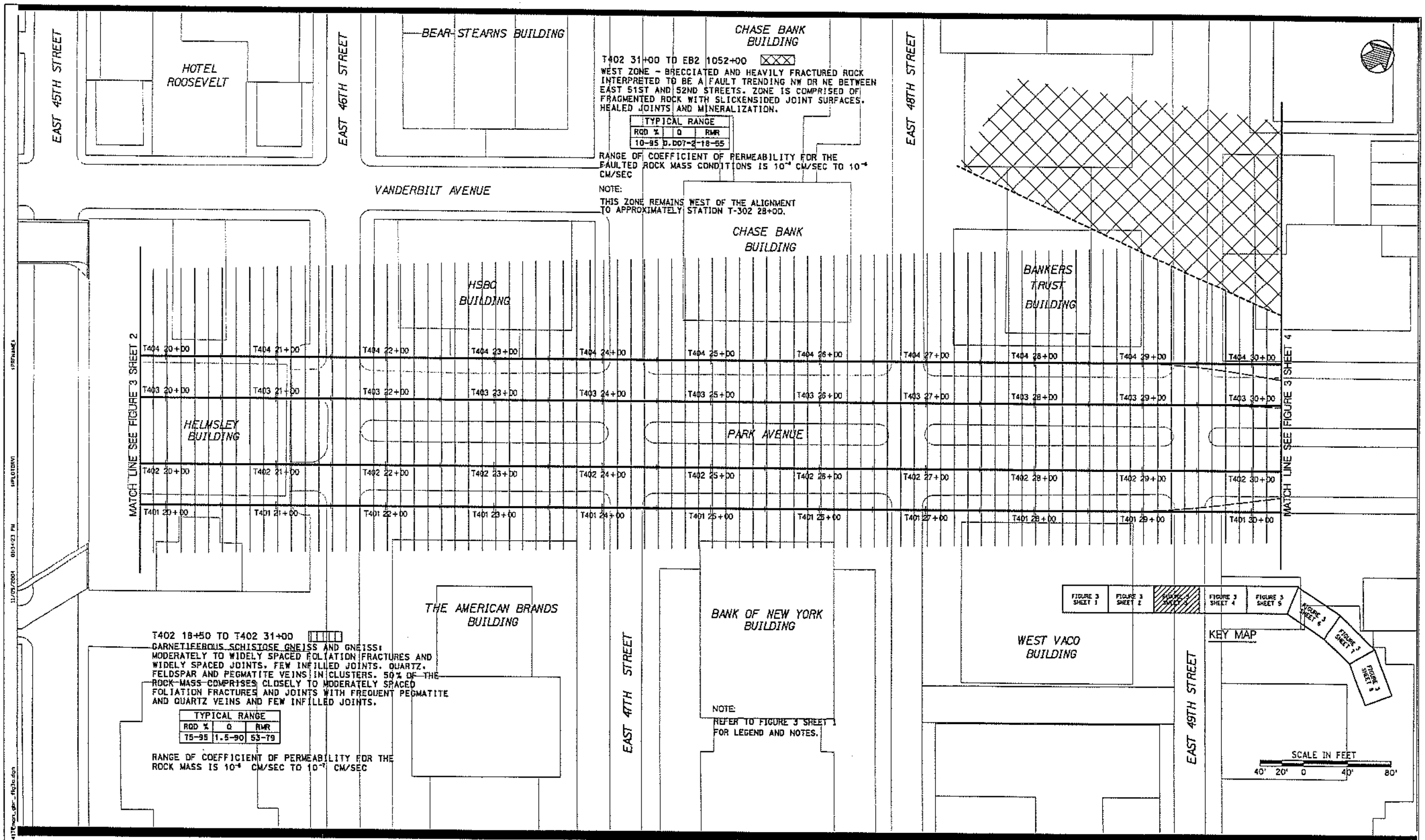

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MANHATTAN SEGMENT
GEOLOGIC ZONES AND SUMMARY DESCRIPTIONS
FIGURE 3 – SHEET 3 OF 8

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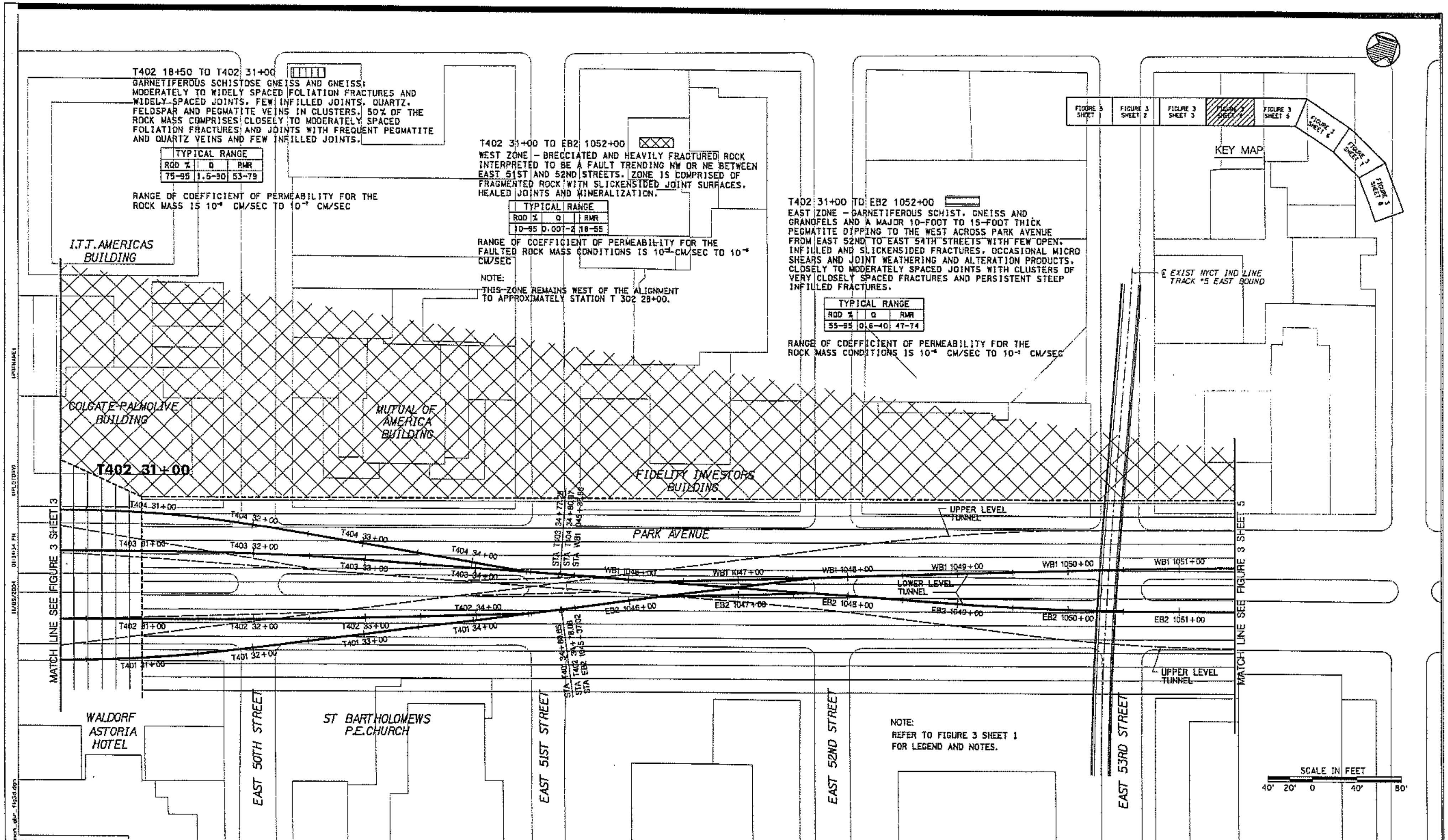

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MANHATTAN SEGMENT

GEOLOGIC ZONES AND SUMMARY DESCRIPTIONS

FIGURE 3 – SHEET 4 OF 8

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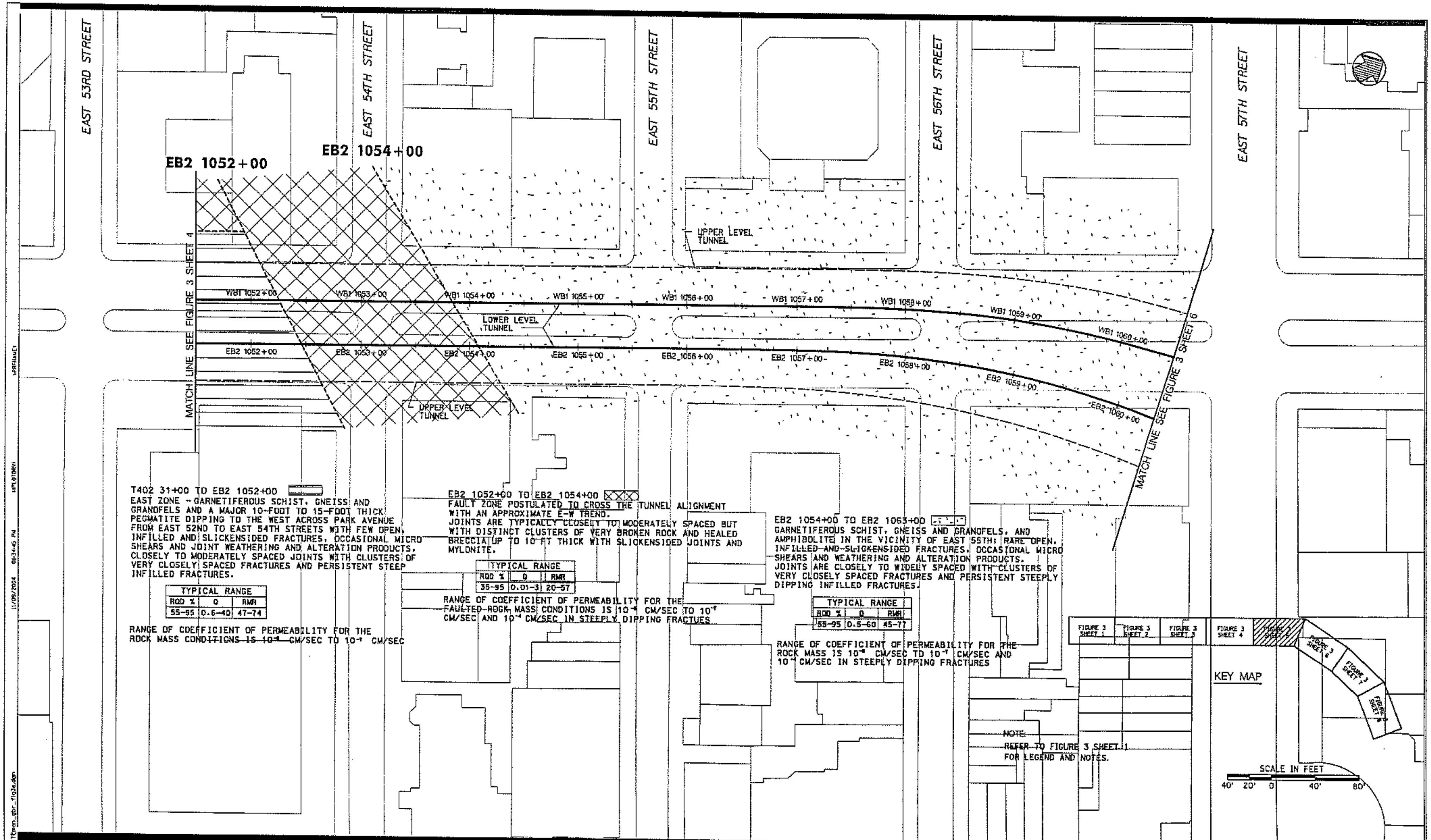

T402 31+00 TO EB2 1052+00

EAST ZONE – GARNETIFEROUS SCHIST, GNEISS AND GRANOFELS AND A MAJOR 10-FOOT TO 15-FOOT THICK PEGMATITE DIPPING TO THE WEST ACROSS PARK AVENUE FROM EAST 52ND TO EAST 54TH STREETS WITH FEW OPEN, INFILLED AND SLICKENSIDED FRACTURES, OCCASIONAL MICRO SHEARS AND JOINT WEATHERING AND ALTERATION PRODUCTS. CLOSELY TO MODERATELY SPACED JOINTS WITH CLUSTERS OF VERY CLOSELY SPACED FRACTURES AND PERSISTENT STEEP INFILLED FRACTURES.

TYPICAL RANGE		
RQD %	Q	RMR
55-95	0.6-40	47-74

RANGE OF COEFFICIENT OF PERMEABILITY FOR THE ROCK MASS CONDITIONS IS 10^{-5} CM/SEC TO 10^{-7} CM/SEC

EB2 1052+00 TO EB2 1054+00

FAULT ZONE POSTULATED TO CROSS THE TUNNEL ALIGNMENT WITH AN APPROXIMATE E-W TREND.
JOINTS ARE TYPICALLY CLOSELY TO MODERATELY SPACED BUT WITH DISTINCT CLUSTERS OF VERY BROKEN ROCK AND HEALED BRECCIA UP TO 10 FT THICK WITH SLICKENSIDED JOINTS AND MYLONITE.

TYPICAL RANGE		
RQD %	Q	RMR
35-95	0.01-3	20-57

RANGE OF COEFFICIENT OF PERMEABILITY FOR THE FAULTED ROCK MASS CONDITIONS IS 10^{-5} CM/SEC TO 10^{-7} CM/SEC AND 10^{-4} CM/SEC IN STEEPLY DIPPING FRACTUES

EB2 1054+00 TO EB2 1063+00

GARNETIFEROUS SCHIST, GNEISS AND GRANOFELS, AND AMPHIBOLITE IN THE VICINITY OF EAST 55TH; RARE OPEN, INFILLED AND SLICKENSIDED FRACTURES, OCCASIONAL MICRO SHEARS AND WEATHERING AND ALTERATION PRODUCTS. JOINTS ARE CLOSELY TO WIDELY SPACED WITH CLUSTERS OF VERY CLOSELY SPACED FRACTURES AND PERSISTENT STEEPLY DIPPING INFILLED FRACTURES.

TYPICAL RANGE		
RQD %	Q	RMR
55-95	0.5-60	45-77

RANGE OF COEFFICIENT OF PERMEABILITY FOR THE ROCK MASS IS 10^{-5} CM/SEC TO 10^{-7} CM/SEC AND 10^{-4} CM/SEC IN STEEPLY DIPPING FRACTURES

NOTE:
REFER TO FIGURE 3 SHEET 1 FOR LEGEND AND NOTES.

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MANHATTAN SEGMENT

GEOLOGIC ZONES AND SUMMARY DESCRIPTIONS

FIGURE 3 – SHEET 5 OF 8

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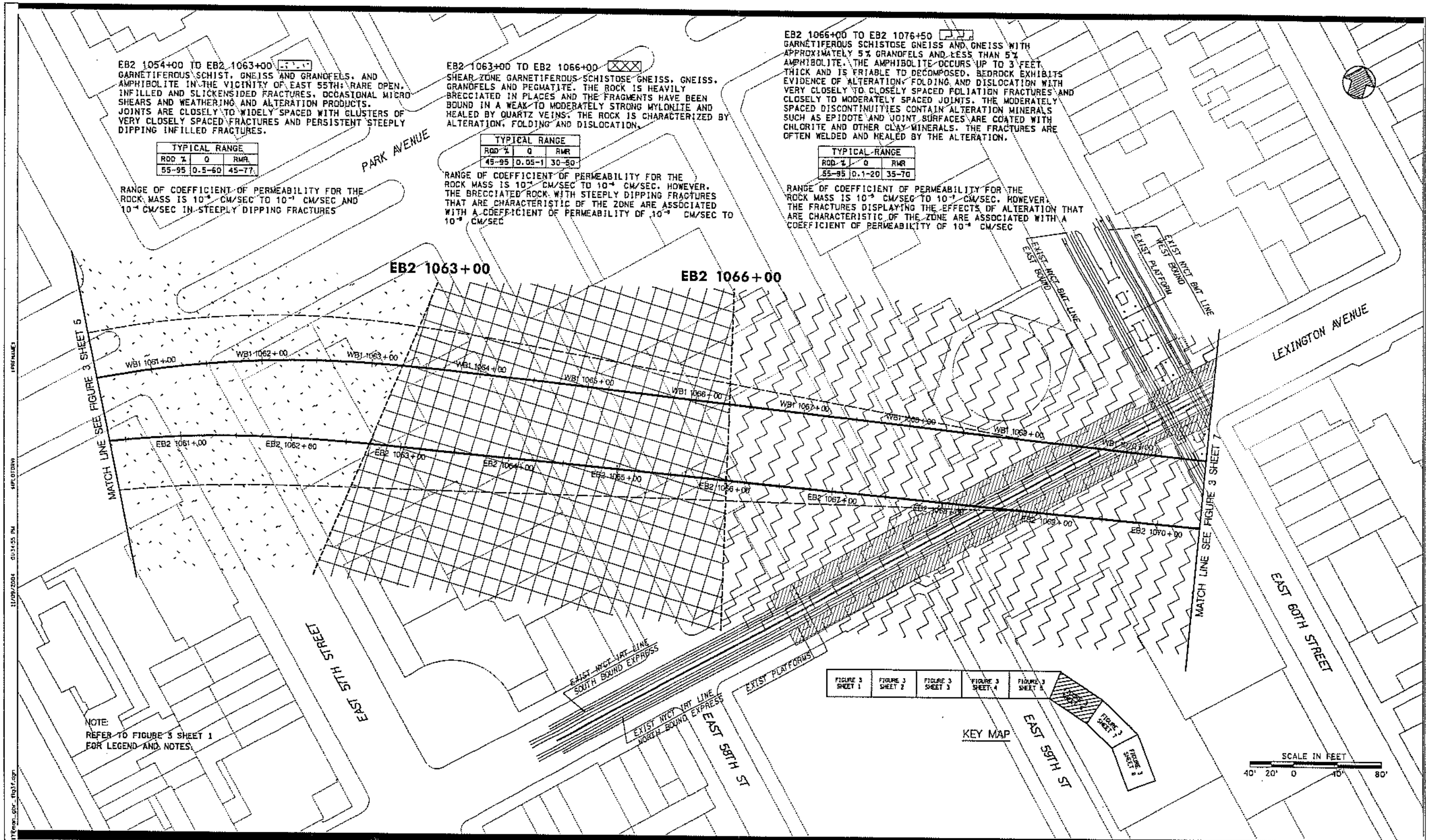

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MANHATTAN SEGMENT
GEOLOGIC ZONES AND SUMMARY DESCRIPTIONS
FIGURE 3 - SHEET 6 OF 8

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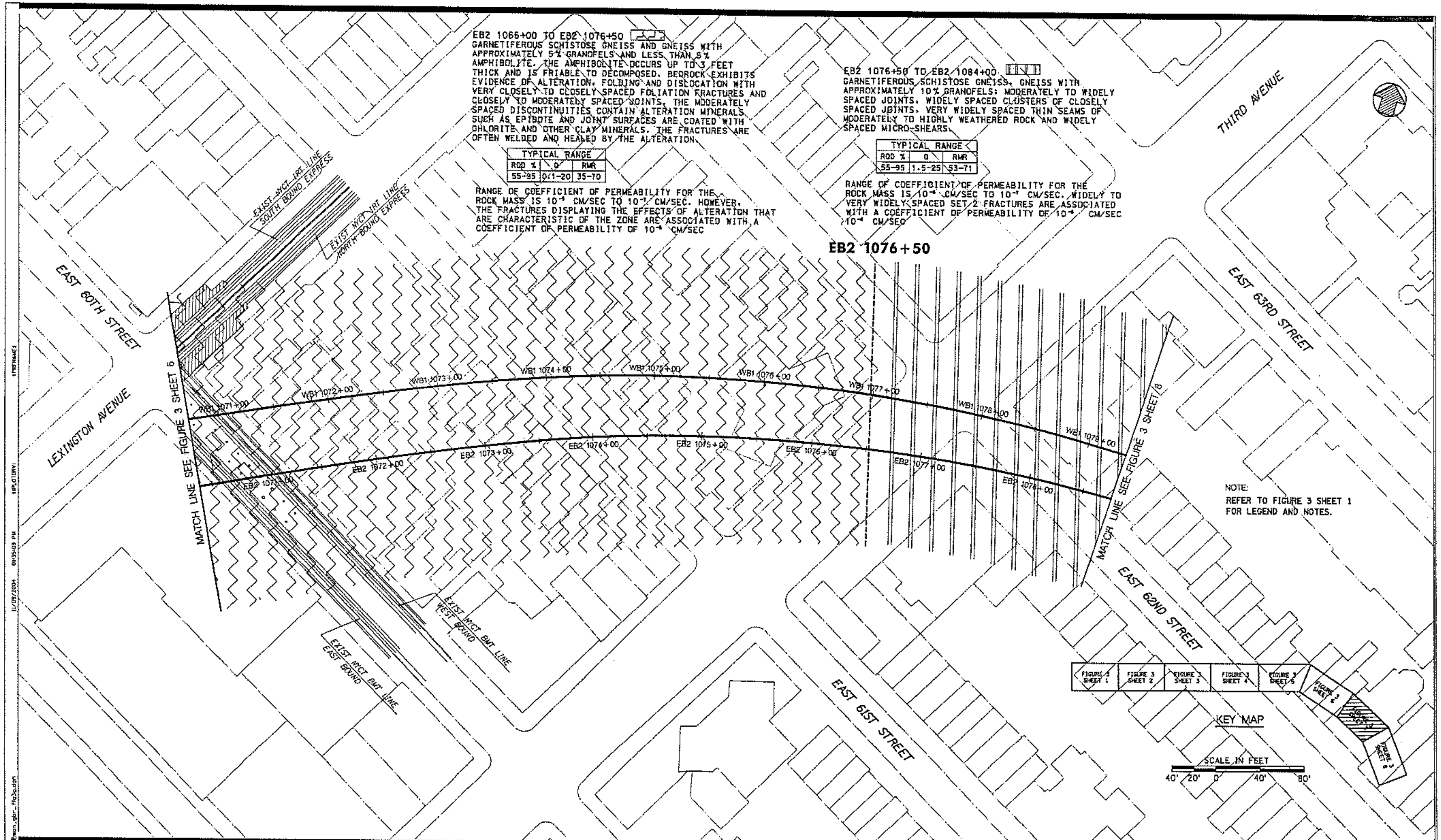

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MANHATTAN SEGMENT
GEOLOGIC ZONES AND SUMMARY DESCRIPTIONS
FIGURE 3 – SHEET 7 OF 8

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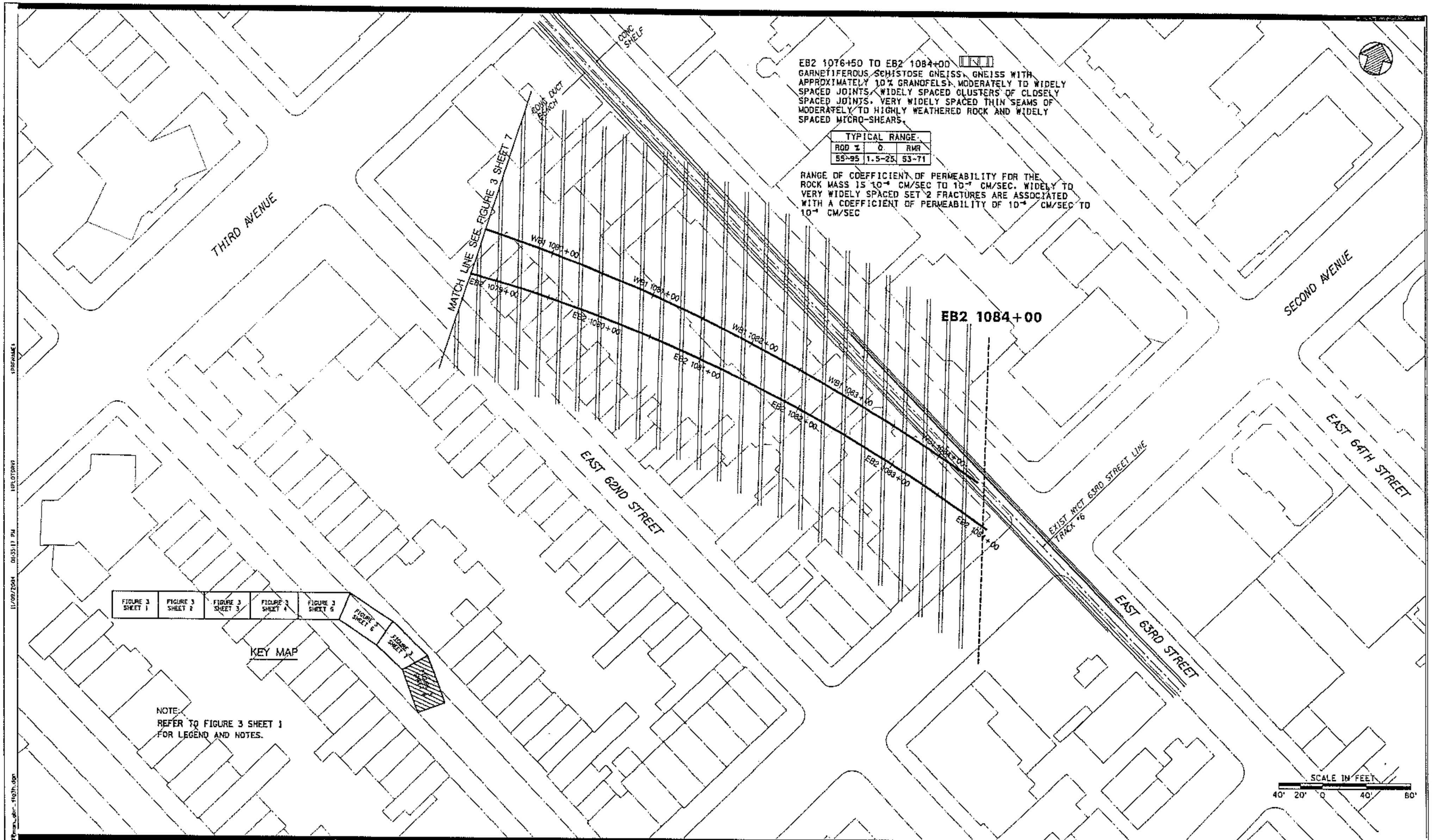

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MANHATTAN SEGMENT

GEOLOGIC ZONES AND SUMMARY DESCRIPTIONS

FIGURE 3 – SHEET 8 OF 8

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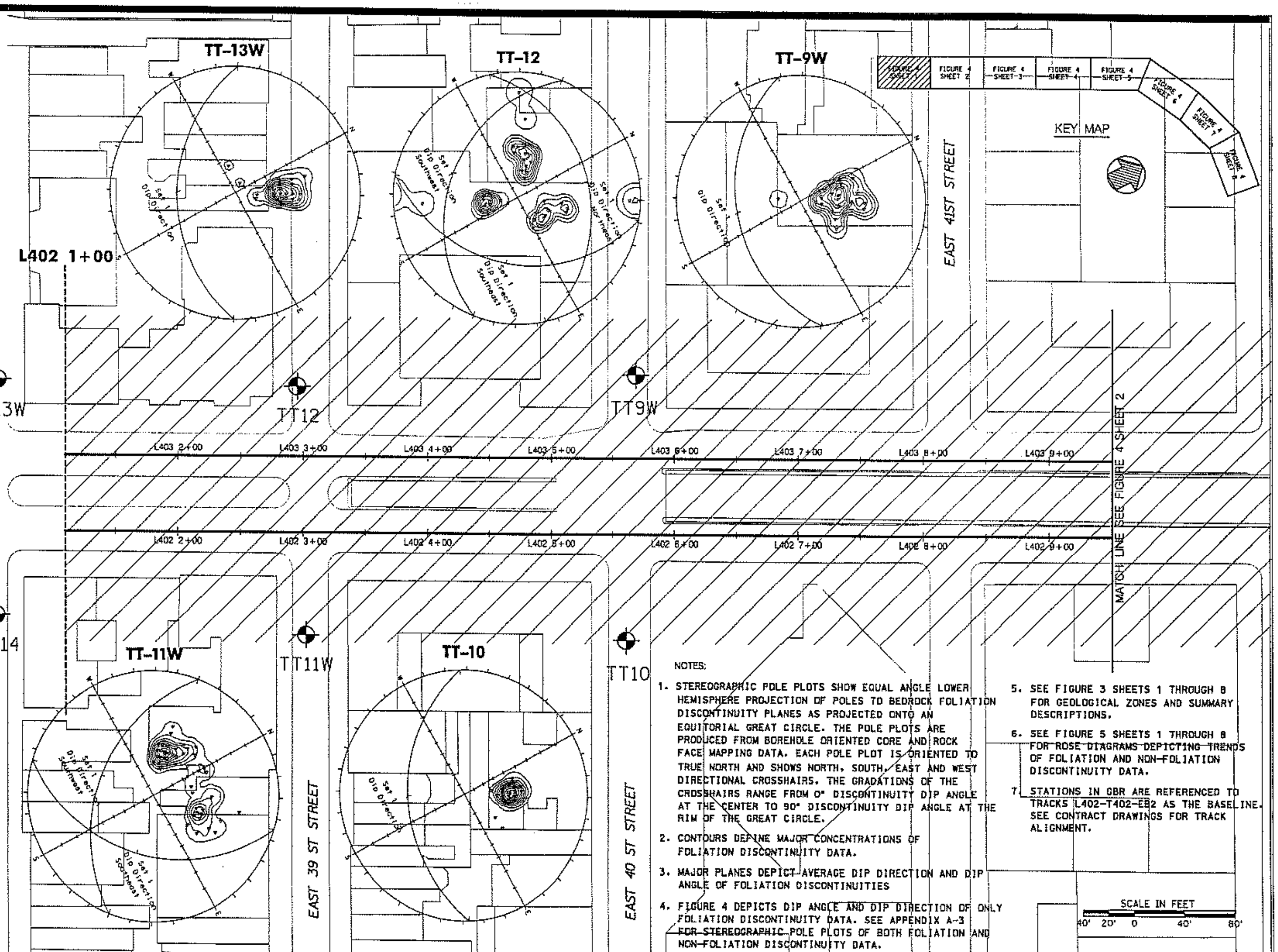
LEGEND:

- - - - - - - -	ZONE BOUNDARY
EB2 1084+00	REFERENCE STATION FOR ZONE BOUNDARY
Δ	FOLIATION DISCONTINUITY
(pattern)	GEOLOGICAL ZONE L402 1+00 TO T402 18+50
(pattern)	GEOLOGICAL ZONE T402 18+50 TO T402 31+00
(pattern)	GEOLOGICAL ZONES T402 31+00 TO EB2 1052+00; EB2 1052+00 TO EB2 1054+00; EB2 1063+00 TO EB2 1066+00
(pattern)	GEOLOGICAL ZONE T402 31+00 TO EB2 1052+00
(pattern)	GEOLOGICAL ZONE EB2 1054+00 TO EB2 1063+00
(pattern)	GEOLOGICAL ZONE EB2 1066+00 TO EB2 1076+50
(pattern)	GEOLOGICAL ZONE EB2 1076+50 TO EB2 1084+00



NOTES:

1. STEREOGRAPHIC POLE PLOTS SHOW EQUAL ANGLE LOWER HEMISPHERE PROJECTION OF POLES TO BEDROCK FOLIATION DISCONTINUITY PLANES AS PROJECTED ONTO AN EQUITORIAL GREAT CIRCLE. THE POLE PLOTS ARE PRODUCED FROM BOREHOLE ORIENTED CORE AND ROCK FACE MAPPING DATA. EACH POLE PLOT IS ORIENTED TO TRUE NORTH AND SHOWS NORTH, SOUTH, EAST AND WEST DIRECTIONAL CROSSHAIRS. THE GRADATIONS OF THE CROSSHAIRS RANGE FROM 0° DISCONTINUITY DIP ANGLE AT THE CENTER TO 90° DISCONTINUITY DIP ANGLE AT THE RIM OF THE GREAT CIRCLE.
2. CONTOURS DEFINE MAJOR CONCENTRATIONS OF FOLIATION DISCONTINUITY DATA.
3. MAJOR PLANES DEPICT AVERAGE DIP DIRECTION AND DIP ANGLE OF FOLIATION DISCONTINUITIES
4. FIGURE 4 DEPICTS DIP ANGLE AND DIP DIRECTION OF ONLY FOLIATION DISCONTINUITY DATA. SEE APPENDIX A-3 FOR STEREOGRAPHIC POLE PLOTS OF BOTH FOLIATION AND NON-FOLIATION DISCONTINUITY DATA.
5. SEE FIGURE 3 SHEETS 1 THROUGH 8 FOR GEOLOGICAL ZONES AND SUMMARY DESCRIPTIONS.
6. SEE FIGURE 5 SHEETS 1 THROUGH 8 FOR ROSE DIAGRAMS DEPICTING TRENDS OF FOLIATION AND NON-FOLIATION DISCONTINUITY DATA.
7. STATIONS IN GBR ARE REFERENCED TO TRACKS L402-T402-EB2 AS THE BASELINE. SEE CONTRACT DRAWINGS FOR TRACK ALIGNMENT.

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MANHATTAN SEGMENT
AVERAGE DIP DIRECTION AND DIP ANGLE OF FOLIATION DISCONTINUITIES ALONG ALIGNMENT
FIGURE 4 – SHEET 1 OF 4

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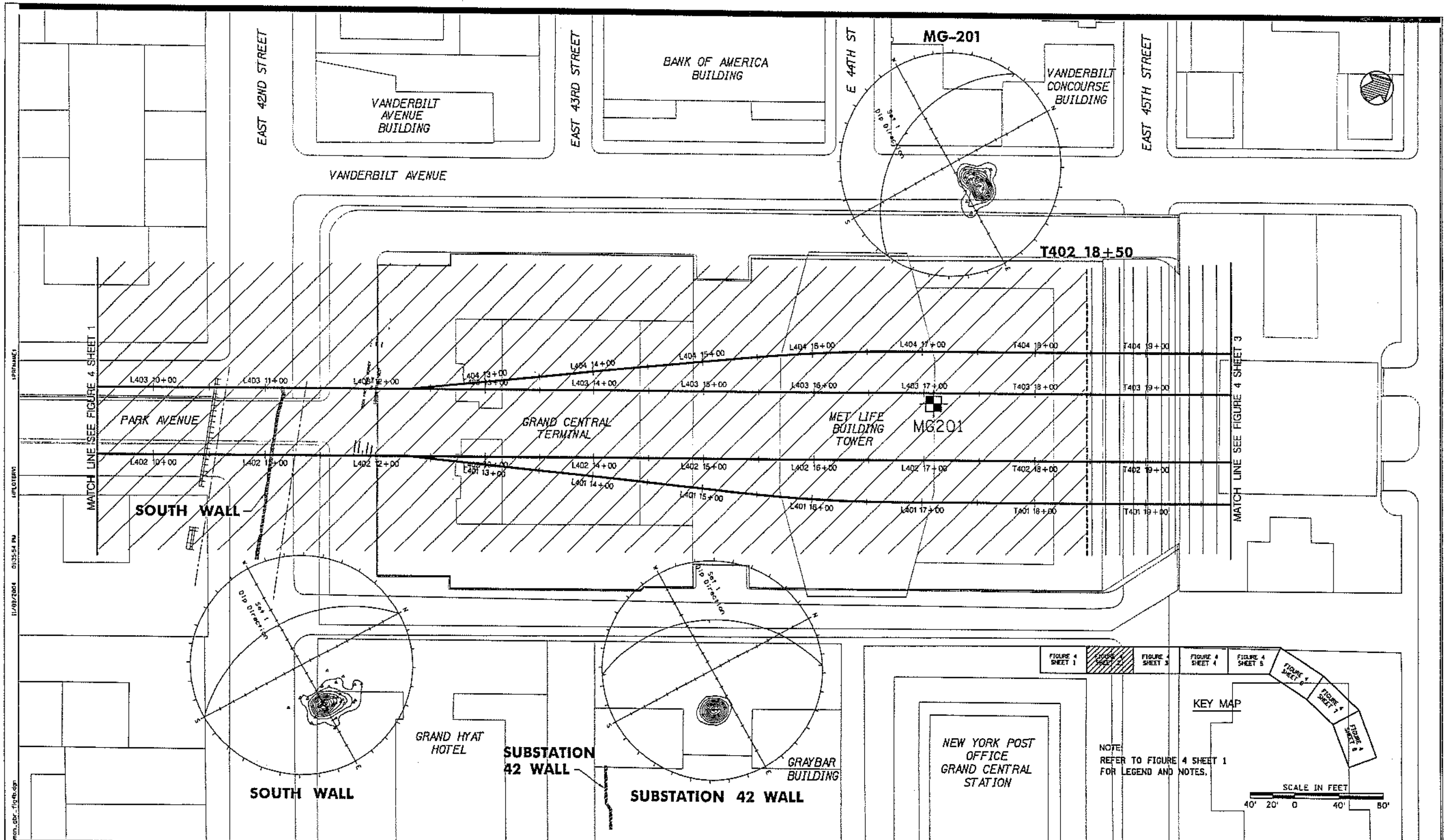

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MANHATTAN SEGMENT

AVERAGE DIP DIRECTION AND DIP ANGLE OF FOLIATION DISCONTINUITIES ALONG ALIGNMENT

FIGURE 4 – SHEET 2 OF 8

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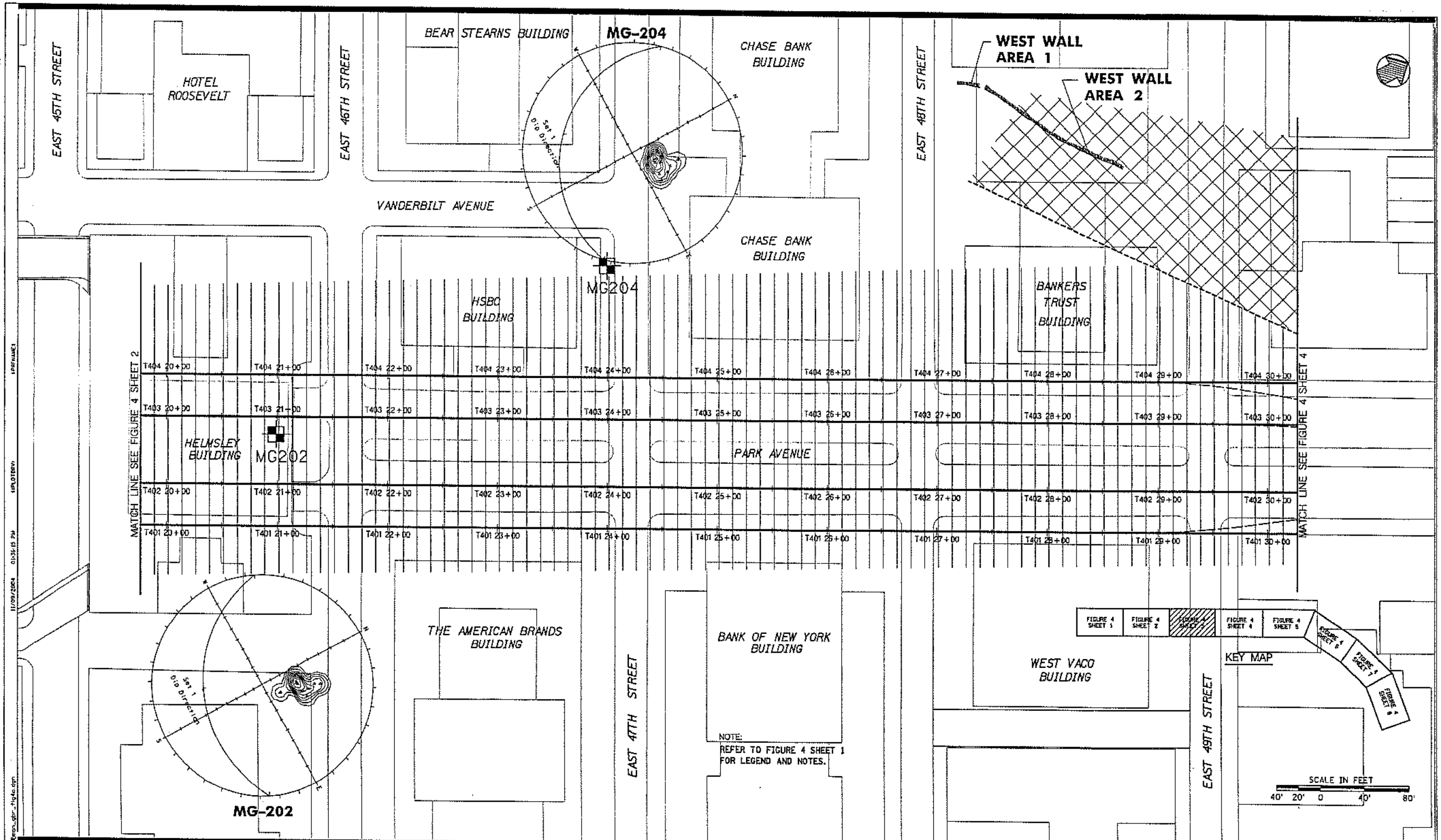

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MANHATTAN SEGMENT
AVERAGE DIP DIRECTION AND DIP ANGLE OF FOLIATION DISCONTINUITIES ALONG ALIGNMENT
FIGURE 4 – SHEET 3 OF 8

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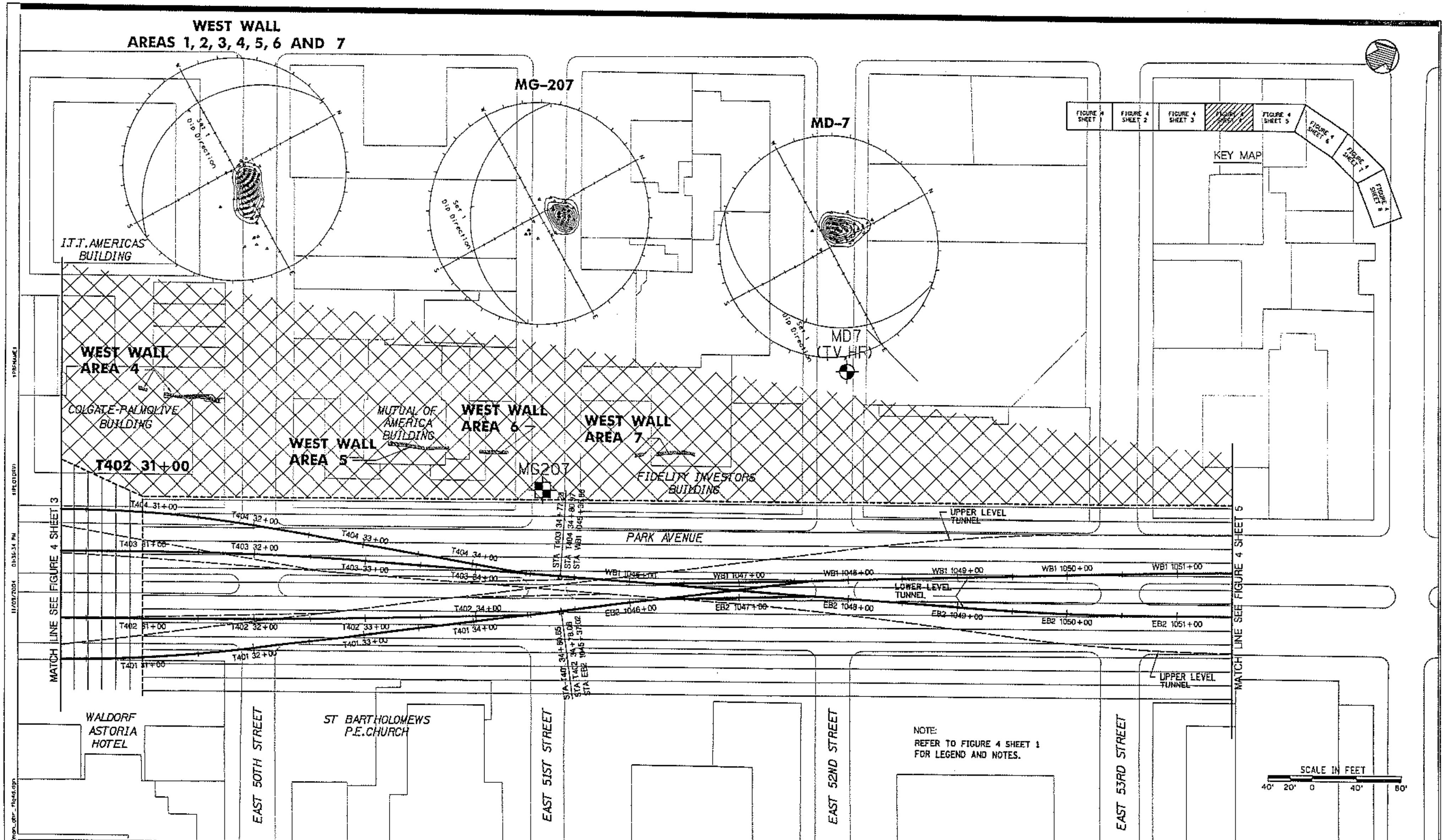

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MANHATTAN SEGMENT

AVERAGE DIP DIRECTION AND DIP ANGLE OF FOLIATION DISCONTINUITIES ALONG ALIGNMENT

FIGURE 4 – SHEET 4 OF 8

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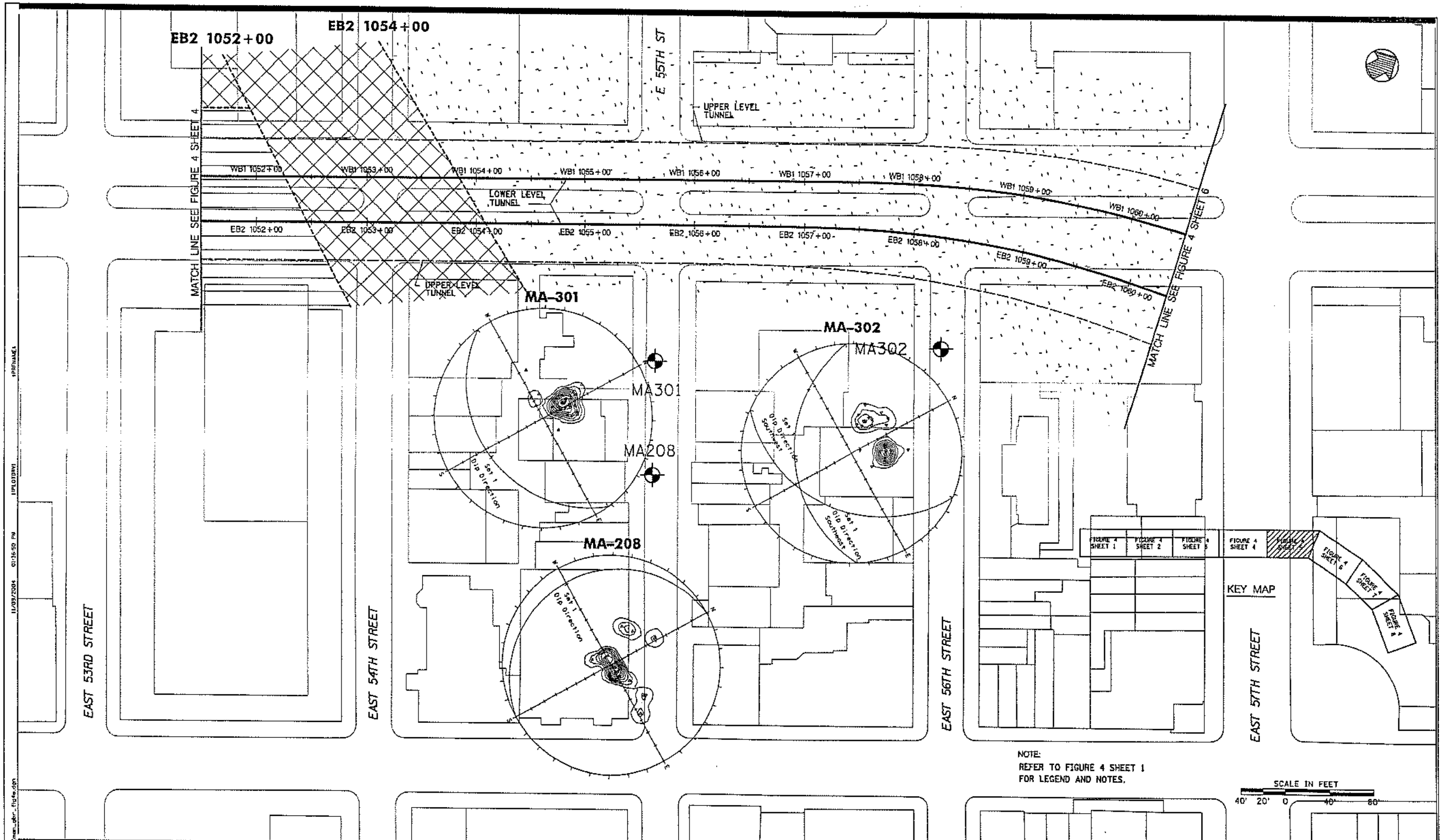

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MANHATTAN SEGMENT
AVERAGE DIP DIRECTION AND DIP ANGLE OF FOLIATION DISCONTINUITIES ALONG ALIGNMENT
FIGURE 4 – SHEET 5 OF 8

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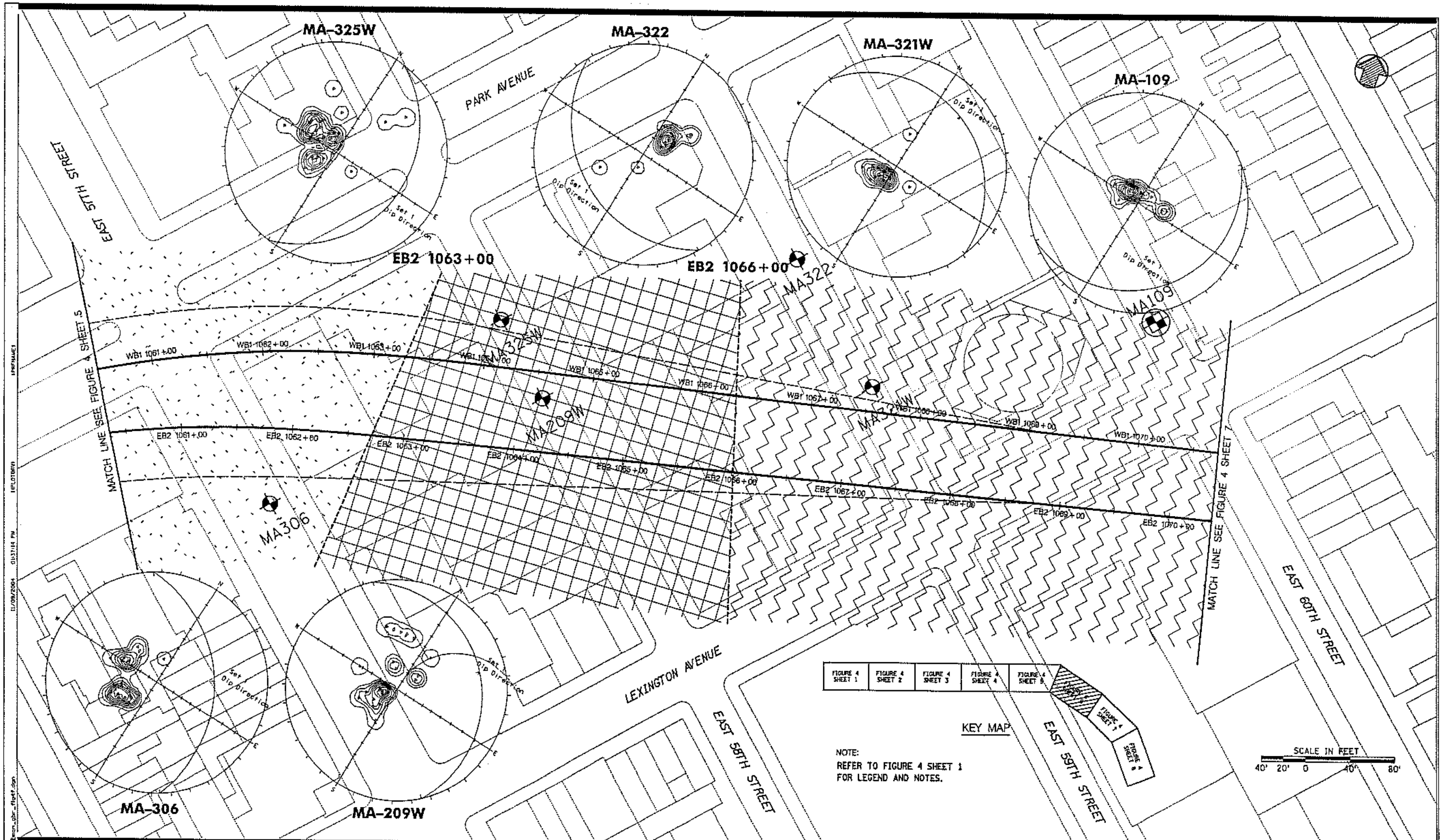

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MANHATTAN SEGMENT

AVERAGE DIP DIRECTION AND DIP ANGLE OF FOLIATION DISCONTINUITIES ALONG ALIGNMENT

FIGURE 4 – SHEET 6 OF 8

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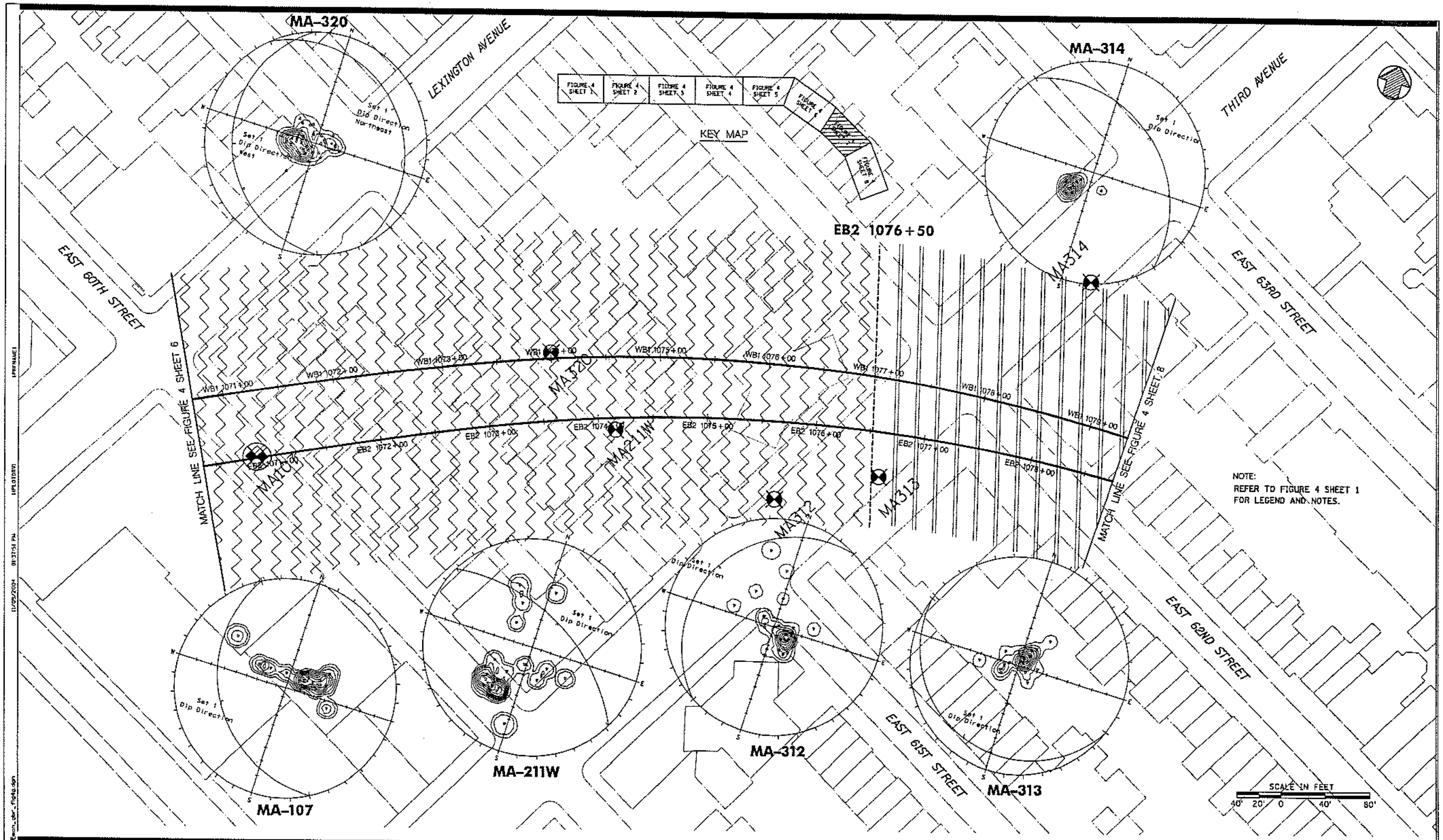

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MANHATTAN SEGMENT
AVERAGE DIP DIRECTION AND DIP ANGLE OF FOLIATION DISCONTINUITIES ALONG ALIGNMENT
FIGURE 4 – SHEET 7 OF 8

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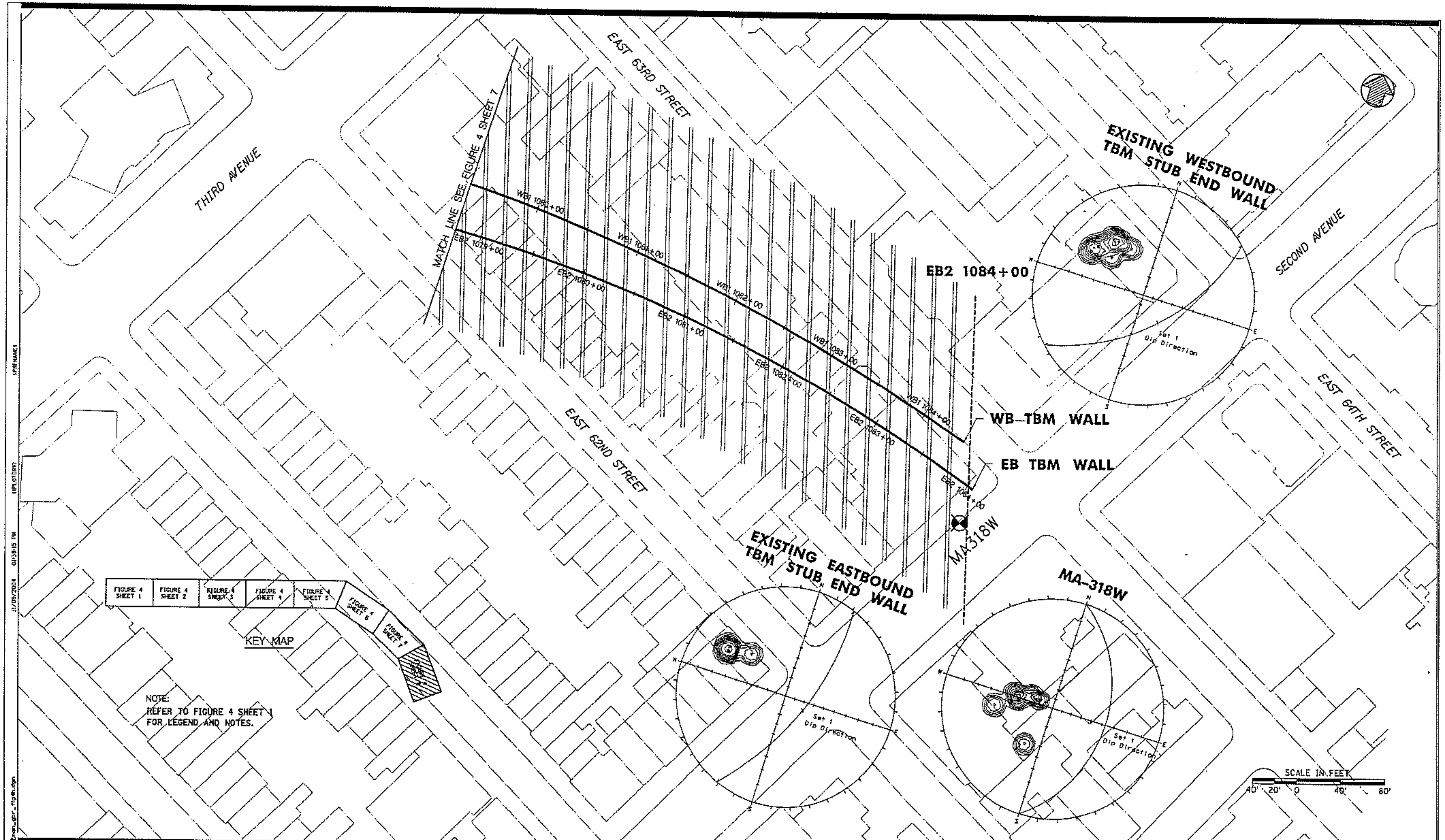

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MANHATTAN SEGMENT

AVERAGE DIP DIRECTION AND DIP ANGLE OF FOLIATION DISCONTINUITIES ALONG ALIGNMENT

FIGURE 4 – SHEET 8 OF 8

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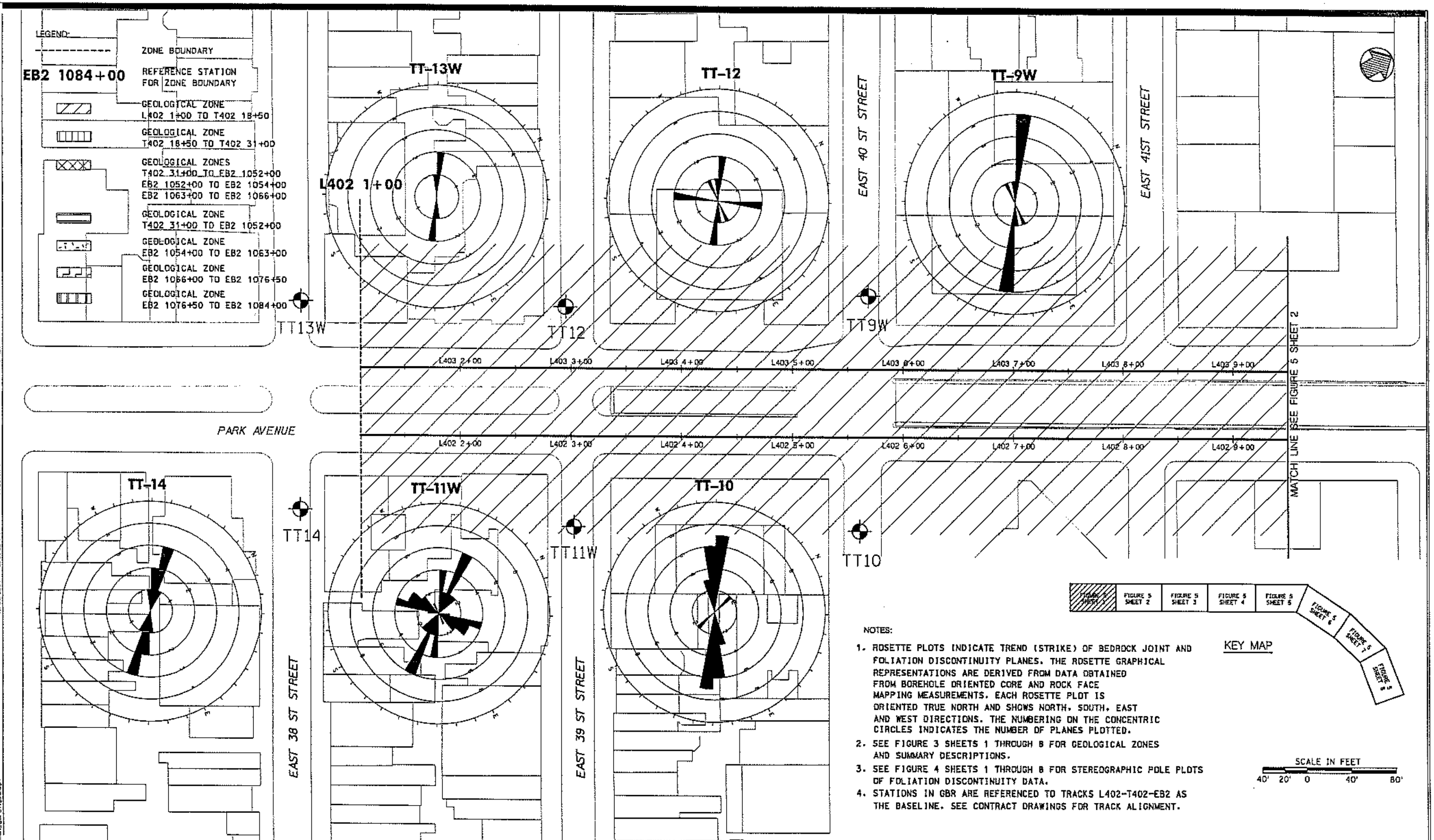

NOTES:

1. ROSETTE PLOTS INDICATE TREND (STRIKE) OF BEDROCK JOINT AND FOLIATION DISCONTINUITY PLANES. THE ROSETTE GRAPHICAL REPRESENTATIONS ARE DERIVED FROM DATA OBTAINED FROM BOREHOLE ORIENTED CORE AND ROCK FACE MAPPING MEASUREMENTS. EACH ROSETTE PLOT IS ORIENTED TRUE NORTH AND SHOWS NORTH, SOUTH, EAST AND WEST DIRECTIONS. THE NUMBERING ON THE CONCENTRIC CIRCLES INDICATES THE NUMBER OF PLANES PLOTTED.
2. SEE FIGURE 3 SHEETS 1 THROUGH 8 FOR GEOLOGICAL ZONES AND SUMMARY DESCRIPTIONS.
3. SEE FIGURE 4 SHEETS 1 THROUGH 8 FOR STEREOGRAPHIC POLE PLOTS OF FOLIATION DISCONTINUITY DATA.
4. STATIONS IN GBR ARE REFERENCED TO TRACKS L402-T402-EB2 AS THE BASELINE. SEE CONTRACT DRAWINGS FOR TRACK ALIGNMENT.

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MANHATTAN SEGMENT
TREND OF DISCONTINUITIES
FIGURE 5 – SHEET 1 OF 8

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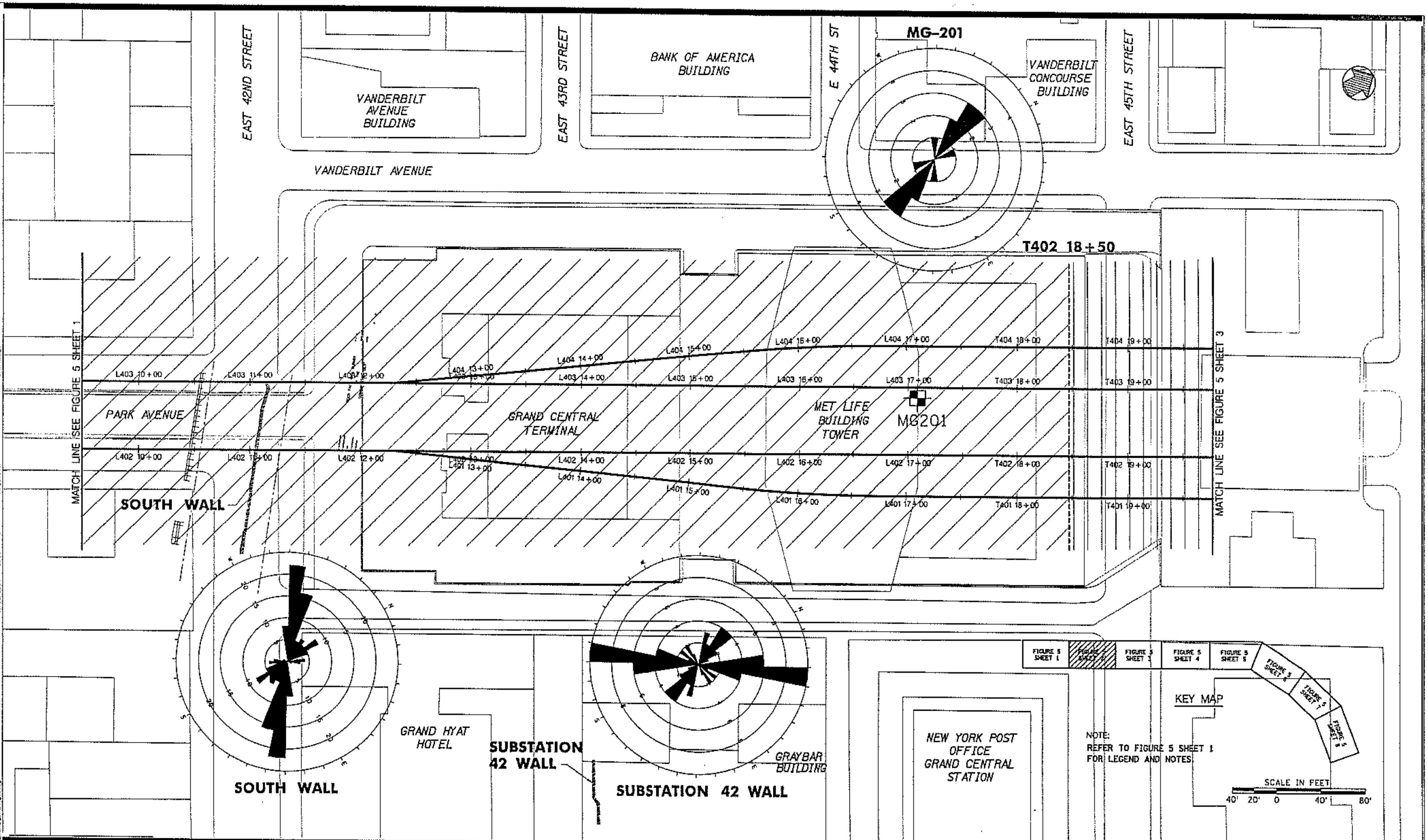

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MANHATTAN SEGMENT
TREND OF DISCONTINUITIES
FIGURE 5 – SHEET 2 OF 8

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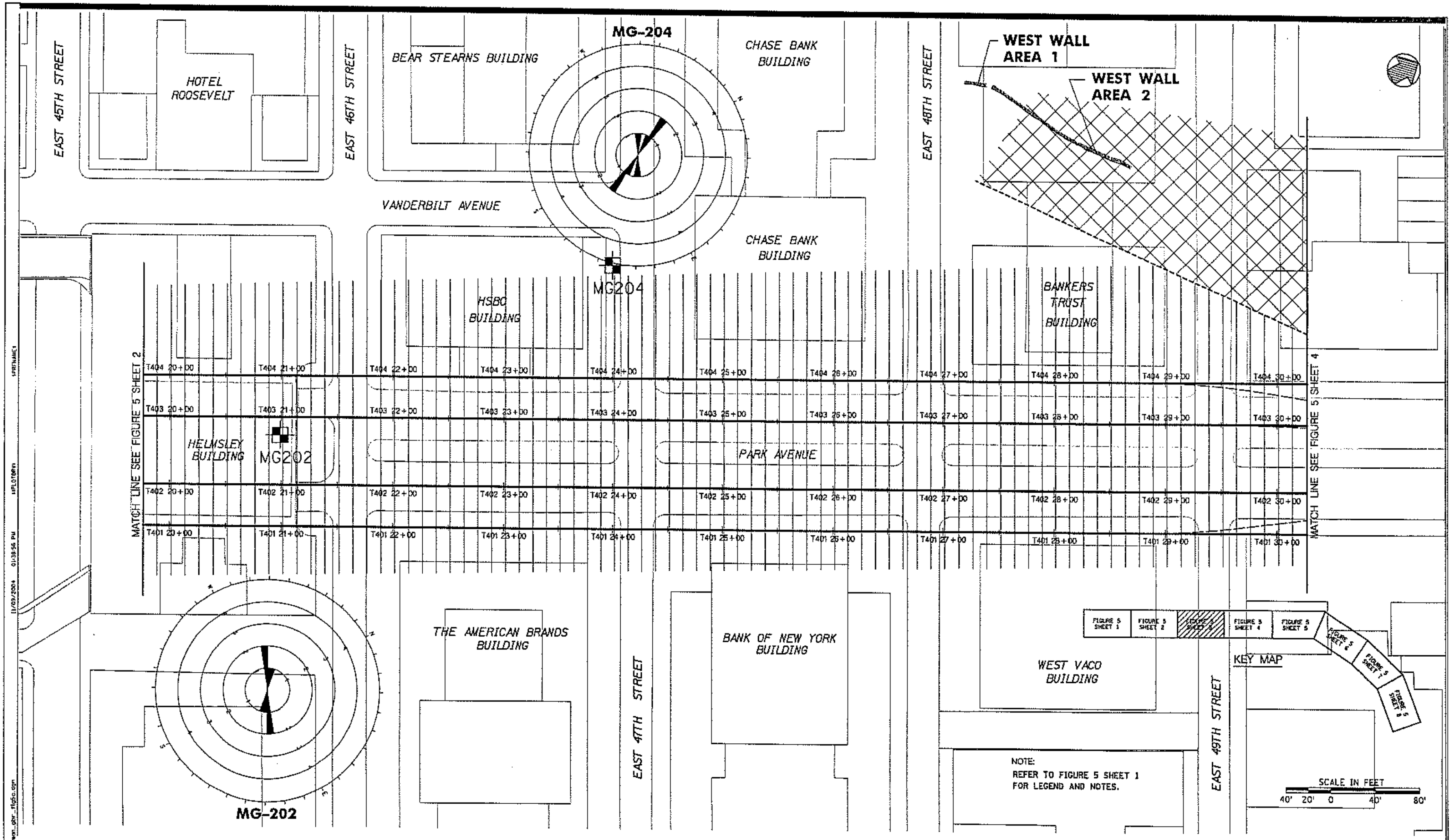

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MANHATTAN SEGMENT
TREND OF DISCONTINUITIES
FIGURE 5 – SHEET 3 OF 8

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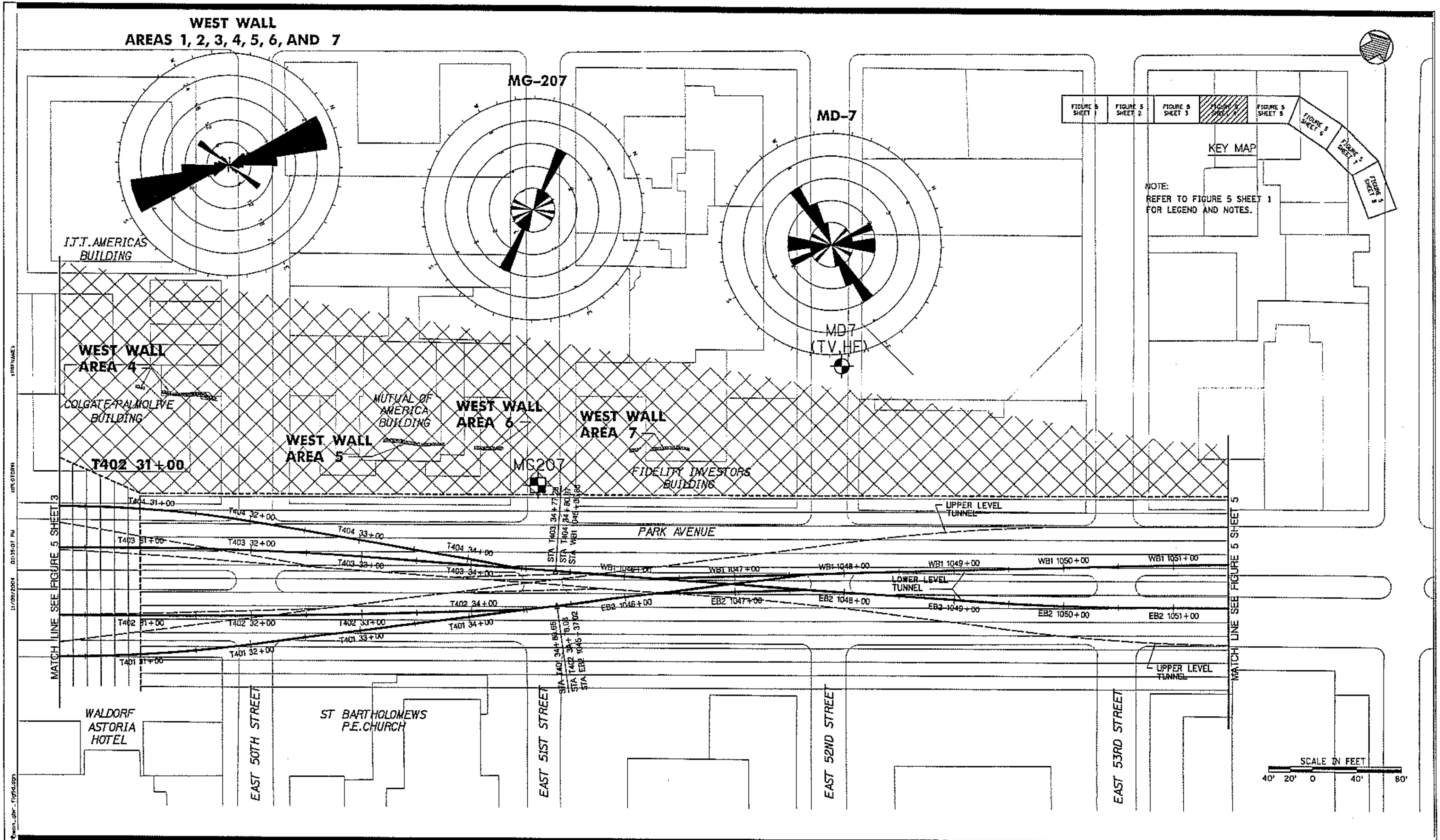

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MANHATTAN SEGMENT
TREND OF DISCONTINUITIES
FIGURE 5 – SHEET 4 OF 8

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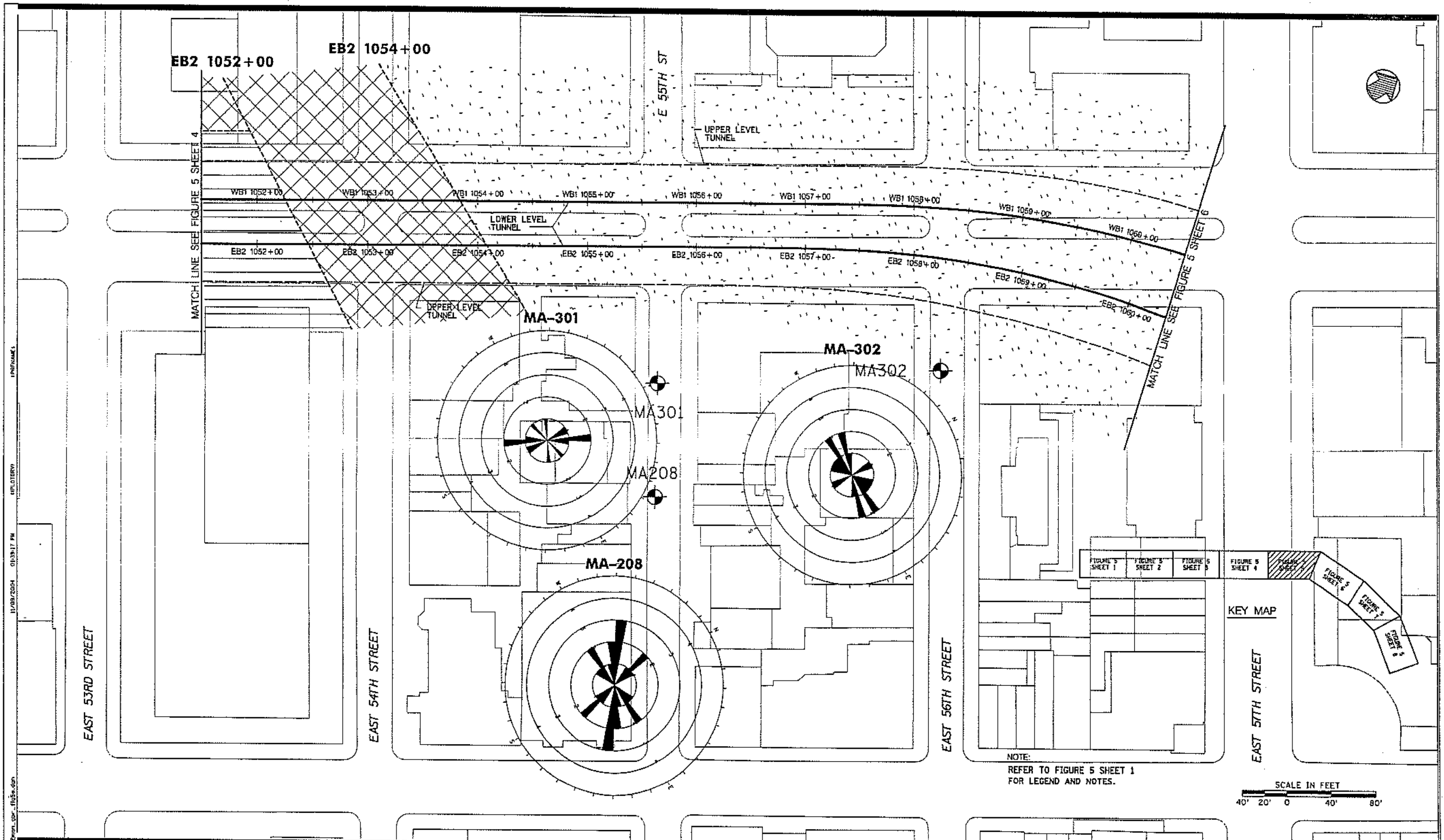

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MANHATTAN SEGMENT
TREND OF DISCONTINUITIES
FIGURE 5 - SHEET 5 OF 8

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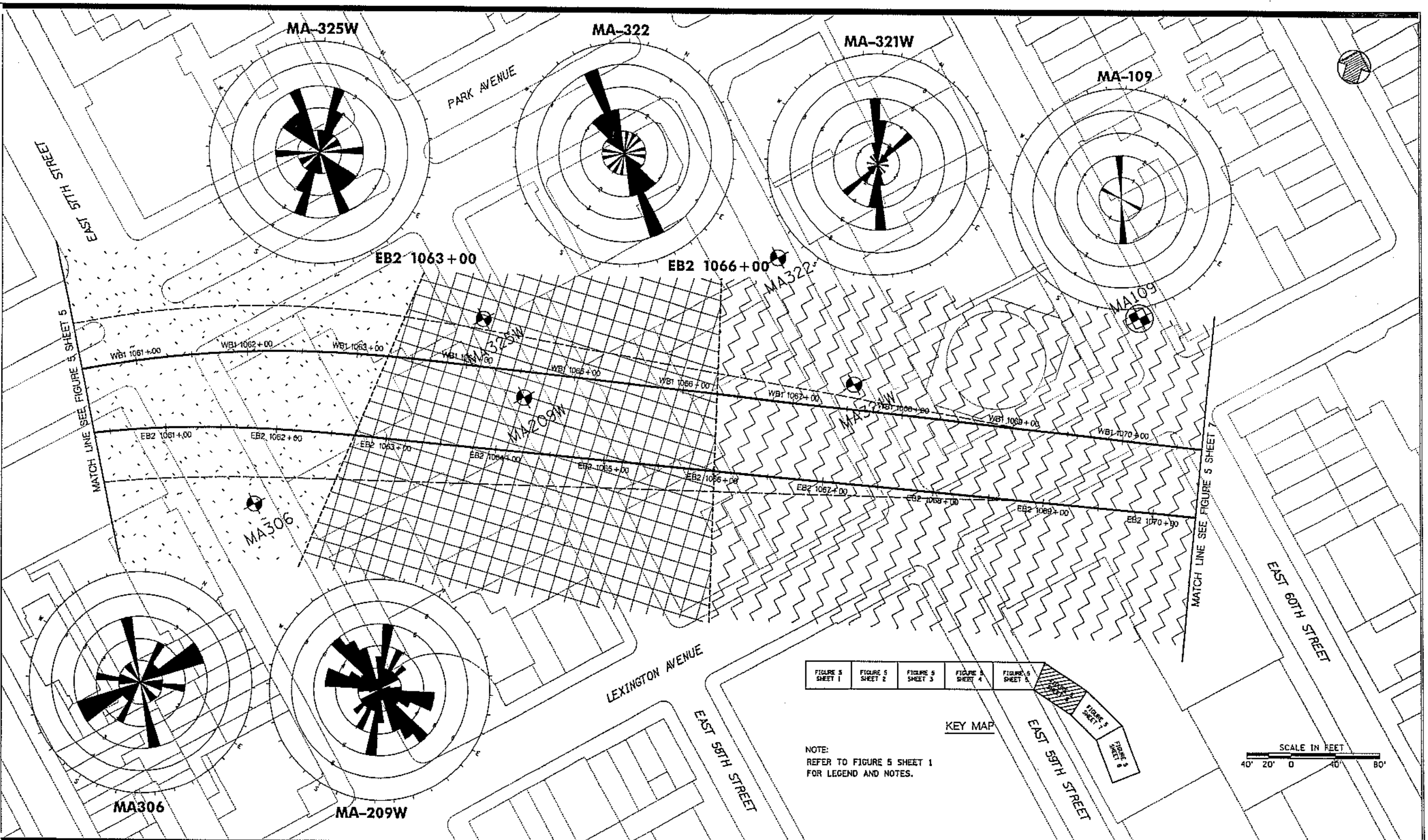

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MANHATTAN SEGMENT
TREND OF DISCONTINUITIES
FIGURE 5 – SHEET 6 OF 8

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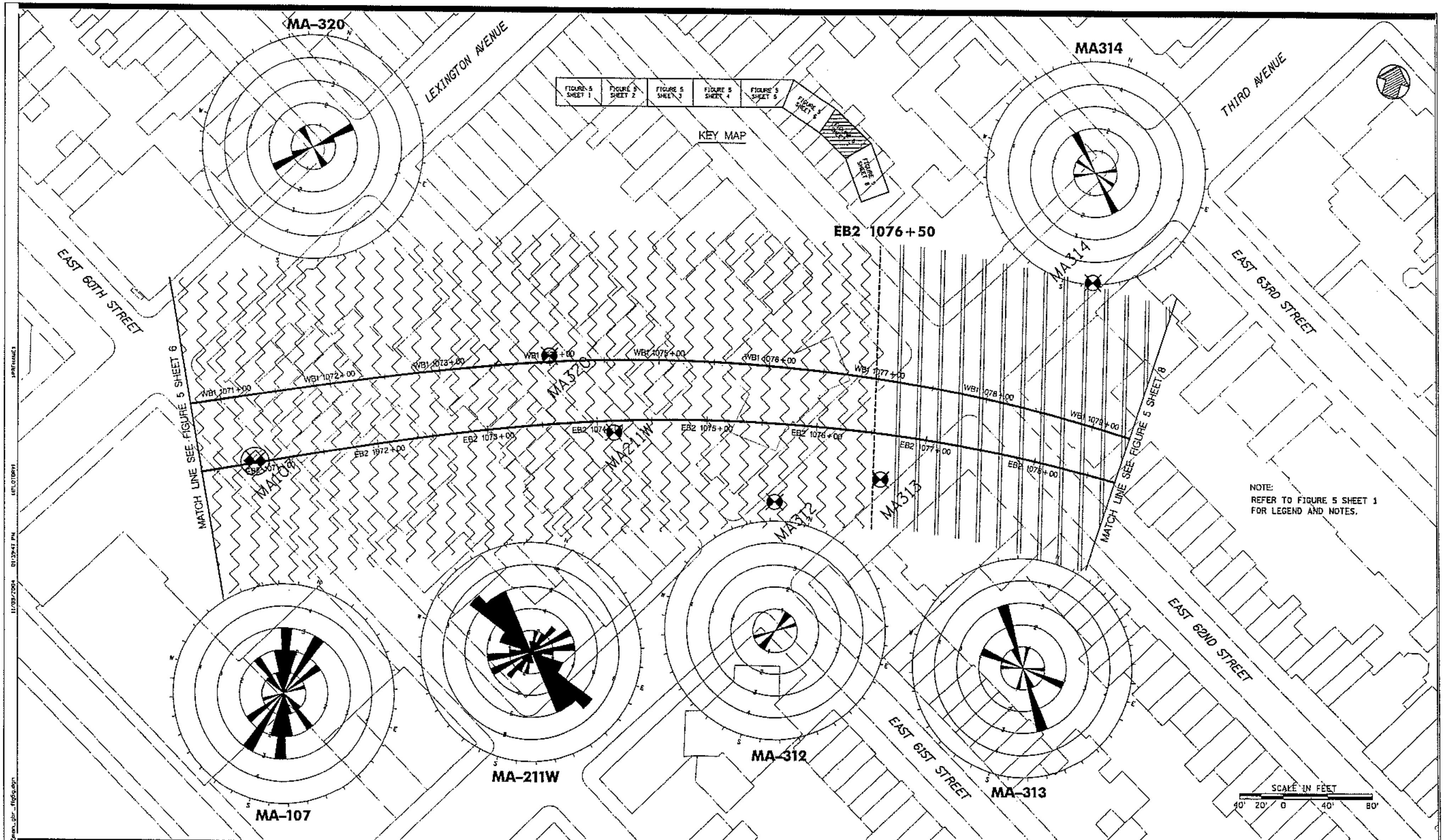

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MANHATTAN SEGMENT
TREND OF DISCONTINUITIES
FIGURE 5 – SHEET 7 OF 8

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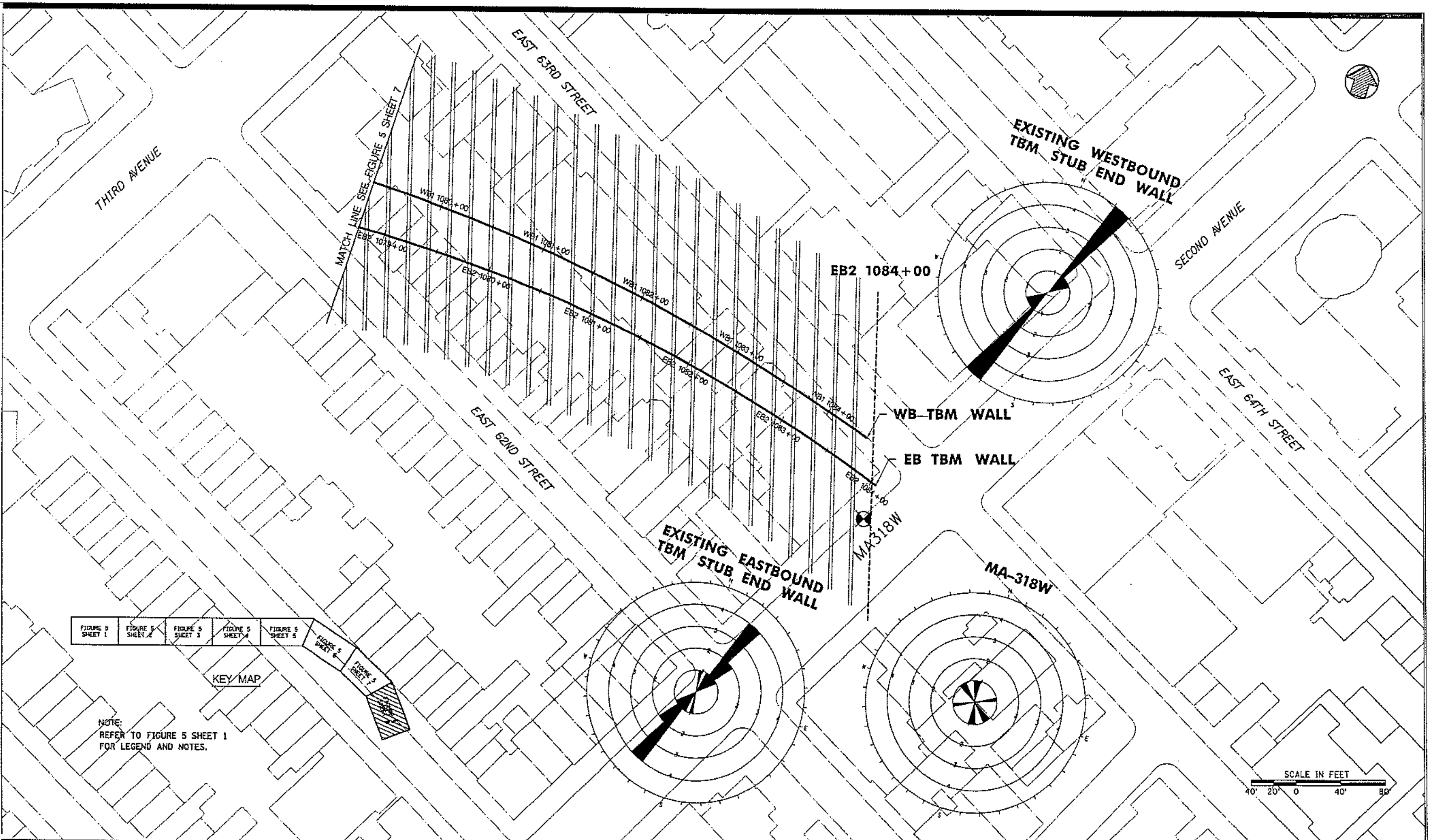

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MANHATTAN SEGMENT
TREND OF DISCONTINUITIES
FIGURE 5 - SHEET 8 OF 8

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ROCK WEATHERING CONDITION

GRADE	CONDITION	TERM	TYPICAL GEOTECHNICAL SITE INVESTIGATION METHODS		DESCRIPTION
			DRILLING	SAMPLING	
	ROCK-LIKE	FRESH	CORE	CORE	NO VISIBLE SIGN OF WEATHERING. NO DISCOLORATION OF THE ROCK MATERIAL VISIBLE ON MAJOR DISCONTINUITY SURFACES.
1		UNWEATHERED	CORE	CORE	NO VISIBLE SIGN OF ROCK MATERIAL WEATHERING. PERHAPS SLIGHT DISCOLORATION ON MAJOR DISCONTINUITY SURFACES.
2		SLIGHTLY WEATHERED	CORE	CORE	DISCOLORATION INDICATES WEATHERING OF ROCK MATERIAL AND DISCONTINUITY SURFACES. ALL THE ROCK MATERIAL MAY BE DISCOLORED BY WEATHERING AND MAY BE SOMEWHAT WEAKER EXTERNALLY THAN ITS FRESH CONDITION
3		MODERATELY WEATHERED	CORE	CORE	MATRIX OF ROCK-LIKE AND SOIL-LIKE MATERIAL. LESS THAN HALF OF THE ROCK MATERIAL MATRIX IS WEATHERED TO A SOIL. FRESH OR DISCOLORED ROCK IS PRESENT EITHER AS A CONTINUOUS FRAMEWORK OR AS CORESTONES IN THE ROCK MATERIAL MATRIX.
4		HIGHLY WEATHERED	CORE (ROLLER BIT INEFFECTIVE)	CORE	MORE THAN HALF OF THE ROCK MATERIAL MATRIX IS WEATHERED TO A SOIL. FRESH OR DISCOLORED ROCK IS PRESENT EITHER AS A DISCONTINUOUS FRAMEWORK OR AS CORESTONES.
5	SOIL-LIKE	COMPLETELY WEATHERED	CORE OR ROLLER BIT	CORE (DRIVE SAMPLE INEFFECTIVE)	ALL ROCK MATERIAL IS WEATHERED TO SOIL. THE ORIGINAL ROCK MASS STRUCTURE AND MATERIAL FABRIC IS STILL LARGELY INTACT, HOWEVER.
		DISINTEGRATED	CORE OR ROLLER BIT	DRIVE SAMPLE OR CORE	THE ROCK IS WEATHERED TO THE CONDITION OF A SOIL IN WHICH THE ORIGINAL ROCK MASS STRUCTURE IS LOST, BUT THE MATERIAL FABRIC IS STILL INTACT. THE MATERIAL IS FRIABLE, BUT THE MINERAL GRAINS ARE NOT DECOMPOSED.
		DECOMPOSED	ROLLER BIT	DRIVE SAMPLE (CORING INEFFECTIVE)	THE ROCK IS WEATHERED TO THE CONDITION OF A SOIL IN WHICH THE ORIGINAL MATERIAL FABRIC IS STILL INTACT. THE MATERIAL IS HIGHLY FRIABLE, WITH SOME OR ALL OF THE MINERAL GRAINS DECOMPOSED.
6		RESIDUAL	ROLLER BIT	DRIVE SAMPLE	ALL ROCK MATERIAL IS CONVERTED TO SOIL. THE ORIGINAL ROCK MASS STRUCTURE AND MATERIAL FABRIC ARE LOST. DEPOSITS HAVE TYPICALLY EXPANDED CONSIDERABLY FROM THE ORIGINAL ROCK VOLUME, BUT HAVE NOT BEEN TRANSPORTED FAR FROM ORIGINAL ROCK LOCATION.

ROCK JOINT FILLING STRENGTH CLASSIFICATION

THE STRENGTH OF ANY FILLING MATERIALS ALONG DISCONTINUITY SURFACES IS ASSESSED IN ACCORDANCE WITH THE FOLLOWING DESCRIPTIONS AND GRADES

GRADE	STRENGTH DESIGNATION	FIELD IDENTIFICATION	APPROXIMATE UNCONFINED COMPRESSION STRENGTH (KIPS/SQ.FT)
S1	VERY SOFT CLAY	EXTRUDED BETWEEN FINGERS WHEN SQUEEZED.	0.5
S2	SOFT CLAY	MOLDED BY LIGHT FINGER PRESSURE.	0.5 TO 1.0
S3	FIRM CLAY	MOLDED BY STRONG FINGER PRESSURE.	1.0 TO 2.0
S4	STIFF CLAY	READILY INDENTED BY THUMB, BUT PENETRATED BY THUMB ONLY WITH GREAT EFFORT.	2.0 TO 5.0
S5	VERY STIFF CLAY	READILY INDENTED BY THUMBNAIL.	5.0 TO 10.0
S6	HARD CLAY	INDENTED WITH DIFFICULTY BY THUMBNAIL.	>10.0

GRADES S1 TO S6 APPLY TO COHESIVE, GENERALLY SLOW DRAINING SOILS (E.G. CLAYS, SILTY CLAYS, AND COMBINATIONS OF SILTS WITH SAND). IF NON-COHESIVE FILLINGS ARE IDENTIFIED, QUALITATIVE DESCRIPTION IS GENERALLY PROVIDED FOR EACH (E.G. FINE SAND). STRENGTH OF DISCONTINUITIES WITHOUT FILLING MATERIALS WILL GENERALLY BE CHARACTERIZED BY GRADES R0-R6 (ROCK) WHILE S1-S6 (CLAY) WILL GENERALLY APPLY TO FILLED DISCONTINUITIES.

ROCK STRENGTH CLASSIFICATION

GRADE	STRENGTH	FIELD IDENTIFICATION	APPROXIMATE UNCONFINED COMPRESSION STRENGTH (LBS/SQ.IN)
R0	EXTREMELY WEAK ROCK	READILY BREAKABLE BY HAND PRESSURE. CRUMBLES UNDER LIGHT BLOW OF GEOLOGICAL HAMMER. EASILY RAKED BY GEOLOGICAL HAMMER PICK.	40 TO 150
R1	VERY WEAK ROCK	CRUMBLES UNDER FIRM BELOW OF GEOLOGICAL HAMMER OR MODERATE HAND PRESSURE. CAN BE RAKED WITH GEOLOGICAL HAMMER PICK.	150 TO 700
R2	WEAK ROCK	BREAKS WITH LIGHT BLOW OF GEOLOGICAL HAMMER OR STRONG HAND PRESSURE.	700 TO 4,000
R3	MEDIUM STRONG ROCK	BREAKS WITH FIRM BLOW OF GEOLOGICAL HAMMER.	4,000 TO 7,000
R4	STRONG ROCK	SPECIMEN REQUIRES MORE THAN ONE FIRM BLOW OF GEOLOGICAL HAMMER TO BREAK IT.	7,000 TO 15,000
R5	VERY STRONG ROCK	SPECIMEN REQUIRES MANY FIRM BLOWS OF GEOLOGICAL HAMMER TO BREAK.	15,000 TO 36,000
R6	EXTREMELY STRONG ROCK	SPECIMEN CAN ONLY BE CHIPPED WITH GEOLOGICAL HAMMER.	>36,000

ROCK HARDNESS

ROCK HARDNESS DESIGNATION	FIELD IDENTIFICATION
VERY SOFT	INDENTED BY THUMBNAIL
SOFT	CAN BE SCRATCHED WITH THUMBNAIL OR READILY PEELED WITH A POCKET KNIFE. READILY INDENTED BY FIRM BLOWS GEOLOGICAL HAMMER'S BLUNT END.
MODERATELY HARD	CAN BE PEELED BY A POCKET KNIFE WITH DIFFICULTY. SHALLOW INDENTATIONS MADE BY FIRM BLOW WITH POINT OF GEOLOGICAL HAMMER.
MEDIUM HARD	CANNOT BE SCRAPED OR PEELED WITH A POCKET KNIFE. BREAKS WHEN STRUCK WITH FIRM BLOWS BY BLUNT END OF GEOLOGICAL HAMMER.
HARD	DIFFICULT TO SCRATCH WITH EDGE OF A POCKET KNIFE. CHIPS WHEN STRUCK WITH FIRM BLOWS BY BLUNT END OF GEOLOGICAL HAMMER.
VERY HARD	DIFFICULT TO SCRATCH WITH POINT OF A POCKET KNIFE. MAY SPARK WHEN STRUCK WITH GEOLOGICAL HAMMER.
EXTREMELY HARD	PRODUCES ONLY SMALL CHIPS AND FREQUENTLY SPARKS WHEN STRUCK BY FIRM BLOWS WITH PICK OF GEOLOGICAL HAMMER. CANNOT BE SCRATCHED WITH POCKET KNIFE.

ROCK GRAIN TEXTURE

GRAIN DESIGNATION	CONDITION
FINE	GRAIN PARTICLES NOT VISIBLE TO JUST BARELY VISIBLE WITH NAKED EYE.
MEDIUM	GRAIN SIZE BARELY TO EASILY VISIBLE WITH THE NAKED EYE: UP TO 1/8 INCH.
COARSE	GRAIN SIZE 1/8 INCH OR GREATER

ROCK DISCONTINUITY CLASSIFICATIONS

ROCK FRACTURE SPACING

DESCRIPTION	SPACING
EXTREMELY CLOSE OR CRUSHED	<3/4 INCHES
VERY CLOSE	¾TO 2-1/2 INCHES
CLOSE	2-1/2 TO 8 INCHES
MODERATE	8 INCHES TO 2 FEET
WIDE	2 TO 6 FEET
VERY WIDE	6 TO 20 FEET

NOTE:
FRACTURES REFER TO NATURAL BREAKAGES INCLUDING JOINTS, SHEAR ZONES, AND FAULT LINES. FRACTURE SPACING RANGE DESIGNATIONS BASED ON ISRM GUIDELINES.

ROCK LAYERING

DESCRIPTION	SPACING
LAMINATED	<1/2 INCHES
VERY THIN	½ TO 2 INCHES
THIN	2 INCHES TO 1 FEET
MEDIUM	1 TO 3 FEET
THICK	3 TO 10 FEET
MASSIVE	> 10 FEET

NOTE:
LAYERING REFERS TO NATURAL ROCK FORMATION FEATURES SUCH AS FOLIATION, SEAMS, BANDING, OR BEDDING.

SURFACE PLANARITY

DESIGNATION	CONDITION
PLANAR	A FLAT SURFACE
STEPPED	A SURFACE WITH ASPERITIES OR STEPS.
WAVY	A MODERATE UNDULATING SURFACE: CURVED, SMOOTHLY UNEVEN.

JOINT ROUGHNESS, Jr

DISCONTINUITY CATEGORY	DISCONTINUITY CONDITION (CONTACT SURFACE ROUGHNESS)	JOINT ROUGHNESS FACTOR Jr
DIRECT CONTACT BETWEEN SURFACES	DISCONTINOUS JOINTS	4
	ROUGH OR IRREGULAR, UNDULATING	3
	SMOOTH, UNDULATING	2
	SLICKENSIDED, UNDULATING	1.5
	ROUGH OR IRREGULAR, PLANAR	1.5
	SMOOTH, PLANAR	1.0
	SLICKENSIDED, PLANAR	0.5
NO DIRECT CONTACT BETWEEN SURFACES	CLAY MINERAL ZONE PREVENTING ROCK WALL CONTACT	1.0(NOMINAL)
	SANDY, GRAVELLY, OR CRUSHED ZONE PREVENTING WALL CONTACT	1.0(NOMINAL)

JOINT ALTERATION, Ja

JOINT CATEGORY	JOINT CONDITION (CONTRACT SURFACE ALTERATION)		JOINT ALTERATION FACTOR J_a
	DESCRIPTION	CONDITION	
DIRECT CONTACT BETWEEN SURFACES (JOINT COATING LESS THAN 1/8" THICK)	A. TIGHTLY HEALED	TIGHTLY HEALED, HARD, NON-SOFTENING, IMPERMEABLE FILLING	0.75
	B. UNALTERED	UNALTERED JOINT SURFACES, SURFACES STAINING ONLY	1.0
	C. SLIGHTLY ALTERED	SLIGHTLY ALTERED JOINT WALLS, NON-SOFTENING MINERAL COATINGS, SANDY PARTICLES, CLAY FREE DISINTEGRATED ROCK ETC.	2.0
	D. COATED	SILTY OR SANDY CLAY COATINGS, SMALL CLAY FRACTION (NON-SOFTENING)	3.0
	E. CLAY COATED	SOFTENING OR LOW FRICTION CLAY MINERAL COATINGS, IE. KAOLINITE, MICA, CHLORITE, ETC.	4.0
NO DIRECT CONTACT BETWEEN SURFACES (JOINT COATING LESS THAN 1/4" THICK)	F. INFILLED	SANDY PARTICLES, CLAY-FREE DISINTEGRATED ROCK ETC.	4.0
	G. CLAY FILLED	STRONGLY OVERCONSOLIDATED, SOFTENING, CLAY MINERAL FILLINGS	6.0
	H. SOFT CLAY FILLED	MEDIUM OR LOW OVERCONSOLIDATION, SOFTENING, CLAY MINERAL FILLINGS	8.0
	J. SWELLING CLAY FILLED	SWELLING CLAY FILLINGS, IE. MONTMORILLONITE. (Ja VALUE FOR ITEM J DEPENDS ON PERCENT OF SWELLING CLAY-SIZE PARTICLES AND ACCESS TO WATER, ETC.)	8.0-12.0
NO DIRECT CONTACT BETWEEN SURFACES (JOINT COATING GREATER THAN 1/4" THICK)	L. CRUSHED ZONE	CRUSHED ROCK AND CLAY (SEE ITEMS G, H, AND J FOR DESCRIPTION OF CLAY CONDITION)	6.0, 8.0 OR 8.0-12.0
	N. DECOMPOSED ZONE	ZONES OR BANDS OF SILTY-OR SANDY CLAY, SMALL CLAY FRACTION (NON-SOFTENING)	5.0
	O. CLAY ZONE	THICK CONTINUOUS ZONES OR BANDS OF CLAY (SEE ITEMS G, H, AND J FOR DESCRIPTION OF CLAY CONDITION)	10.0, 13.0 OR 13.0-20.0

ROCK QUALITY DESIGNATION, RQD

RQD PERCENT	ROCK QUALITY
< 25	VERY POOR
25-50	POOR
50-75	FAIR
75-90	GOOD
90-100	EXCELLENT

ROCK CORE CONTINUITY

DESCRIPTION	AVERAGE LENGTH OF PIECES
SOUND	> 8 INCHES
SLIGHTLY FRACTURED	4 TO 8 INCHES
MODERATELY FRACTURED	1 TO 4 INCHES
EXTREMELY FRACTURED	< 1 INCH

NOTES:
ROCK CORE CONTINUITY REFERS TO A GENERAL DESCRIPTIVE TERM DESCRIBING THE OVERALL DEGREE OF FRACTURING CONDITION OF EACH ROCK CORE RUN.

ROCK CLASSIFICATION NOTES:

1. CORE RECOVERY: CORE RECOVERY IS EXPRESSED IN TWO WAYS. FIRST, AS THE SIMPLE NET LENGTH OF CORE RECOVERED IN INCHES. SECONDLY, AS THE RATIO OF THE LENGTH OF NET CORE RECOVERED TO THE OVERALL LENGTH OF THE CORE RUN, EXPRESSED AS A PERCENTAGE. CORE RECOVERY IS GENERALLY DETERMINED SEPARATELY FOR EACH SEPARATE CORING RUN.
2. RQD: RQD (ROCK QUALITY DESIGNATION) IS A GENERAL INDEX OF ROCK CORE CONDITION FOR ENGINEERING PURPOSES. RQD IS EXPRESSED AS A MODIFIED CORE RECOVERY PERCENTAGE IN WHICH ONLY THE SUM OF THE LENGTHS OF PIECES OF UNWEATHERED OR SLIGHTLY WEATHERED CORE OVER 4 INCHES LONG IS DIVIDED BY THE OVERALL LENGTH OF THE CORE RUN. THE AVERAGE LENGTH OF CORE PIECES IS USED WHERE END FRACTURES ARE NOT PERPENDICULAR TO THE CORE AXIS (I.E. WHERE ENDS OF CORE PIECES ARE SLANTED, BY MEASURING TO THE MIDDLE OF THE BREAK). FRESH CORE FRACTURES CREATED BY MECHANICAL BREAKAGE DURING DRILLING AND/OR HANDLING OF THE CORE ARE IGNORED IN COMPUTING RQD. RQD IS GENERALLY DETERMINED SEPARATELY FOR EACH SEPARATE CORE RUN.
3. DISCONTINUITY ORIENTATION ANGLE: ORIENTATION OF DISCONTINUITIES IS GENERALLY EXPRESSED AS AN ANGLE (IN DEGREES). THIS ORIENTATION REFERS TO THE ANGLE BETWEEN THE AVERAGE DIRECTION OF A DISCONTINUITY AND A PLANE PERPENDICULAR TO THE CORE AXIS. (E.G. FOR A VERTICAL BORING DISCONTINUTY ANGLE OF 0 DEGREES REFERS TO A HORIZONTAL DISCONTINUITY). THE COMPASS DIRECTION OF ROCK CORE DISCONTINUITES IS GENERALLY NOT DIRECTLY DETERMINABLE FROM CORE INSPECTION ALONE WITH THE CORING METHODS USED FOR THIS PROJECT.

ROCK CLASSIFICATION REFERENCES:

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ROCK CLASSIFICATION SYSTEM TERMINOLOGIES

FIGURE 6 – SHEET 2

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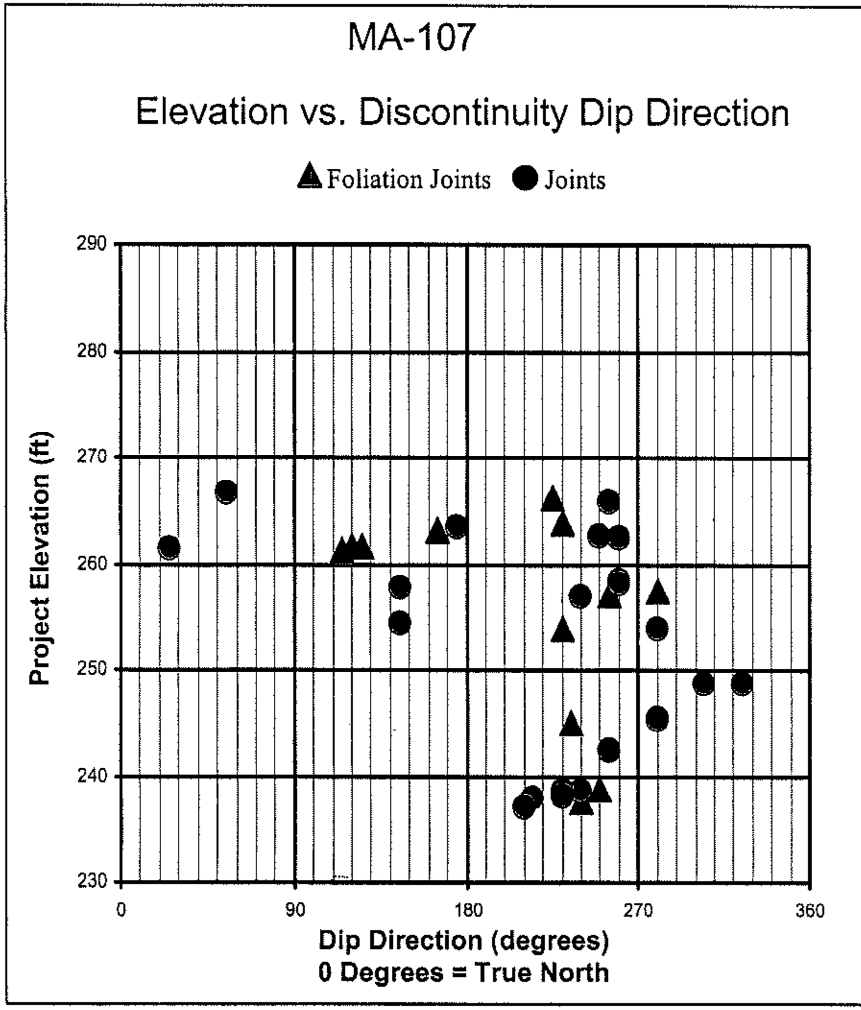
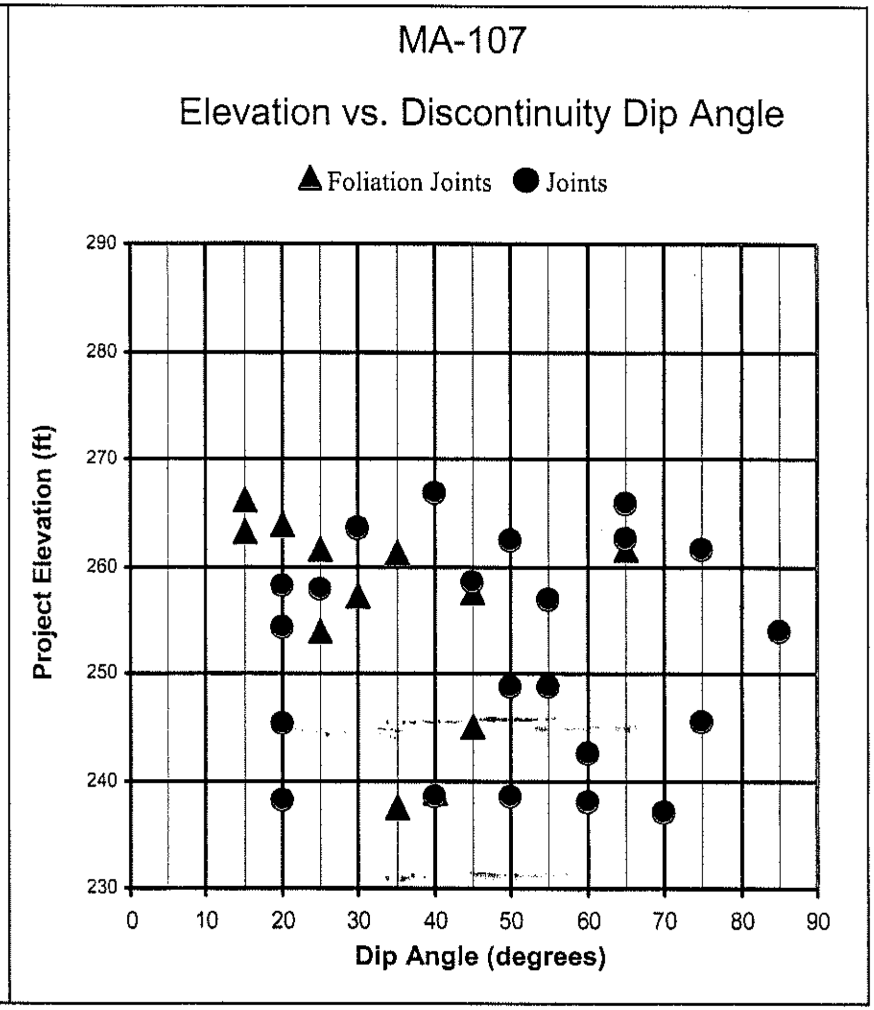
APPENDIX A

ORIENTED ROCK CORE DISCONTINUITY DATA

APPENDIX A-1

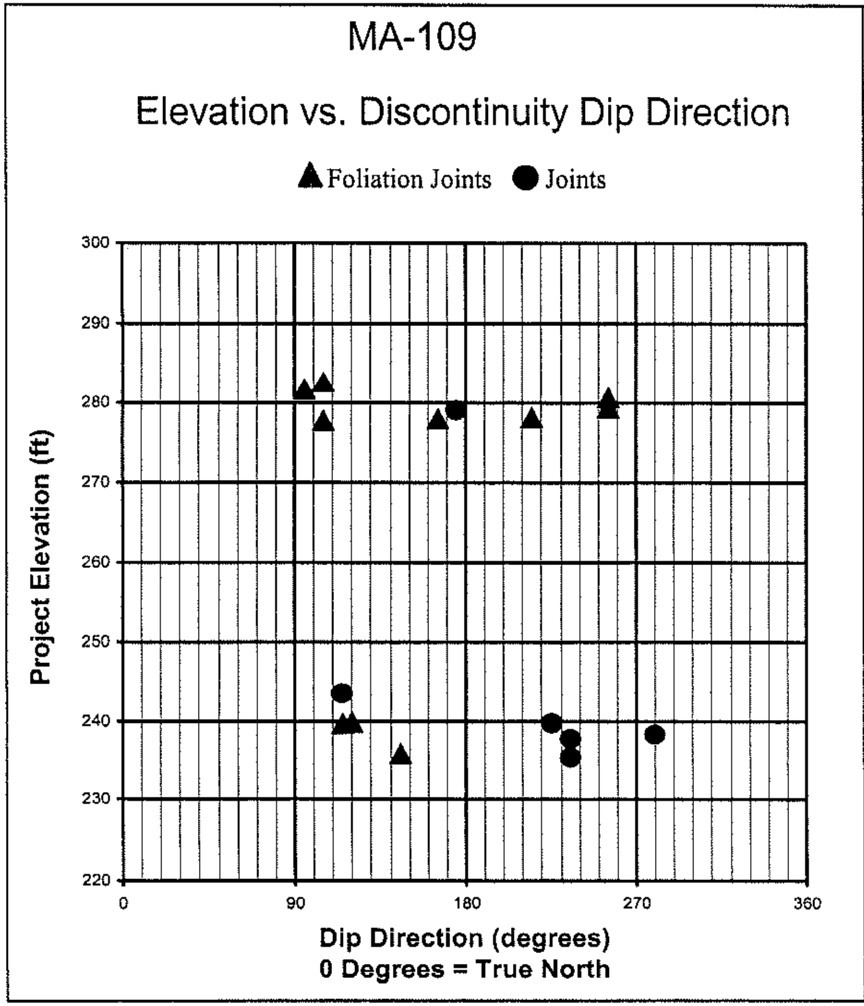
DISCONTINUITY DIP ANGLE AND DIP DIRECTION VS. PROJECT ELEVATION

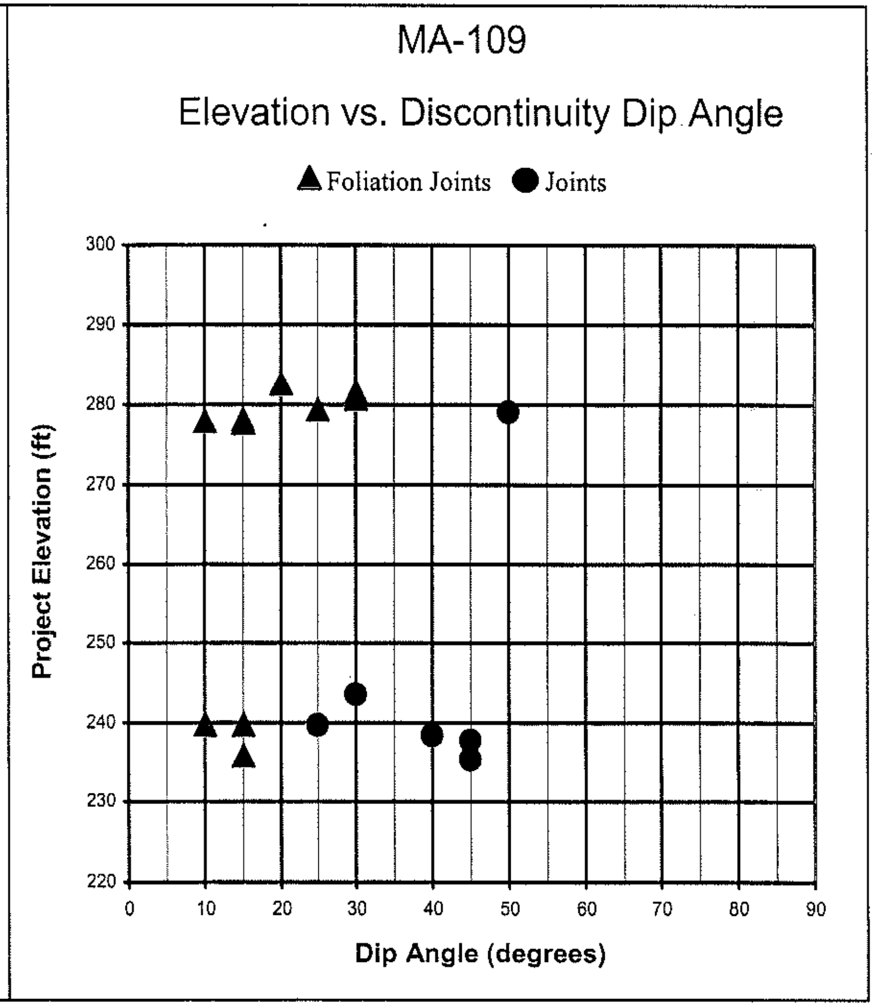




ORIENTED CORE DISCONTINUITY DATA

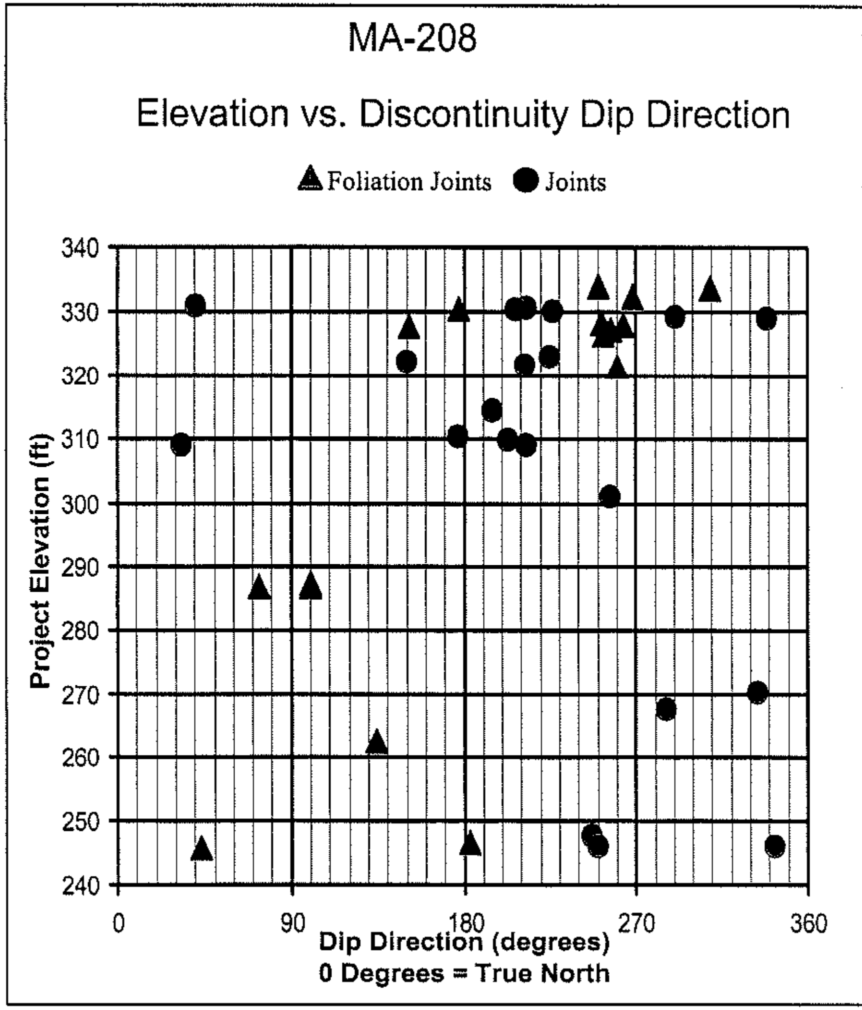
APPENDIX A-1
SHEET 1

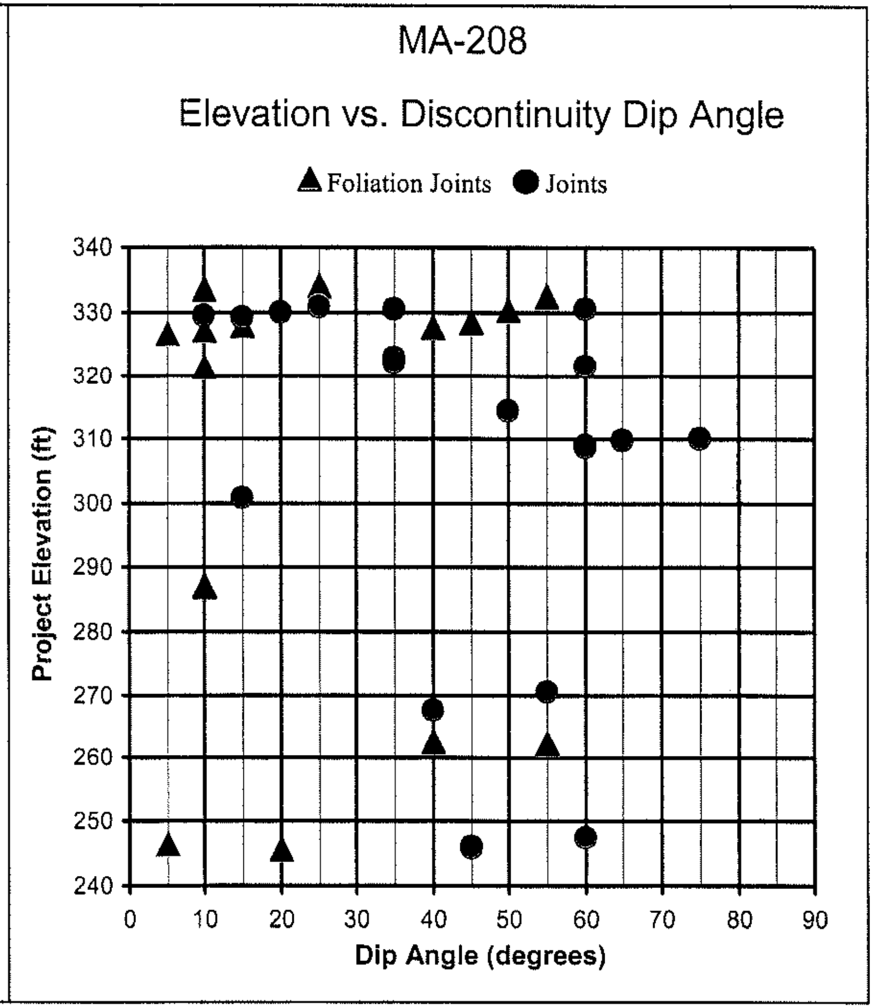




ORIENTED CORE DISCONTINUITY DATA

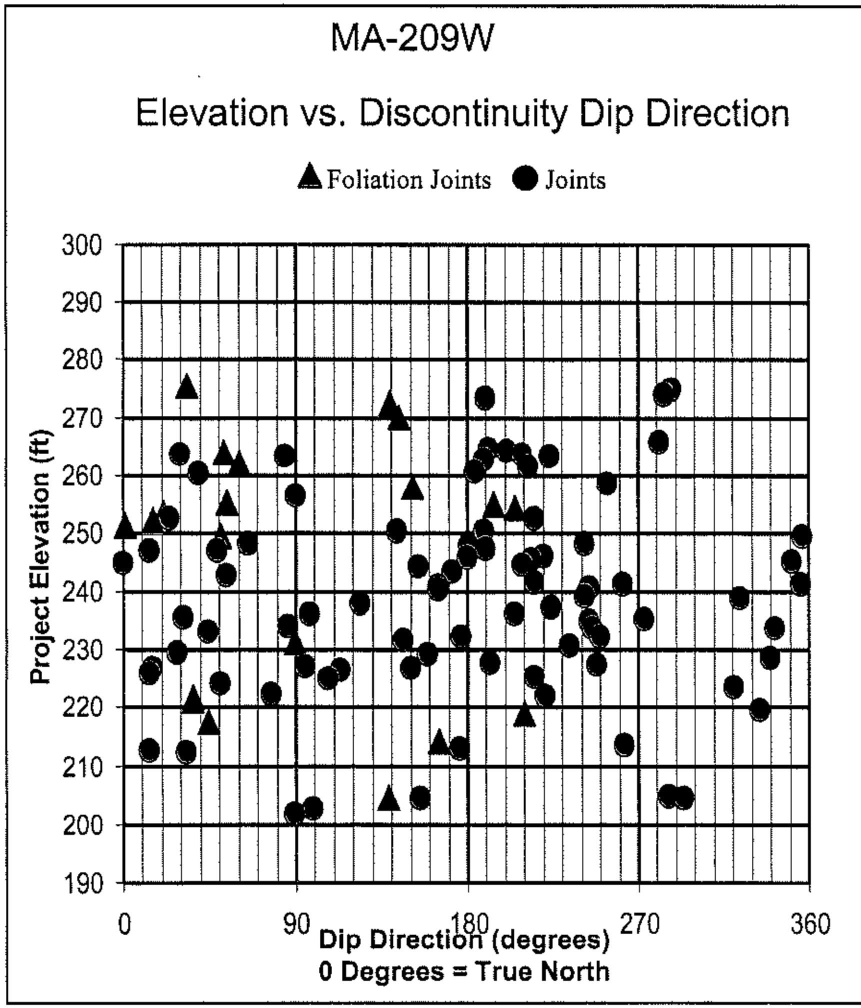
APPENDIX A-1
SHEET 2

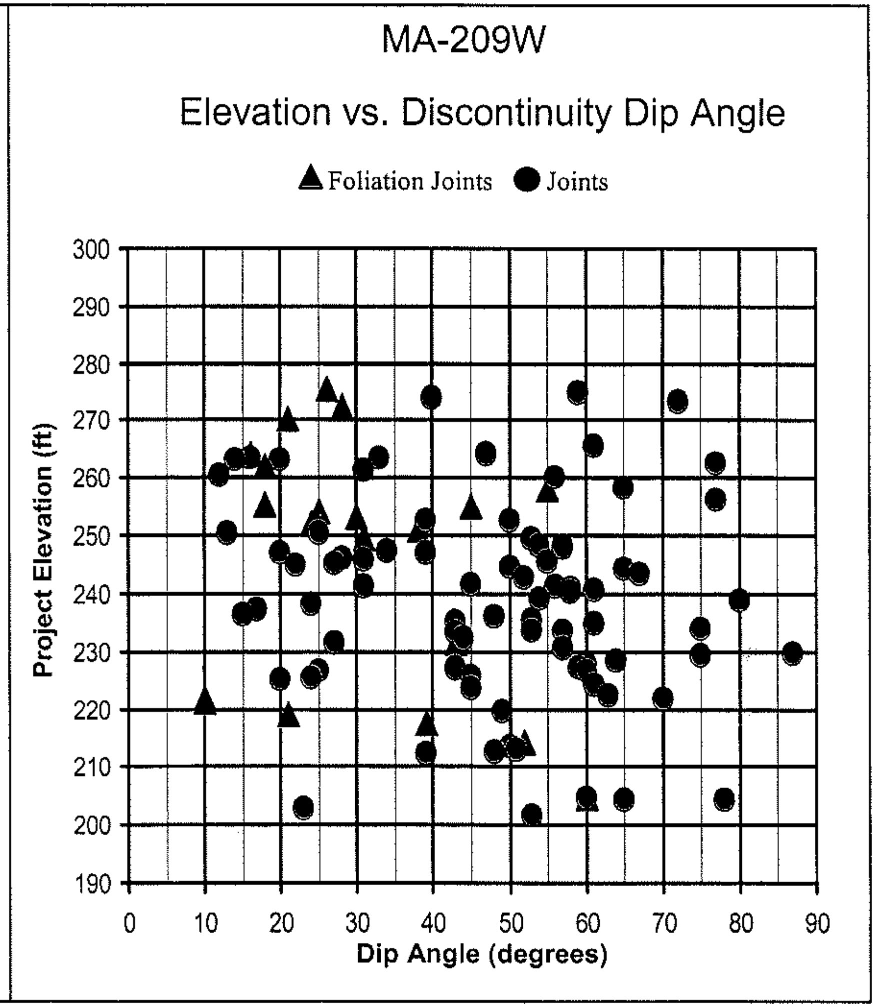




ORIENTED CORE DISCONTINUITY DATA

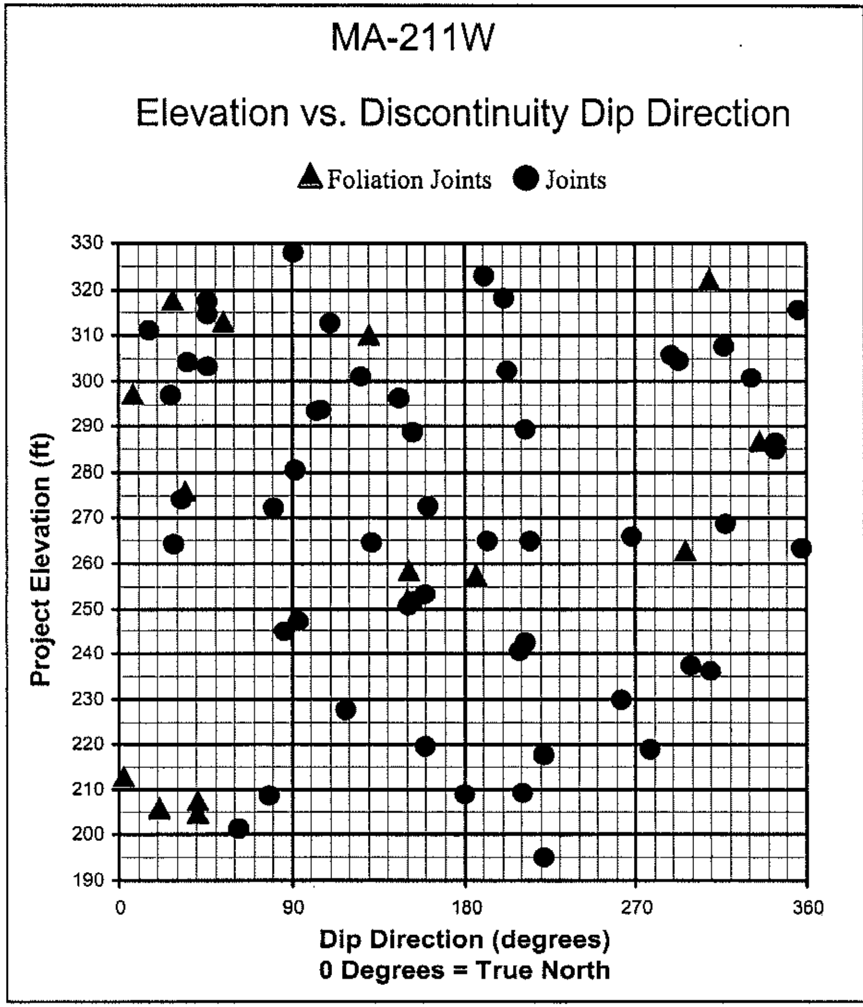
APPENDIX A-1
SHEET 3

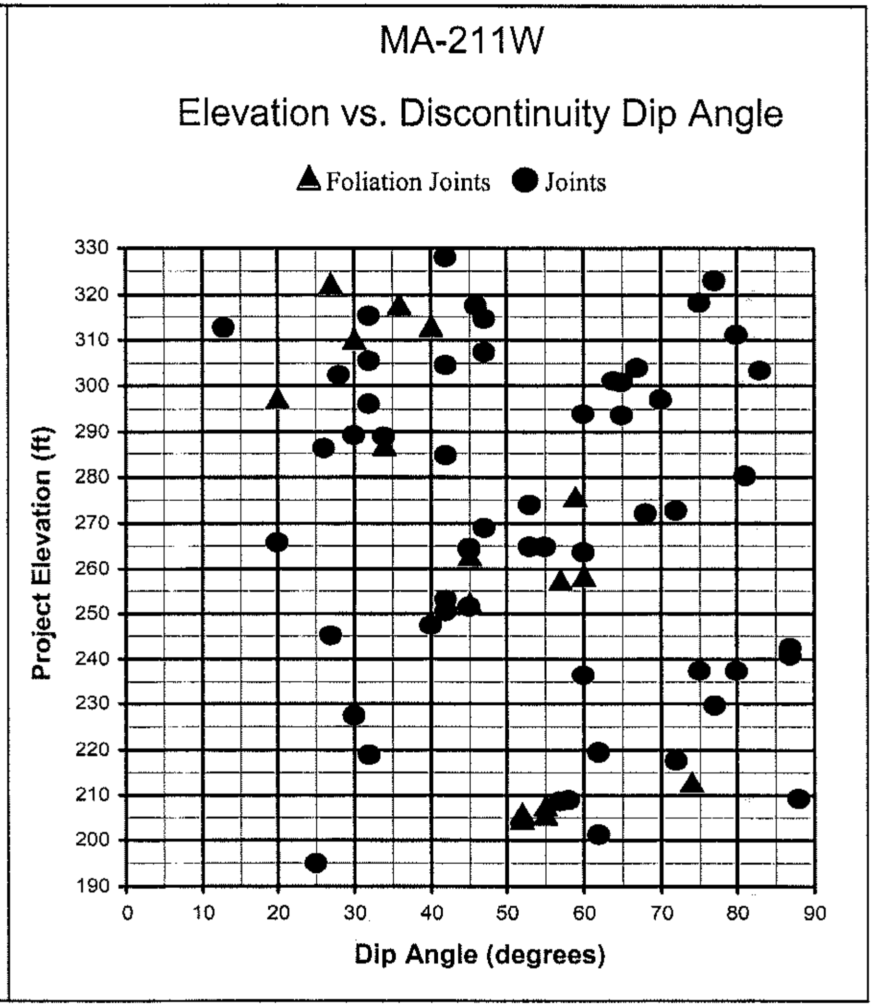




ORIENTED CORE DISCONTINUITY DATA

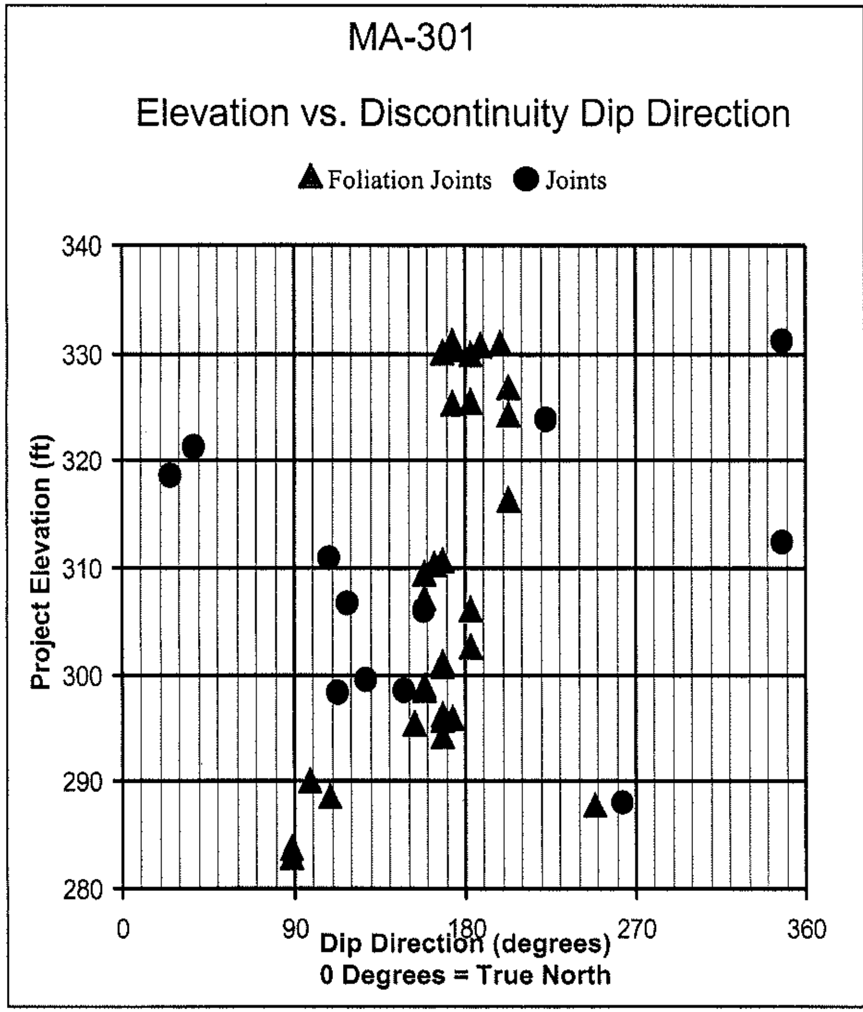
APPENDIX A-1
SHEET 4

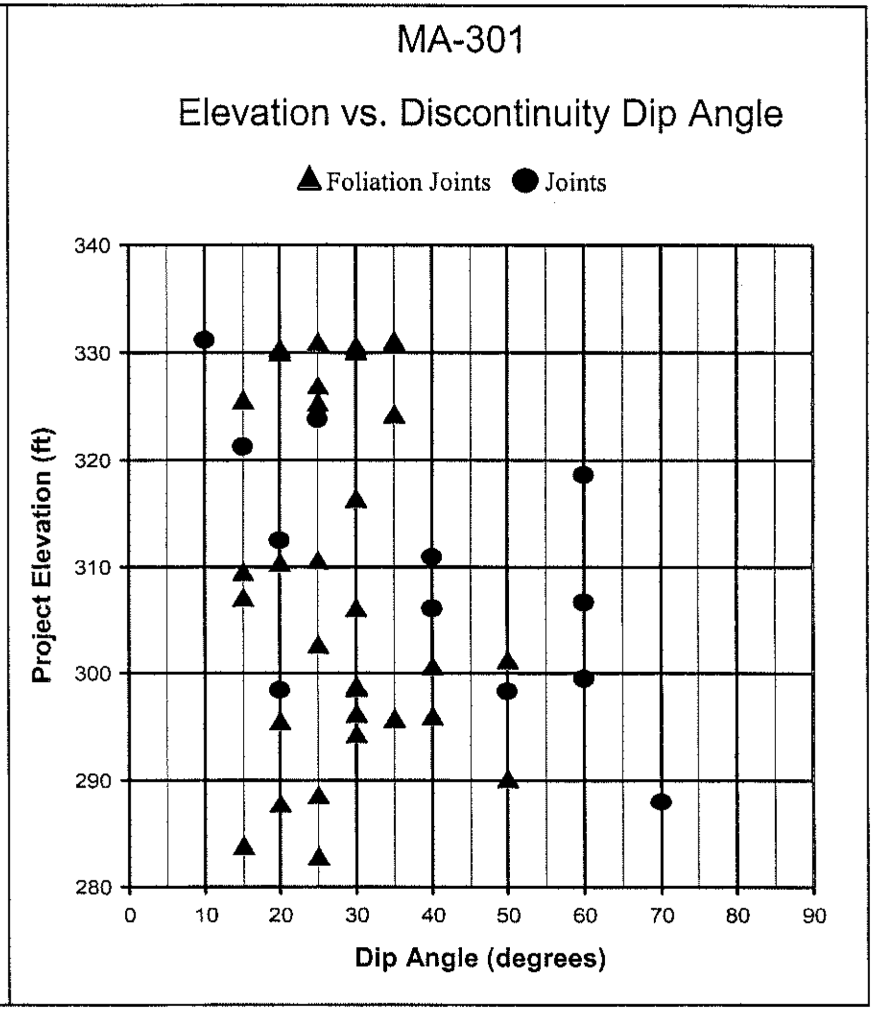




ORIENTED CORE DISCONTINUITY DATA

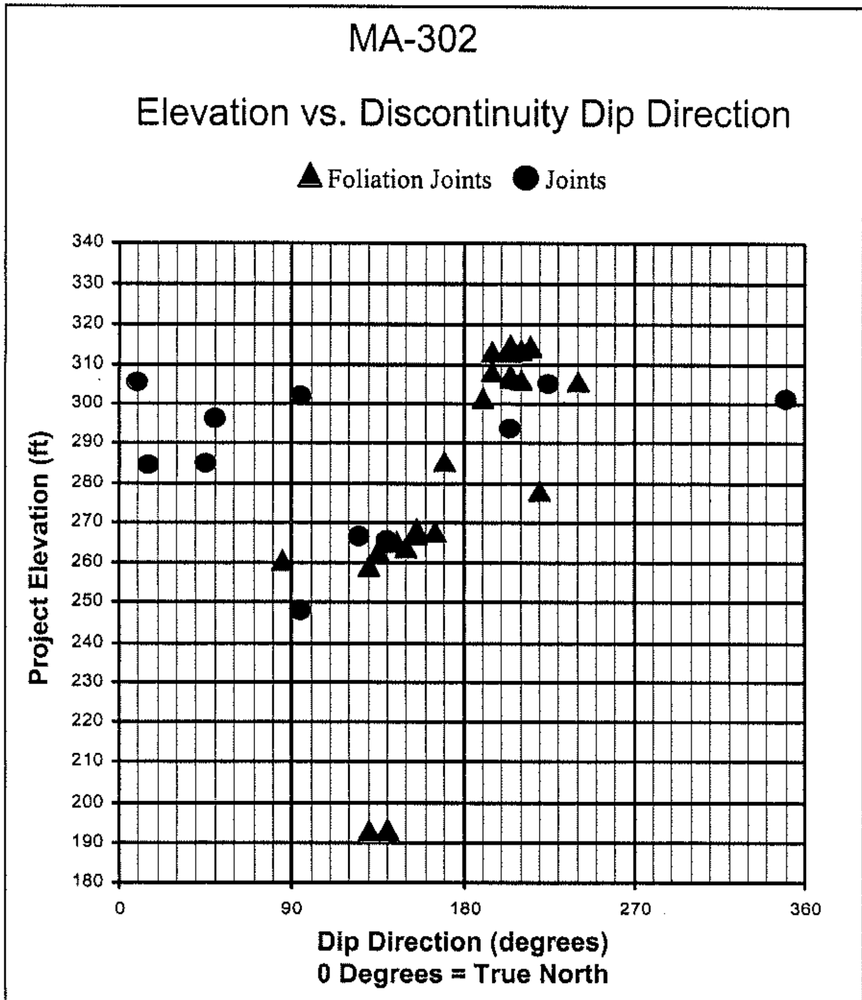
APPENDIX A-1
SHEET 5

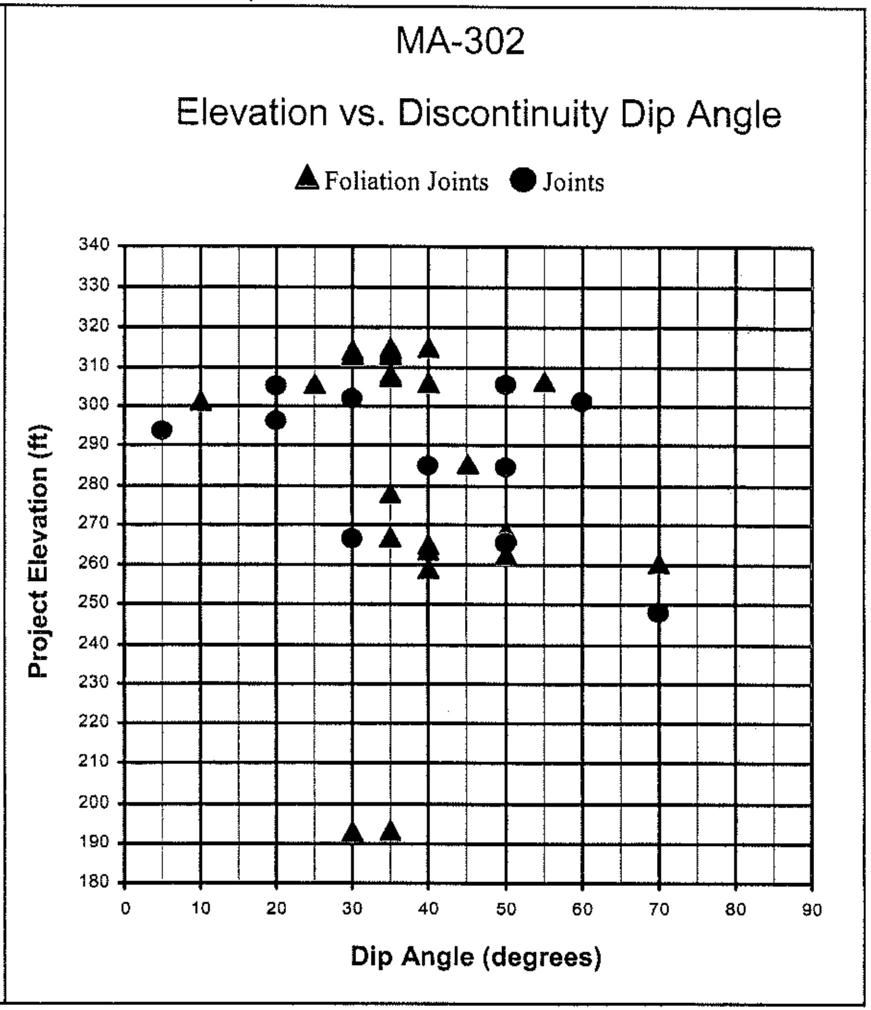




ORIENTED CORE DISCONTINUITY DATA

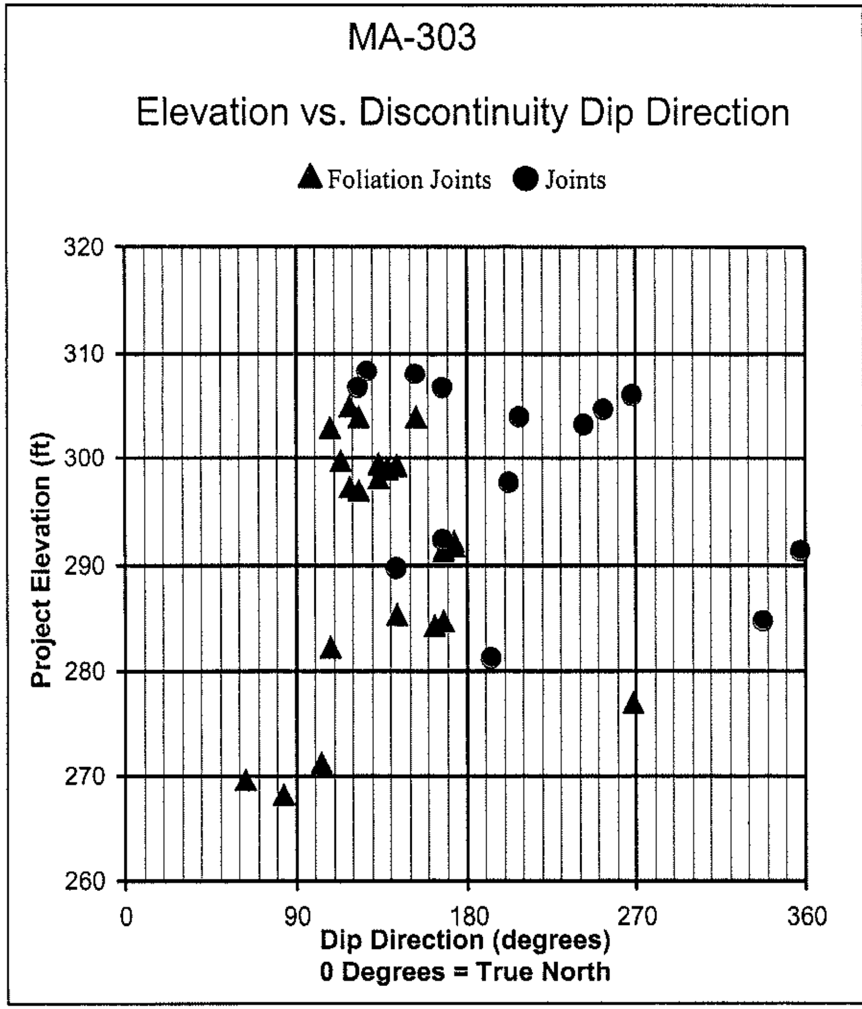
APPENDIX A-1
SHEET 6

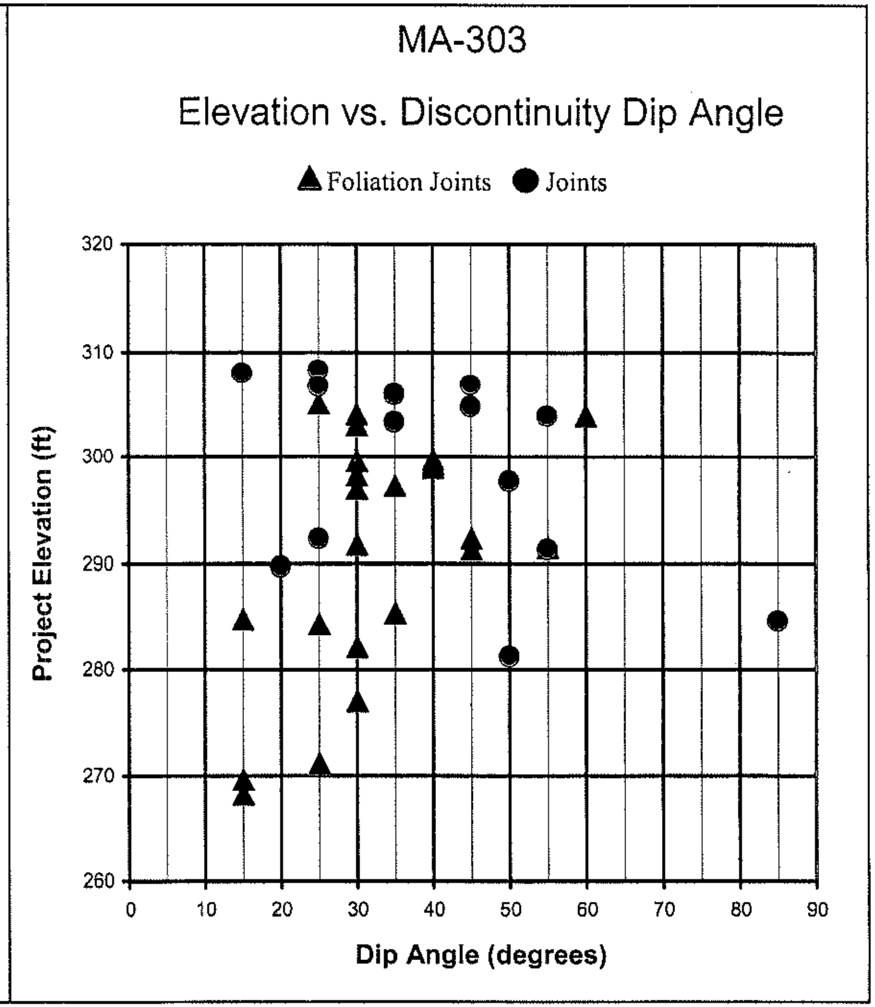




ORIENTED CORE DISCONTINUITY DATA

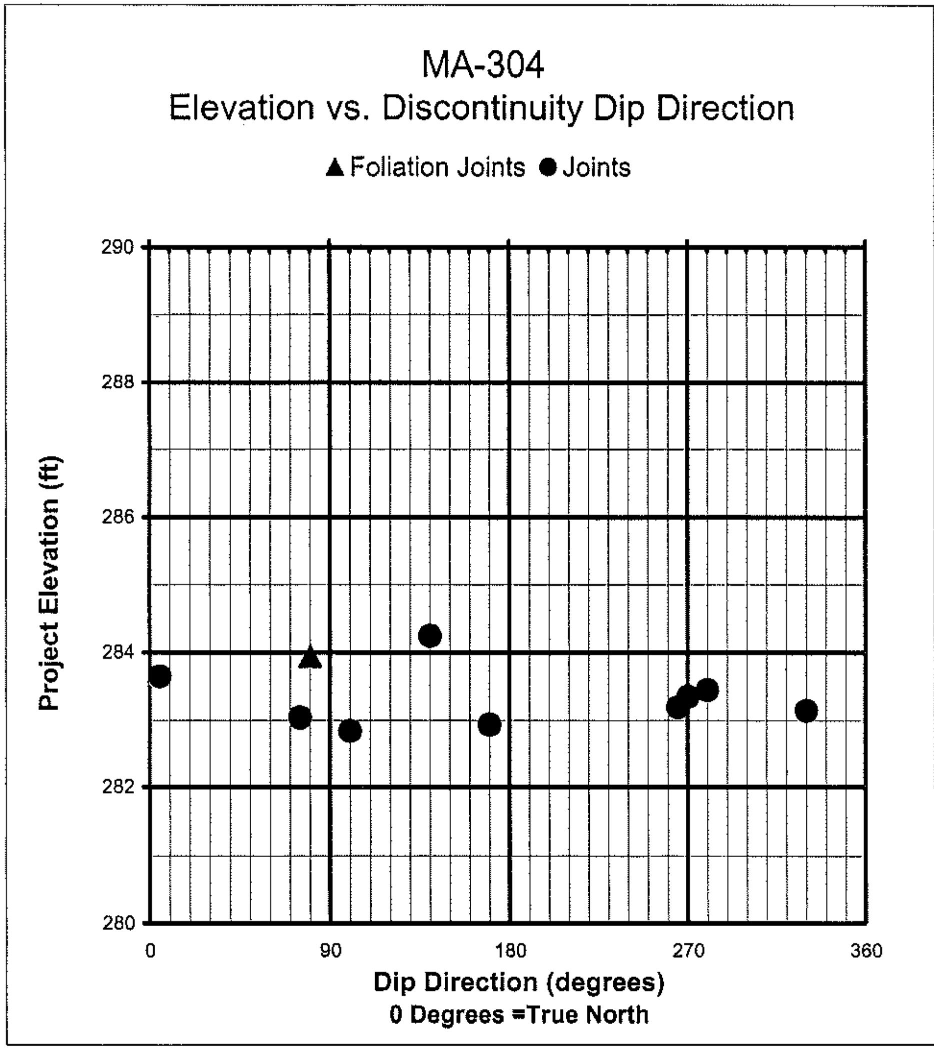
APPENDIX A-1
SHEET 7

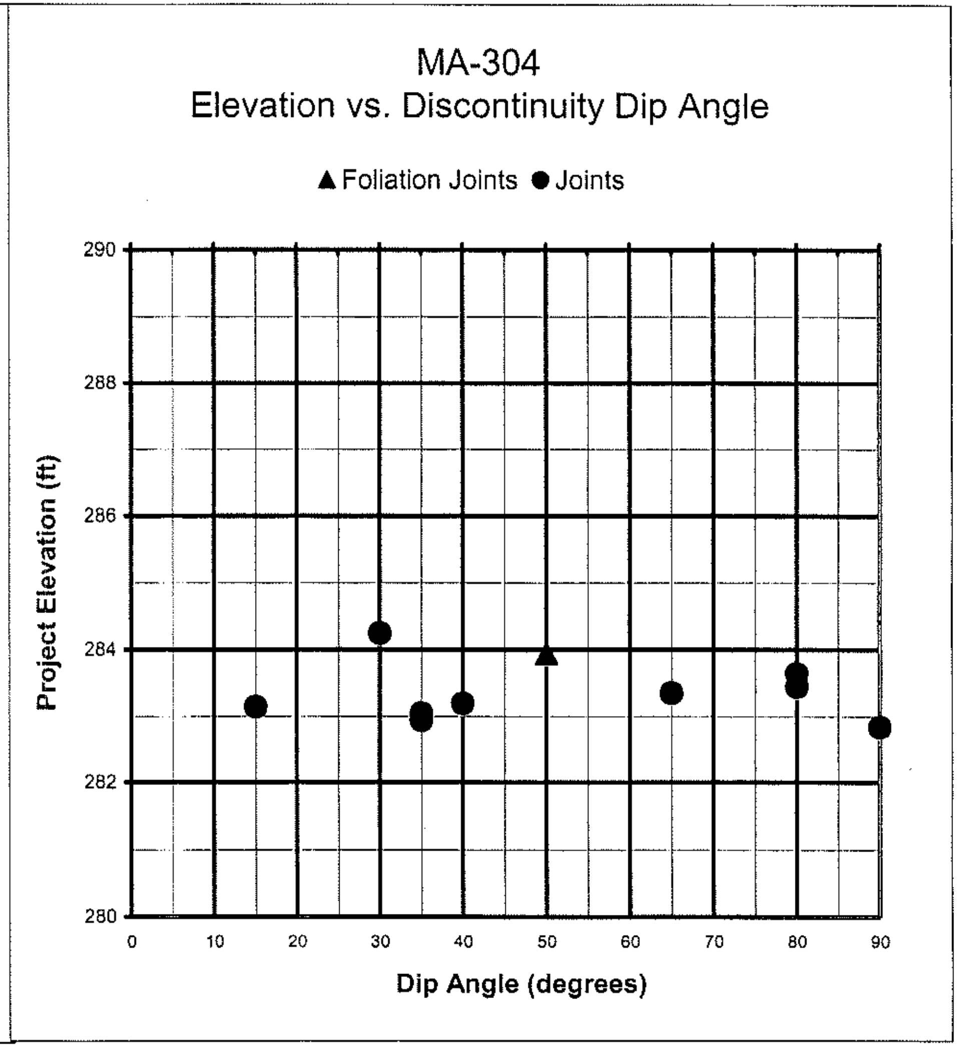




ORIENTED CORE DISCONTINUITY DATA

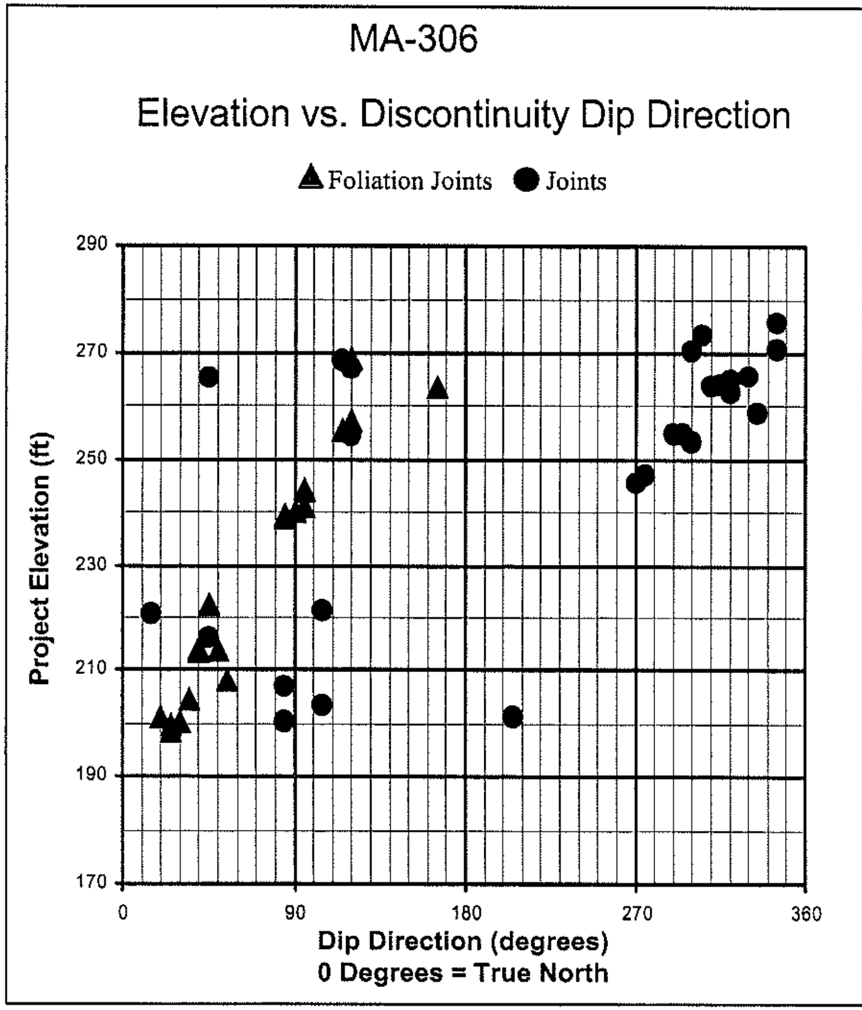
APPENDIX A-1
SHEET 8

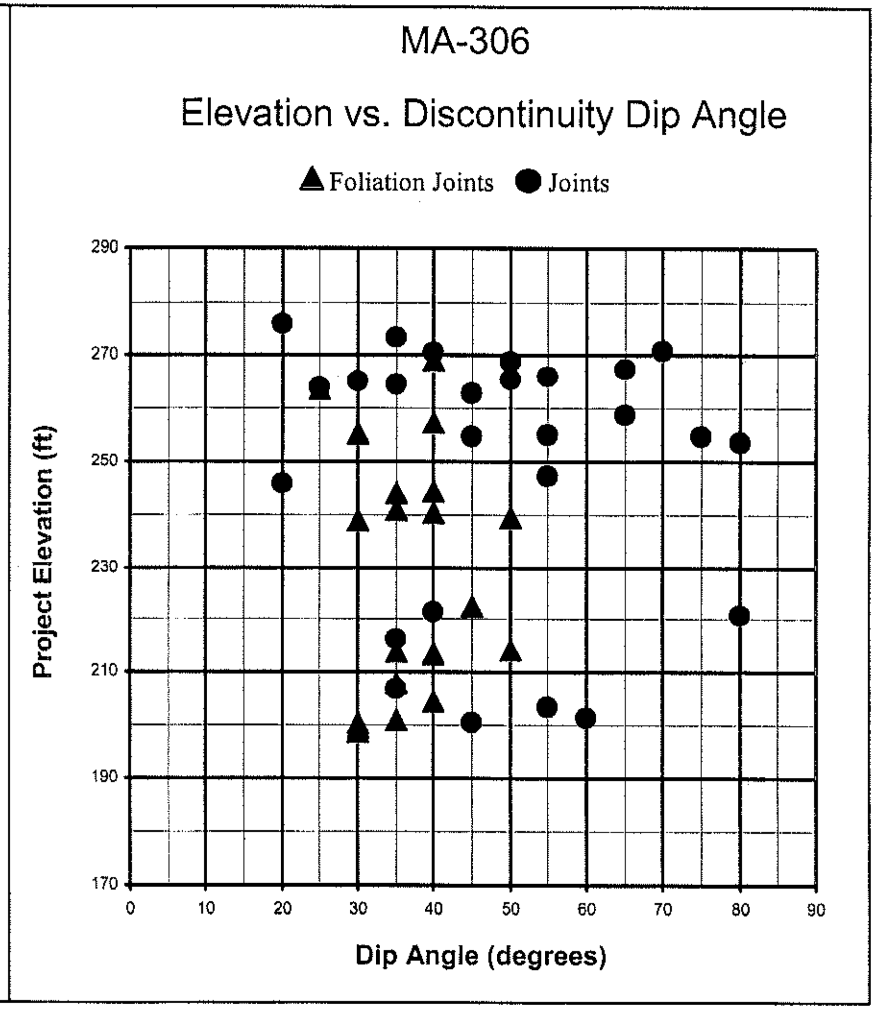




ORIENTED CORE DISCONTINUITY DATA

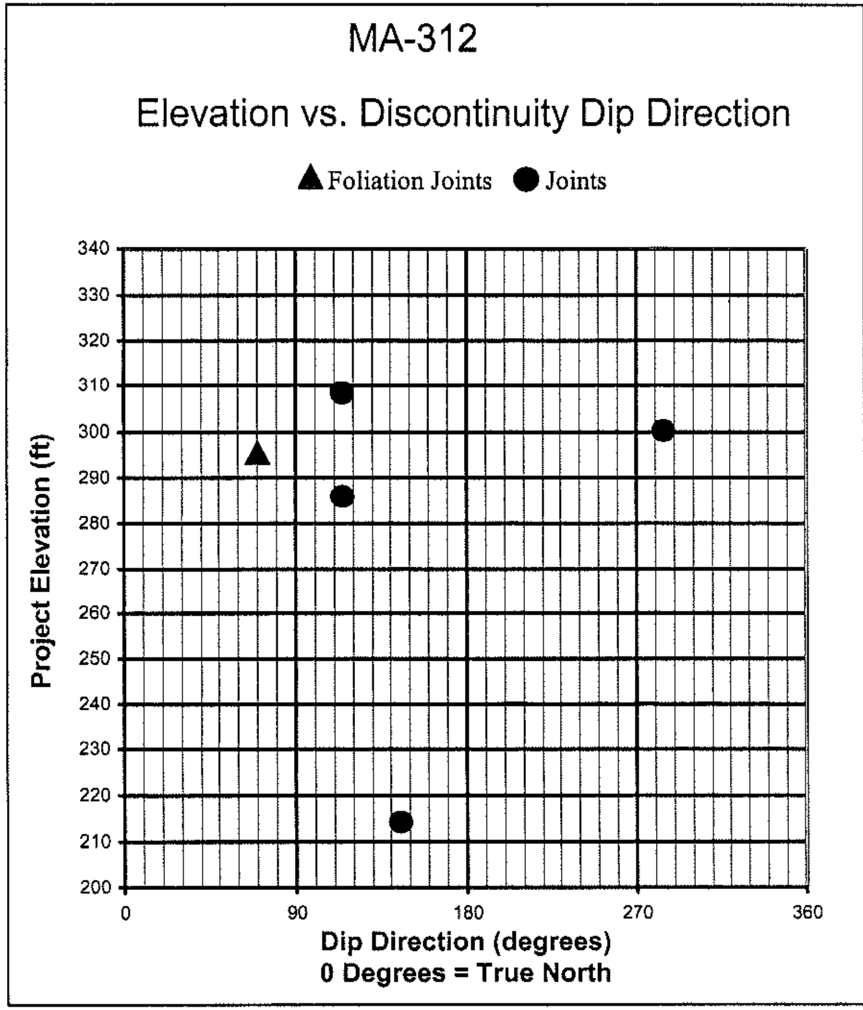
APPENDIX A-1
SHEET 9

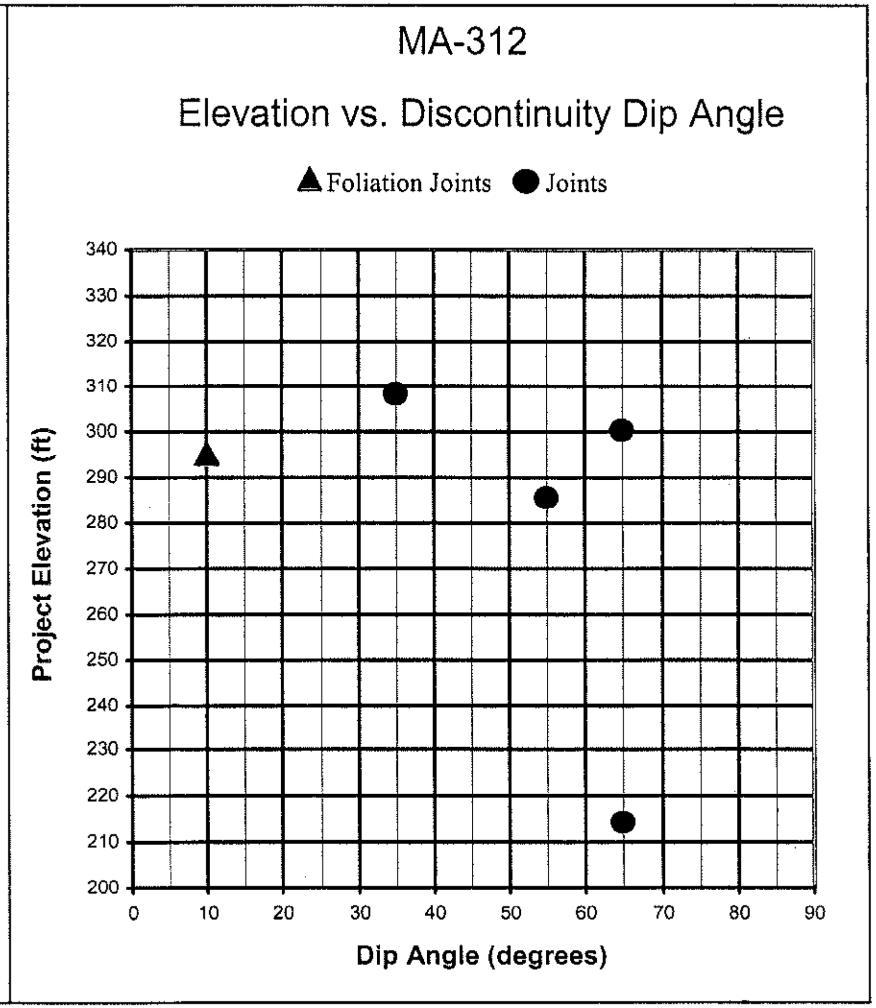




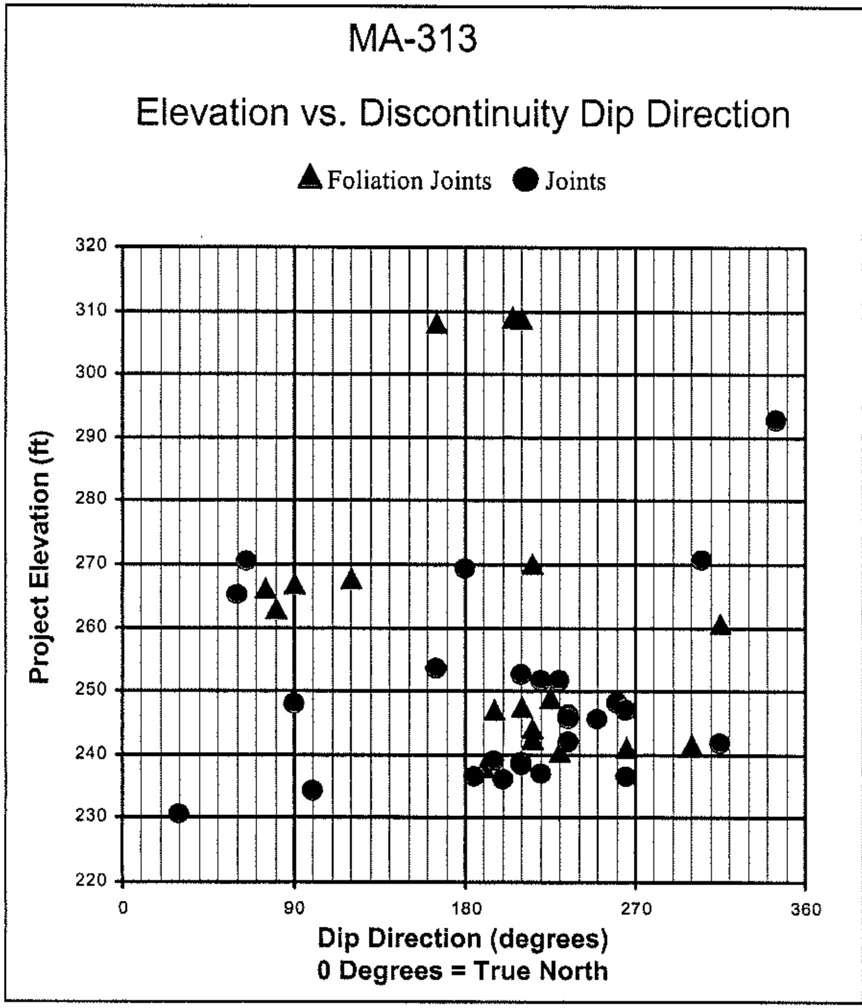
ORIENTED CORE DISCONTINUITY DATA

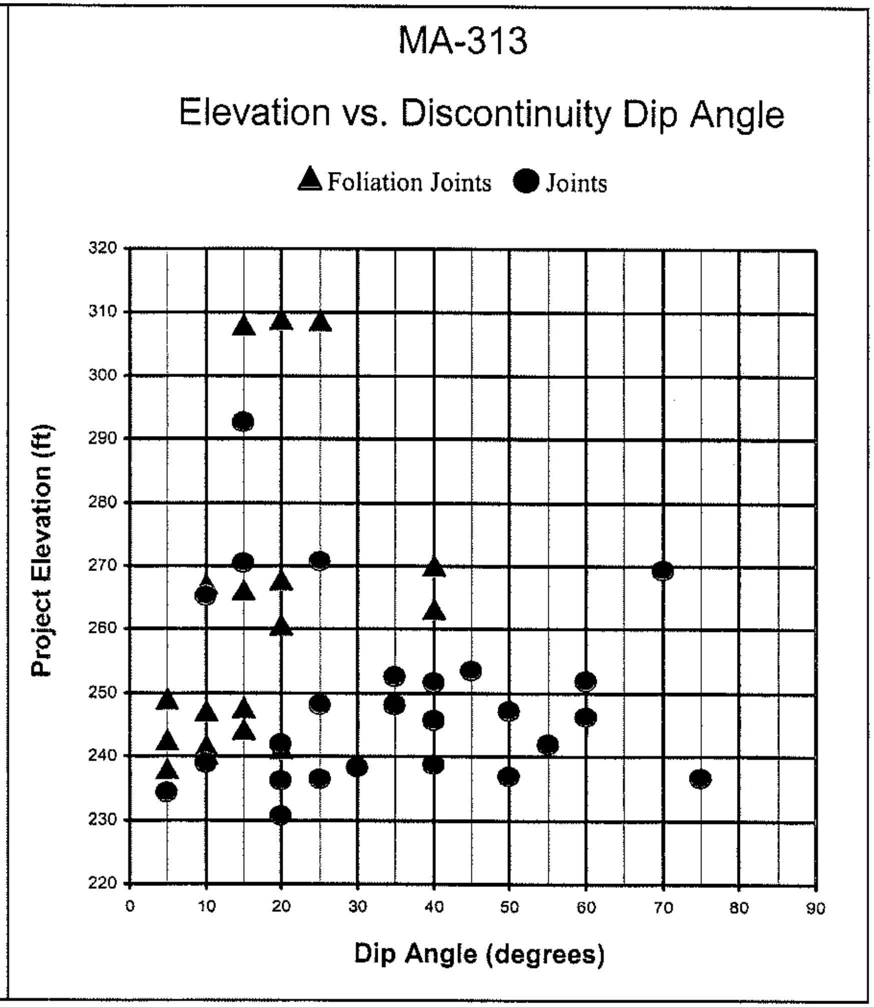
APPENDIX A-1
SHEET 10





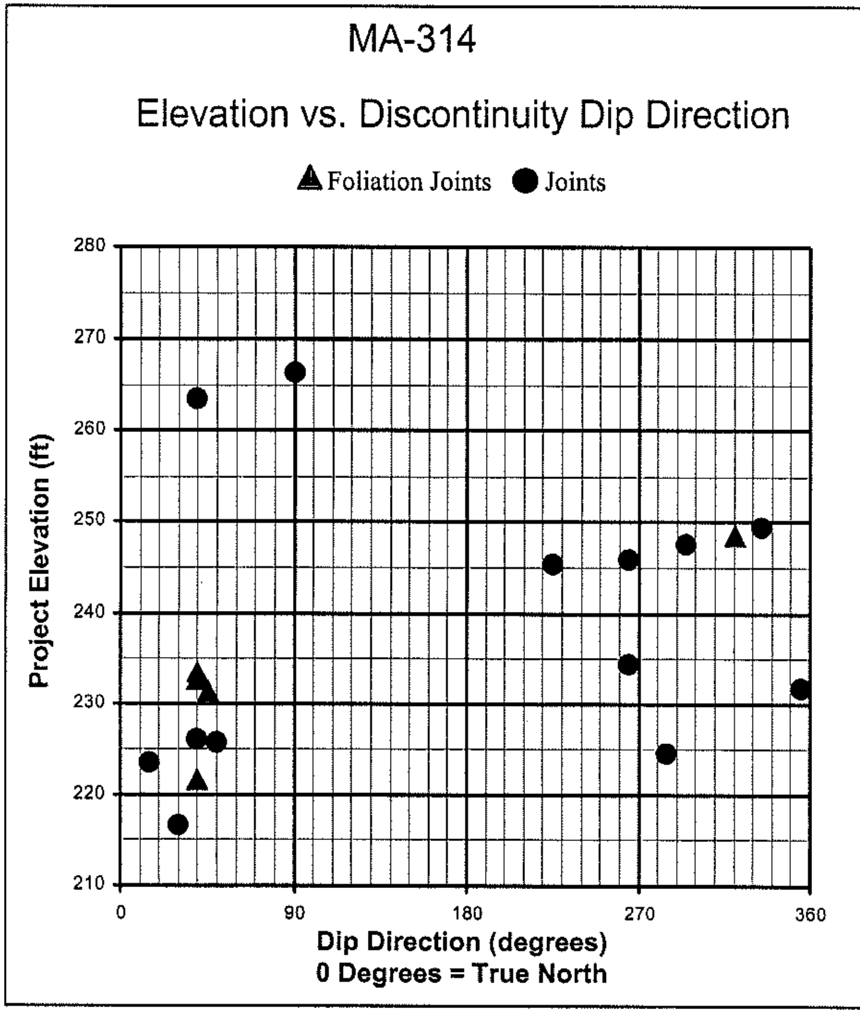
ORIENTED CORE DISCONTINUITY DATA

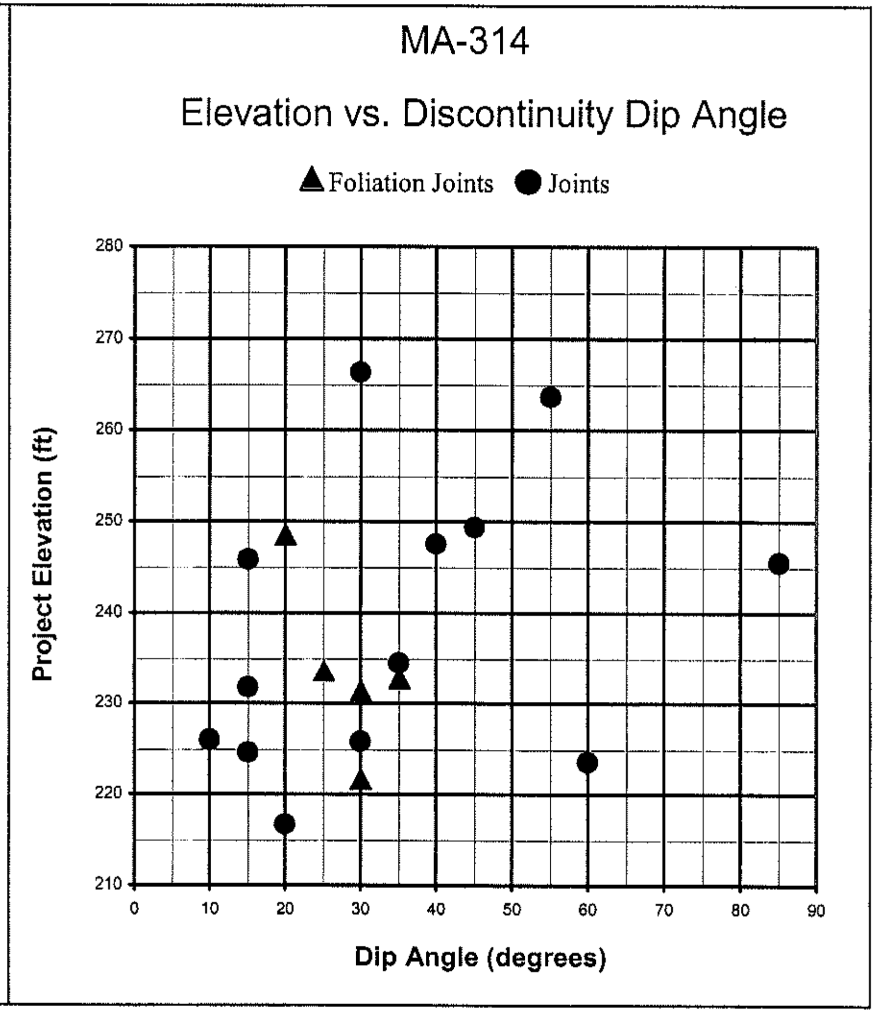




ORIENTED CORE DISCONTINUITY DATA

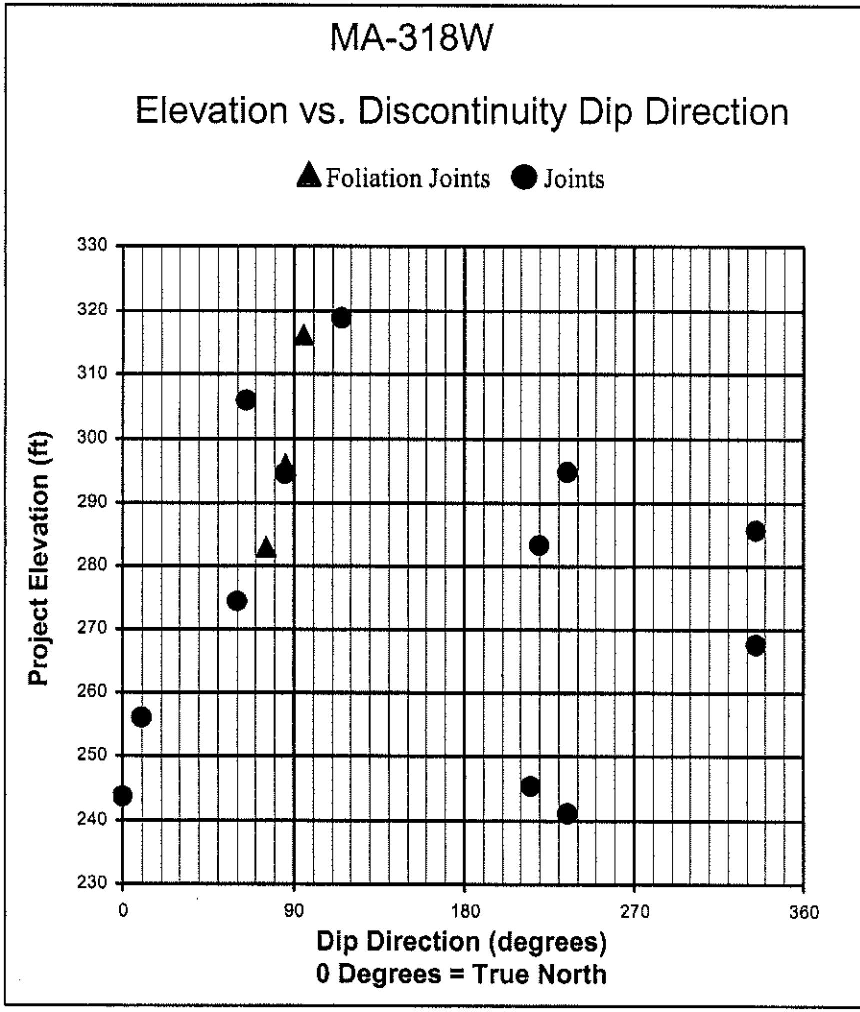
APPENDIX A-1
SHEET 12

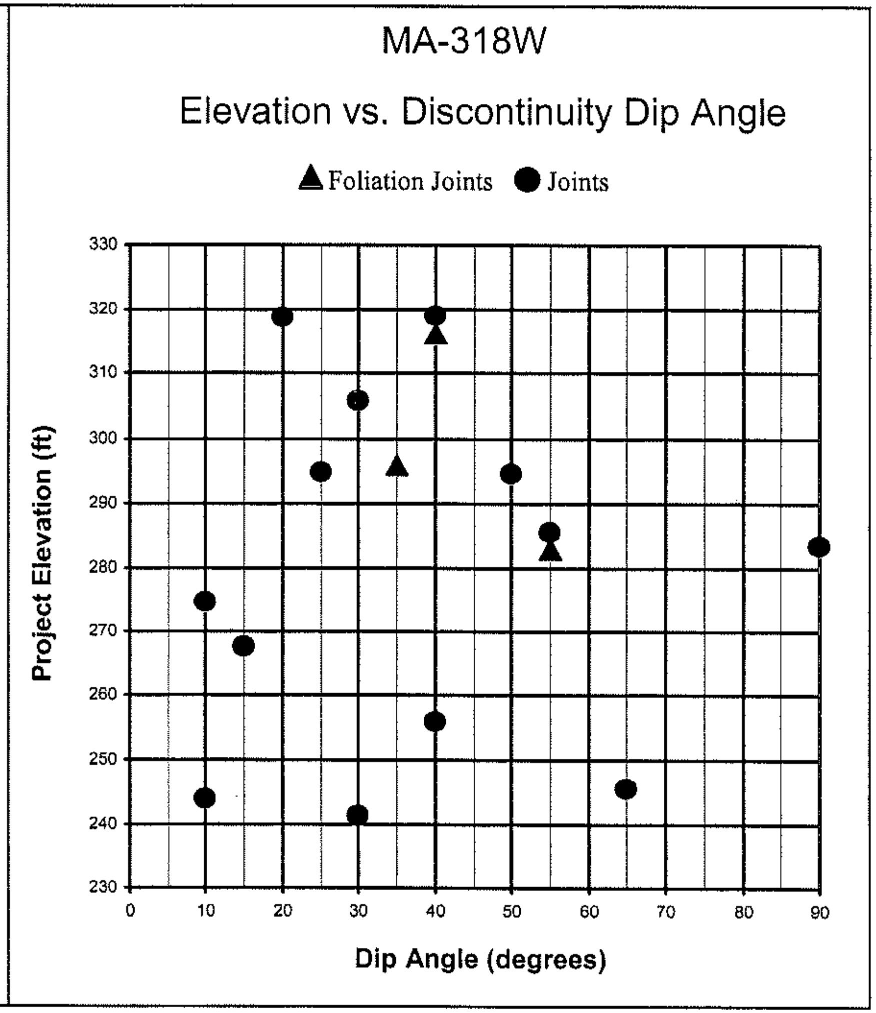




ORIENTED CORE DISCONTINUITY DATA

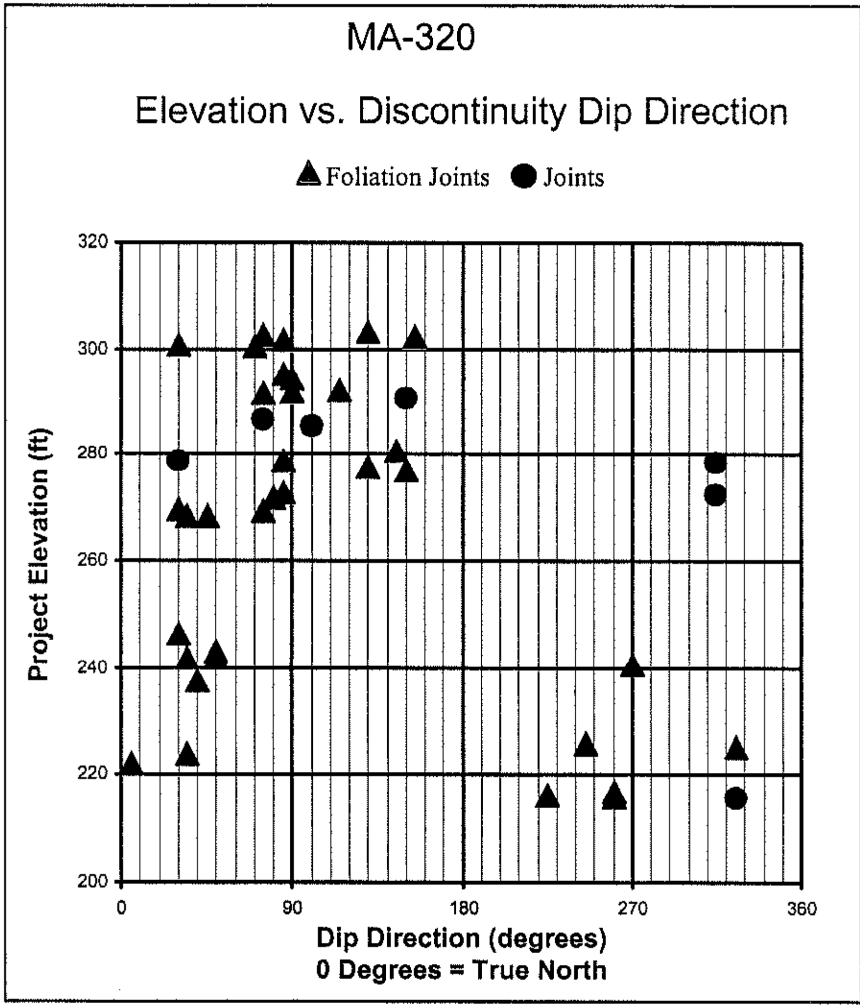
APPENDIX A-1
SHEET 13

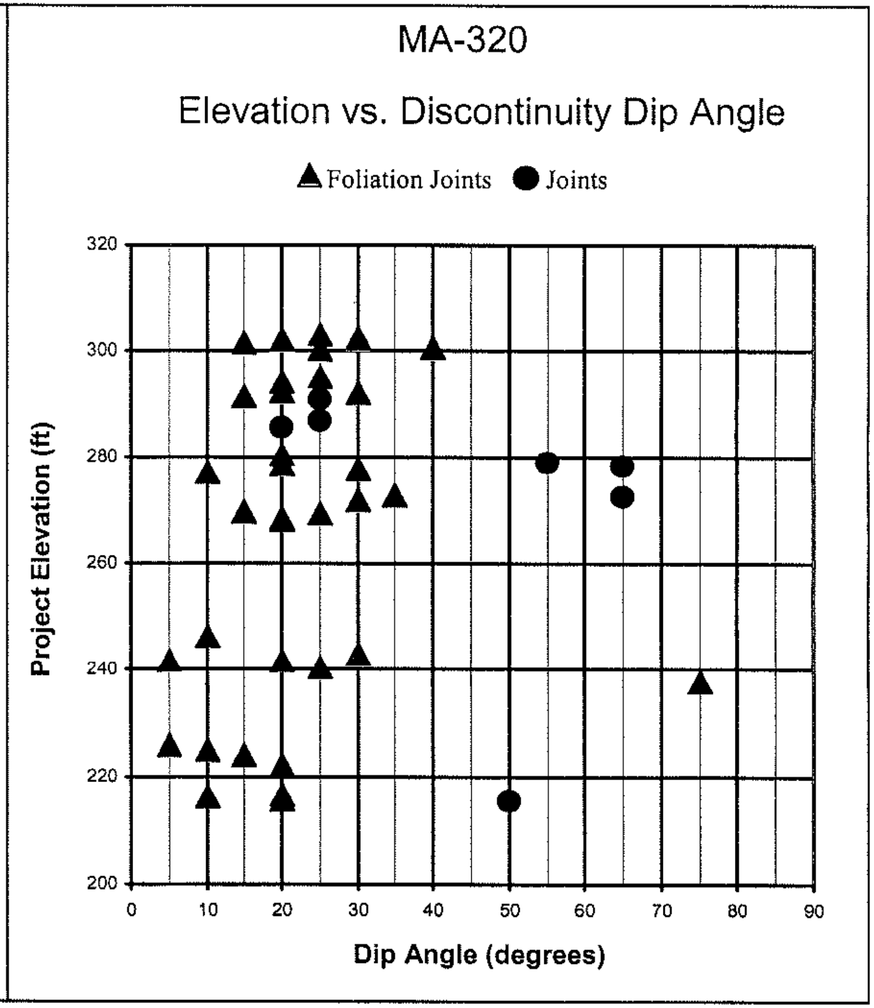




ORIENTED CORE DISCONTINUITY DATA

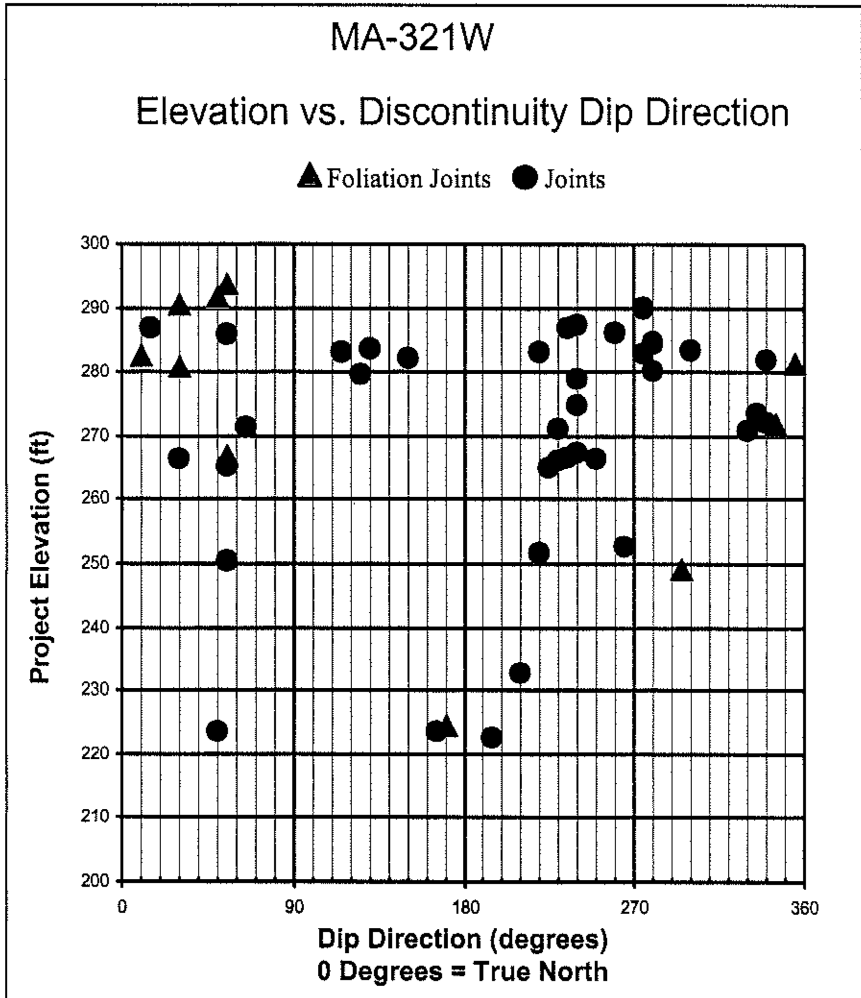
APPENDIX A-1
SHEET 14

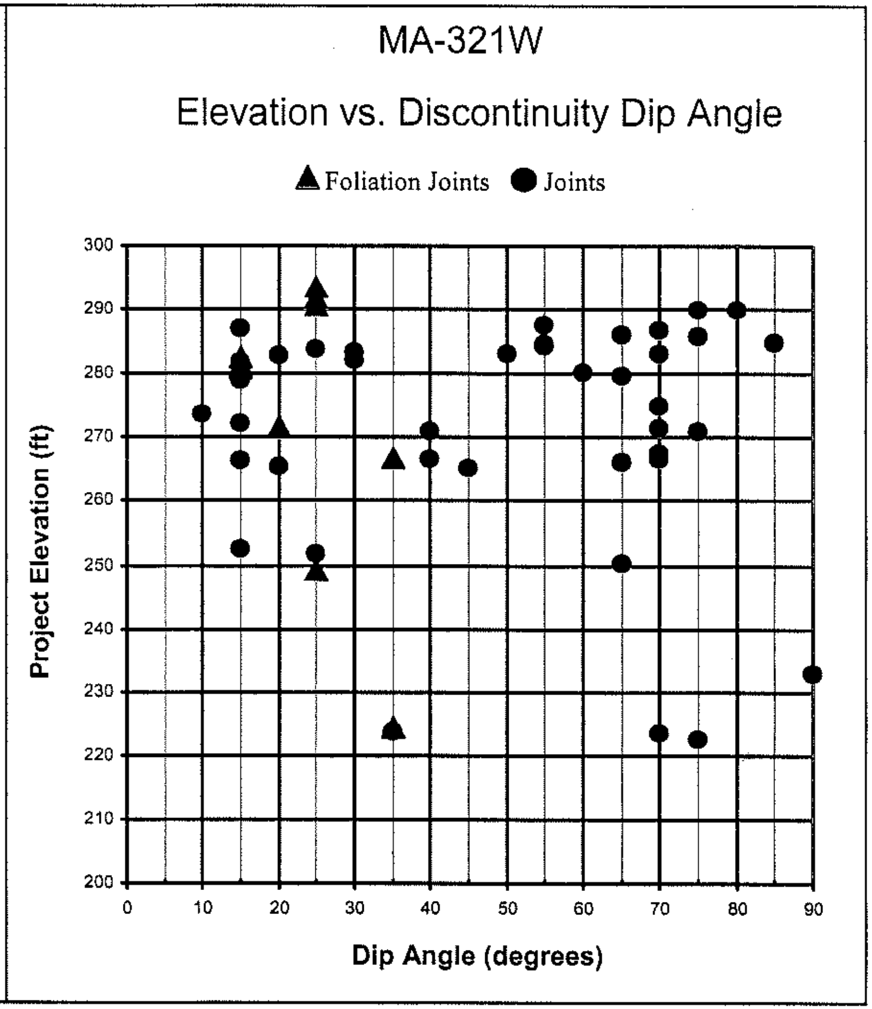




ORIENTED CORE DISCONTINUITY DATA

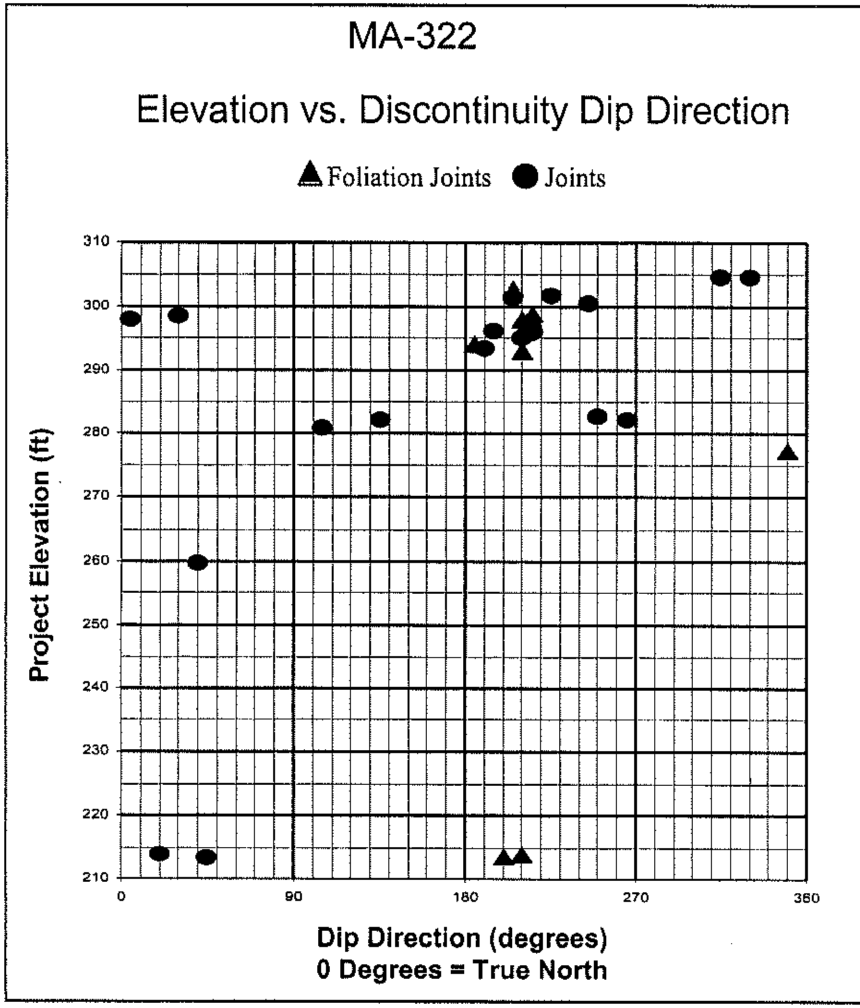
APPENDIX A-1
SHEET 15

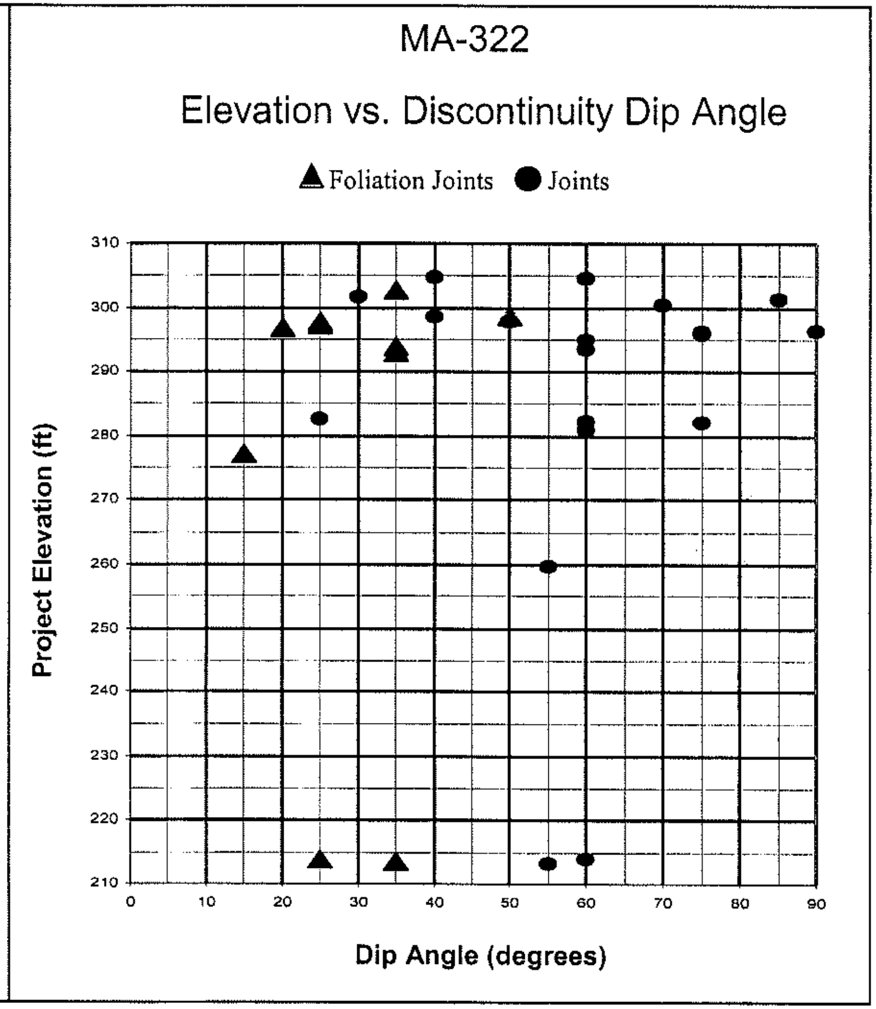




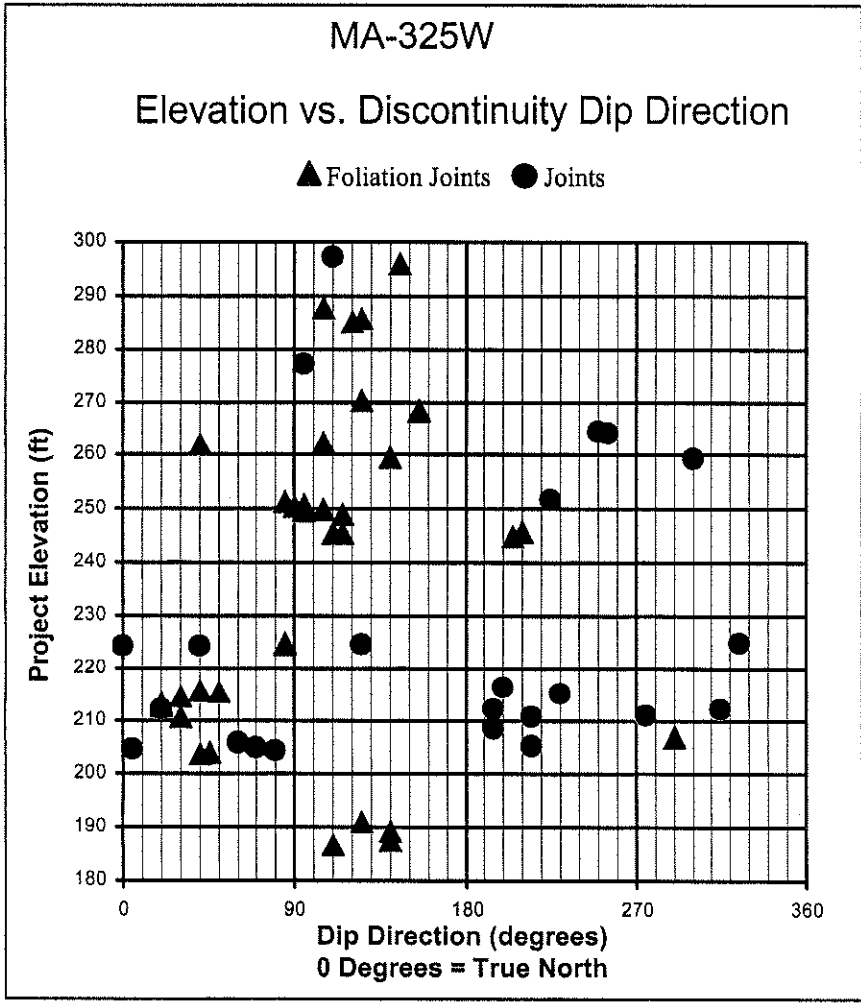
ORIENTED CORE DISCONTINUITY DATA

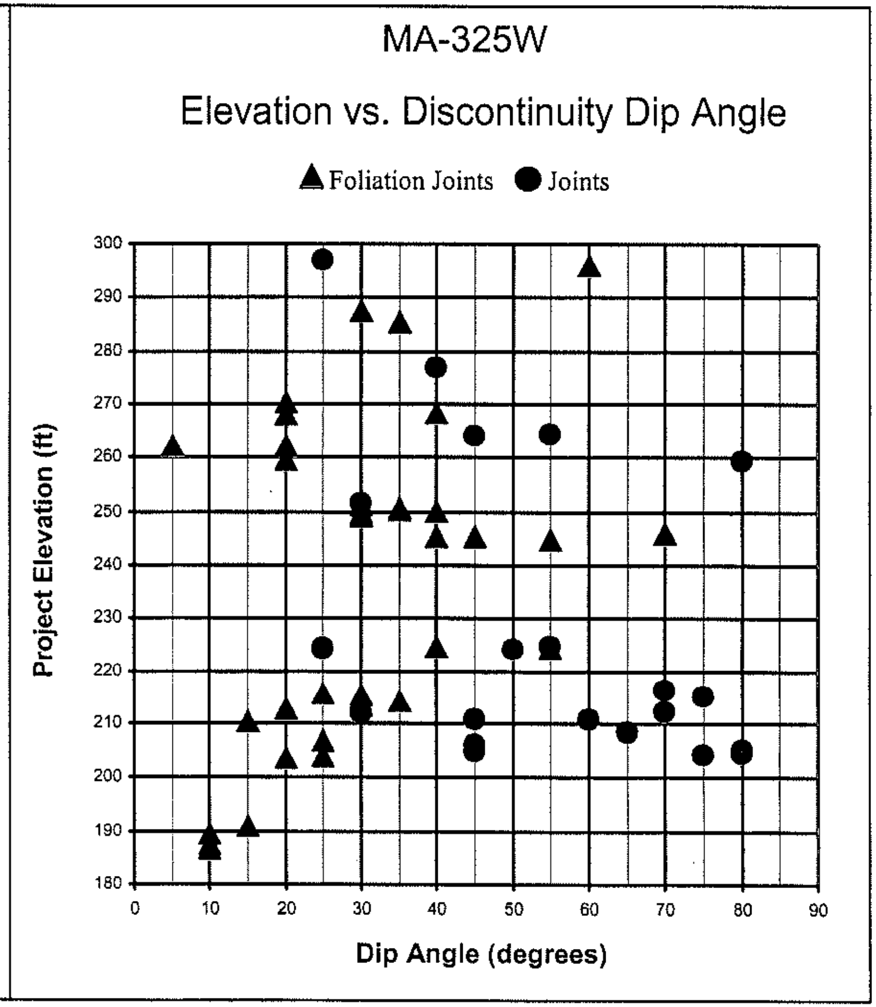
APPENDIX A-1
SHEET 16





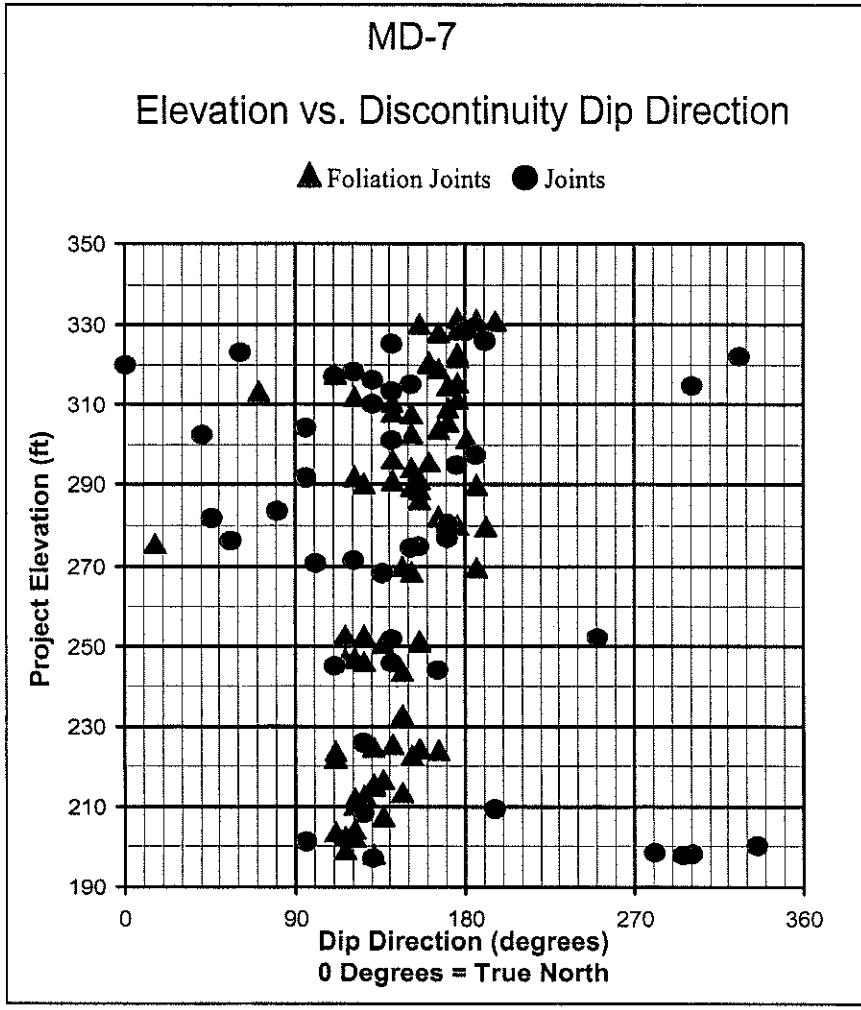
ORIENTED CORE DISCONTINUITY DATA

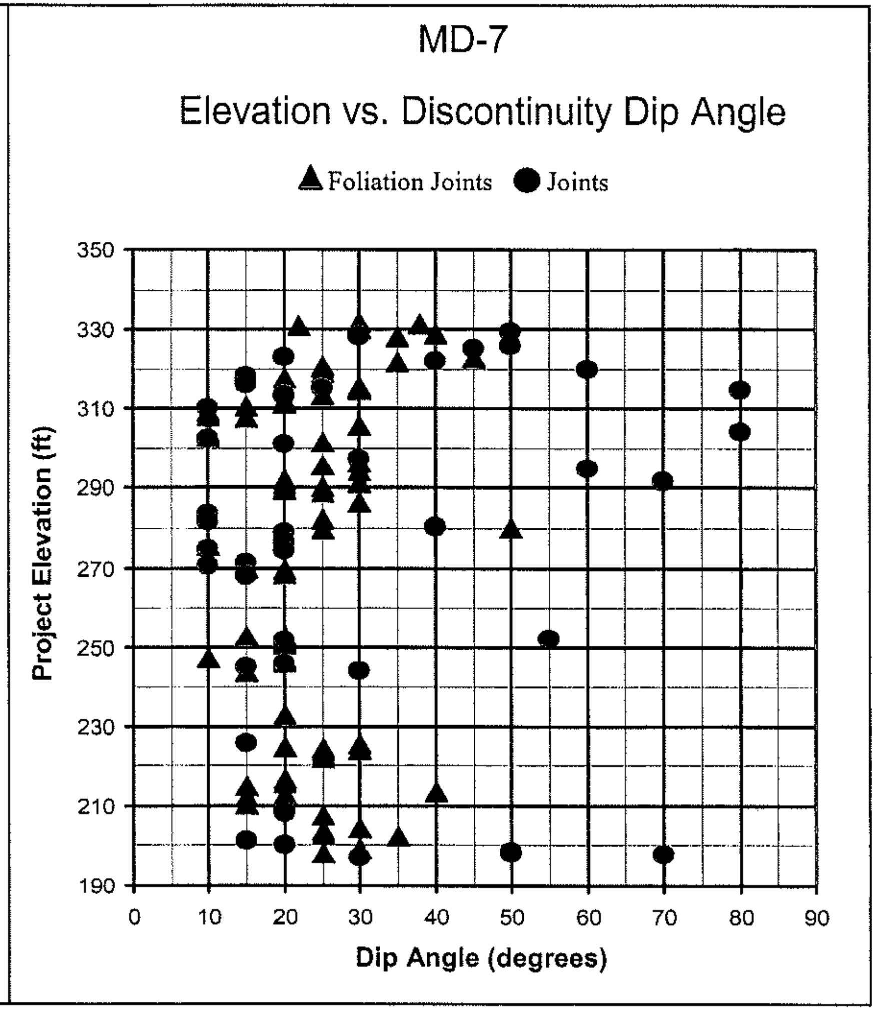




ORIENTED CORE DISCONTINUITY DATA

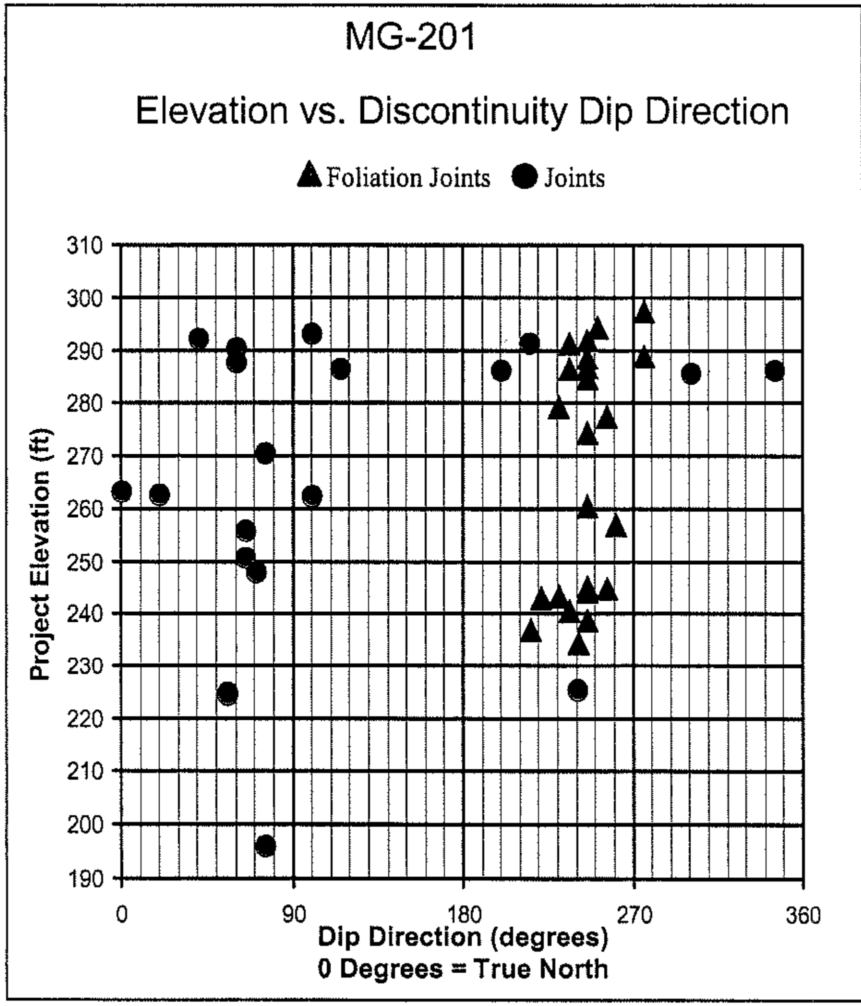
APPENDIX A-1
SHEET 18

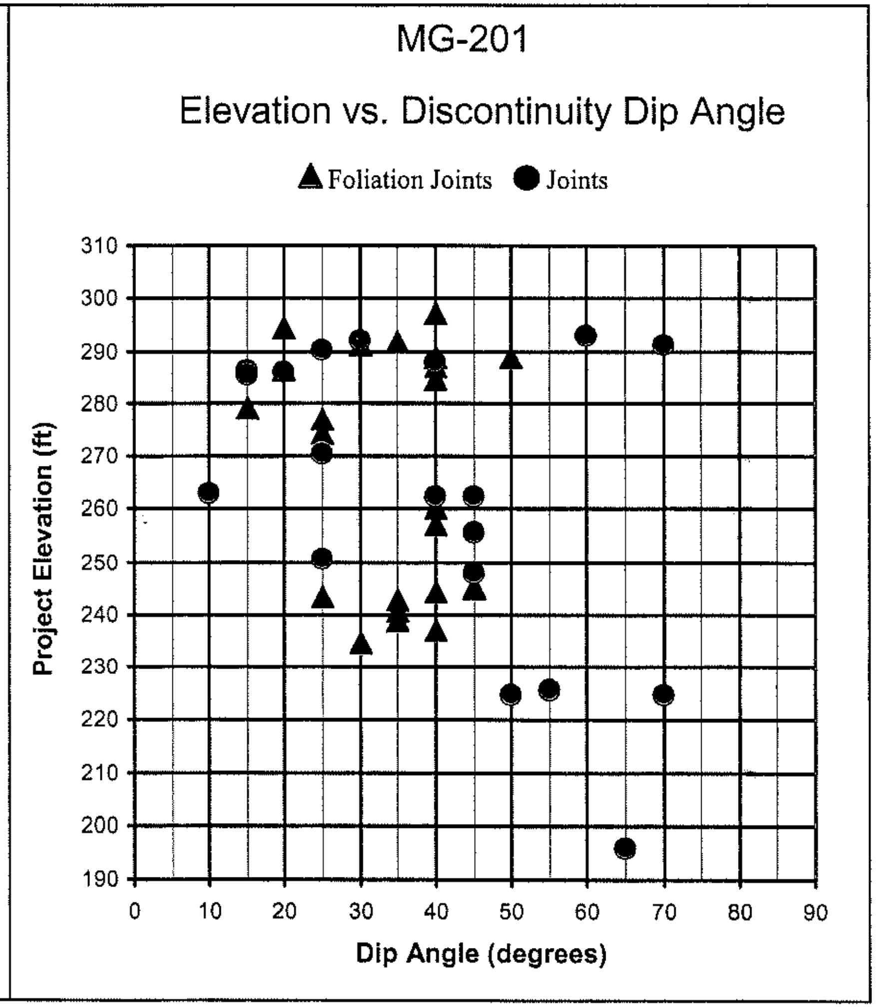




ORIENTED CORE DISCONTINUITY DATA

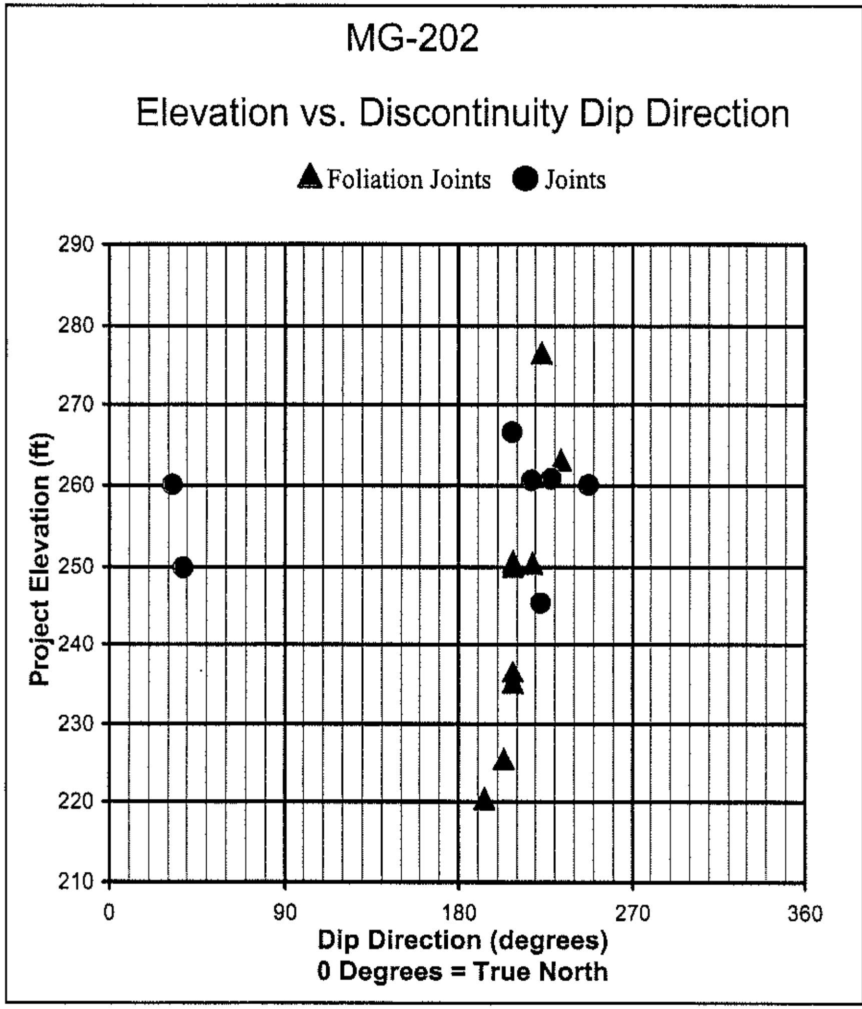
APPENDIX A-1
SHEET 19

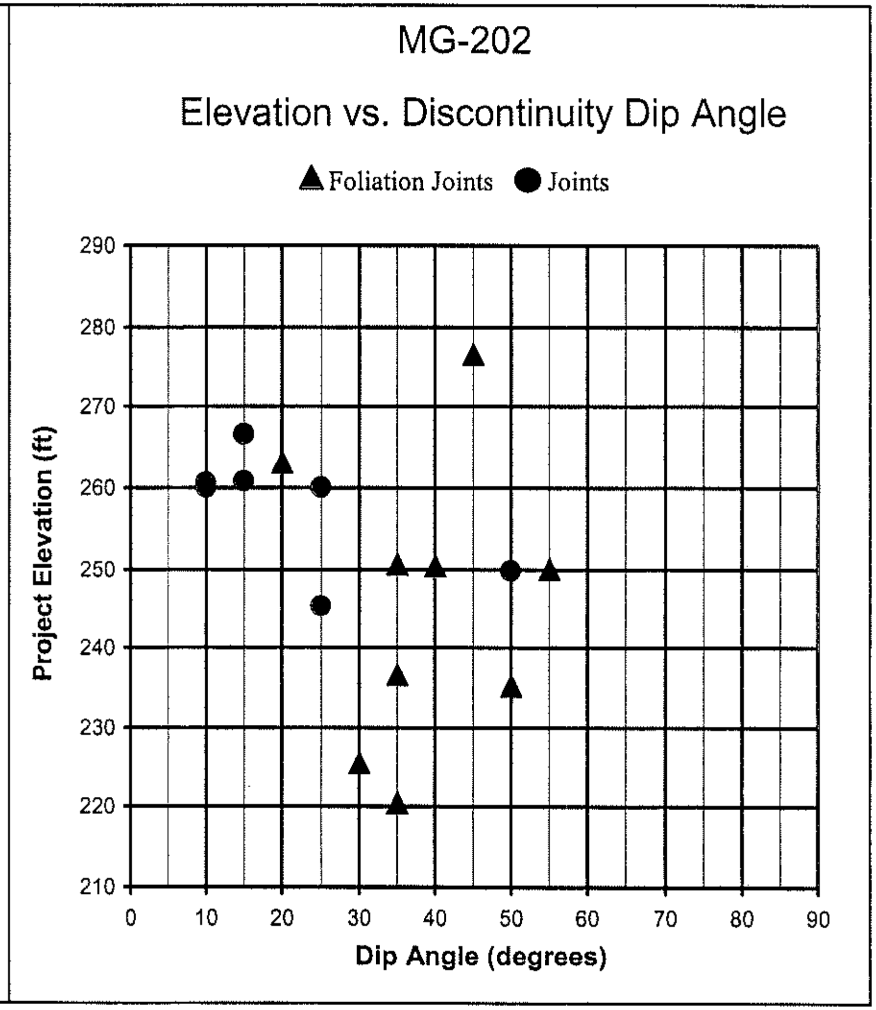




ORIENTED CORE DISCONTINUITY DATA

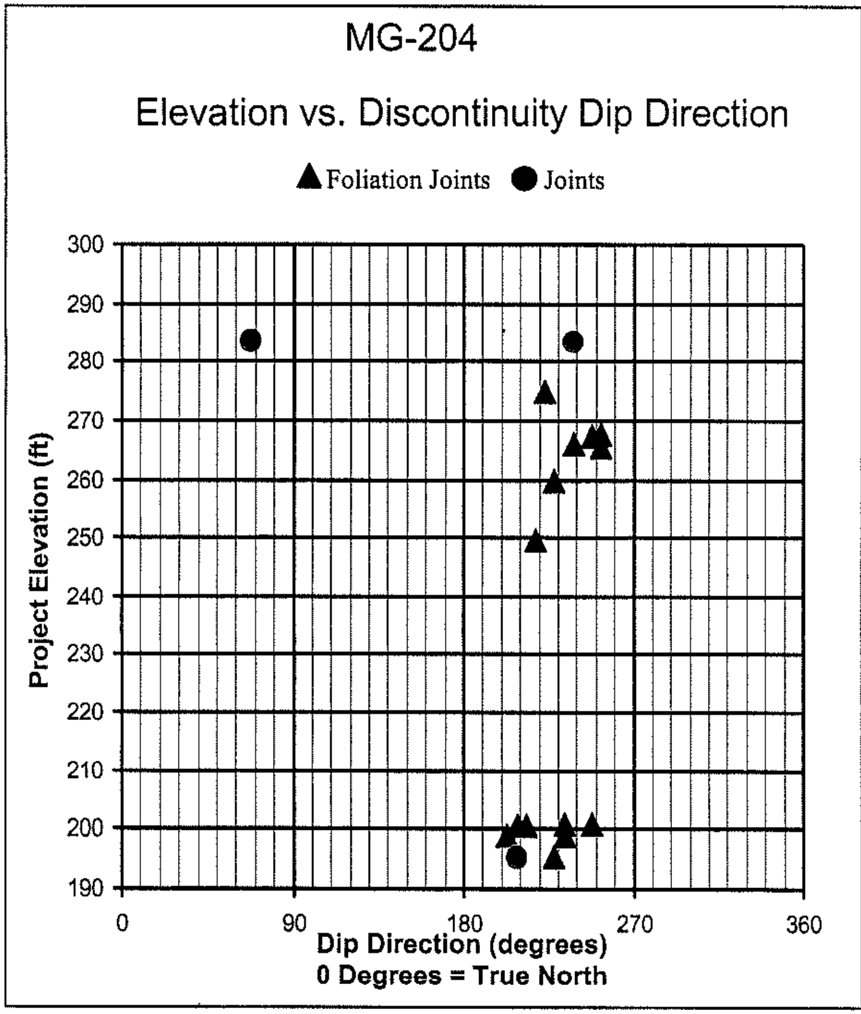
APPENDIX A-1
SHEET 20

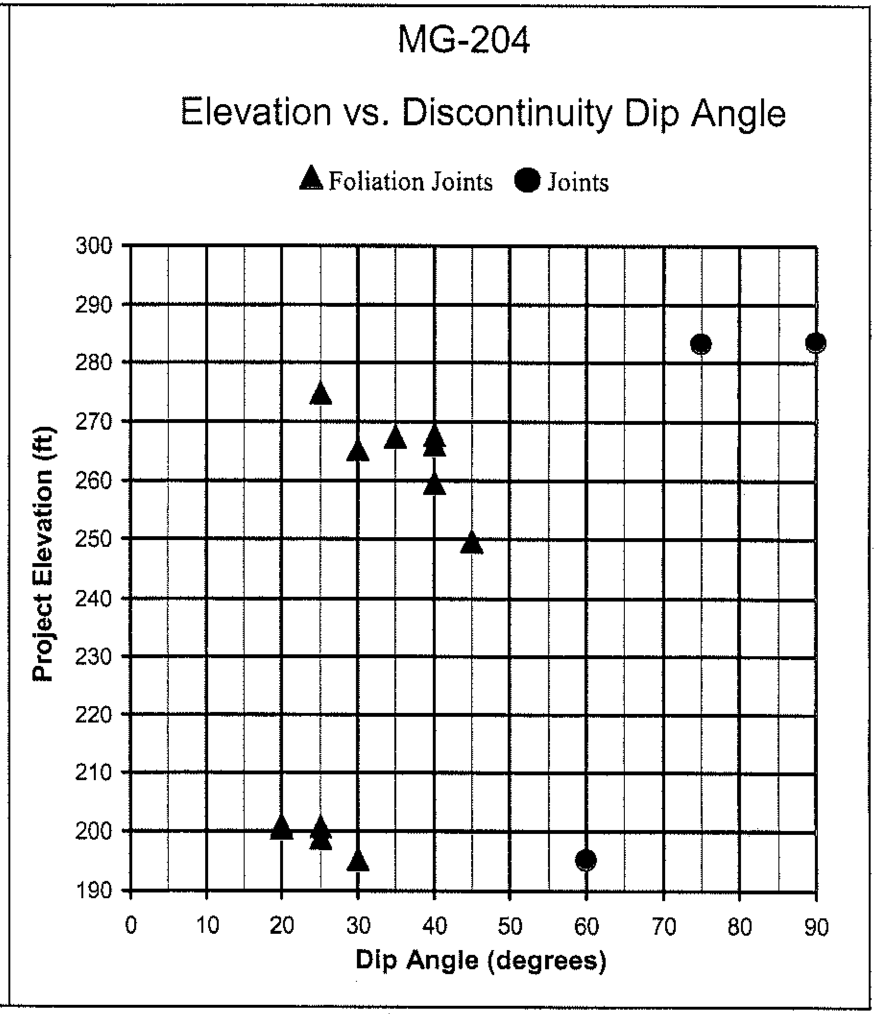




ORIENTED CORE DISCONTINUITY DATA

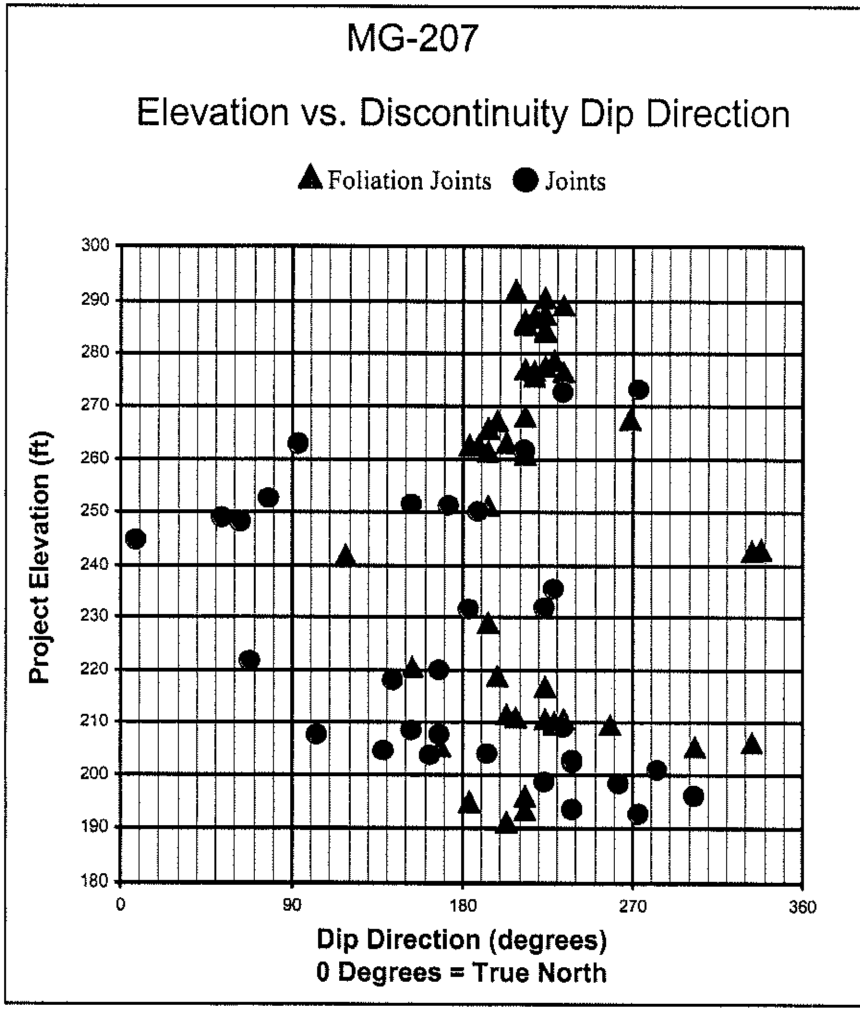
APPENDIX A-1
SHEET 21

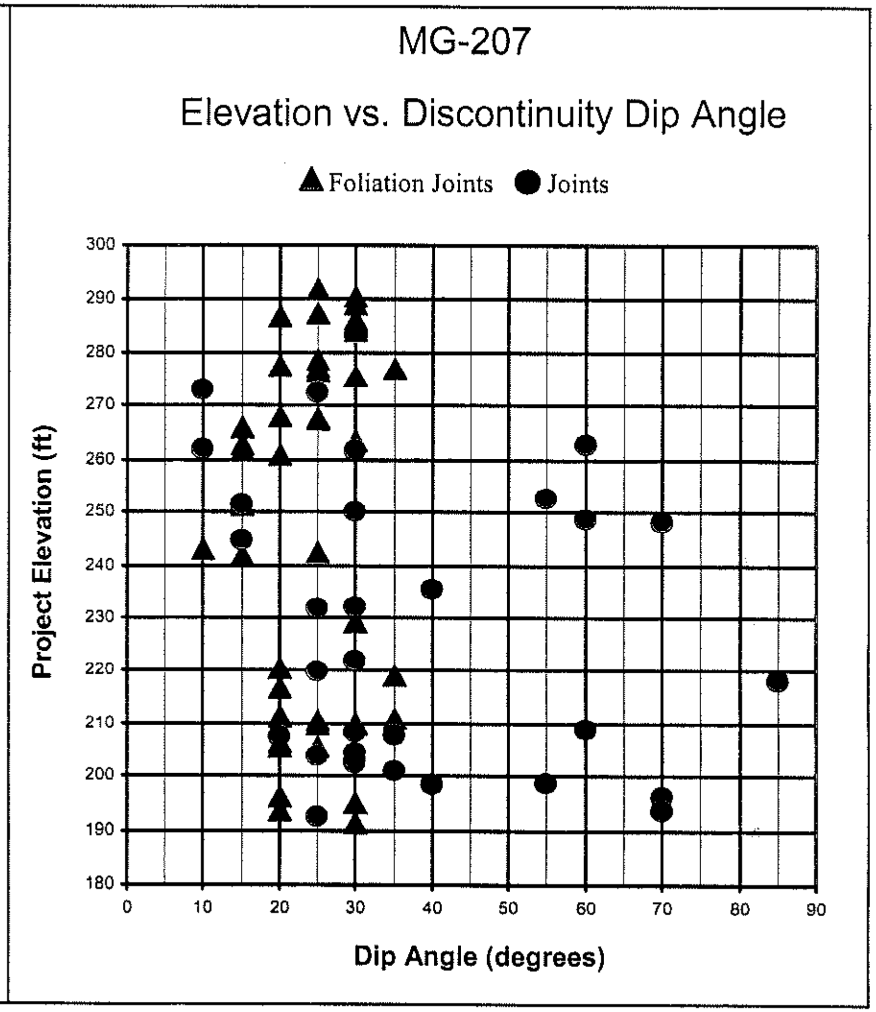




ORIENTED CORE DISCONTINUITY DATA

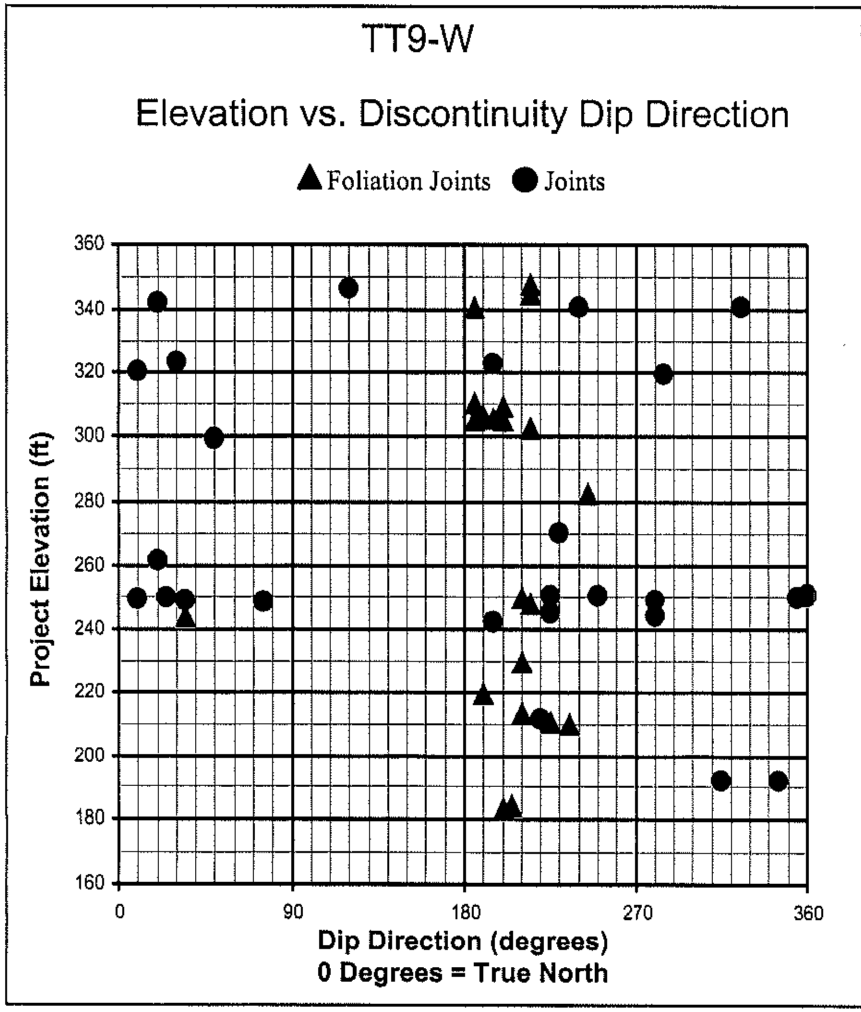
APPENDIX A-1
SHEET 22

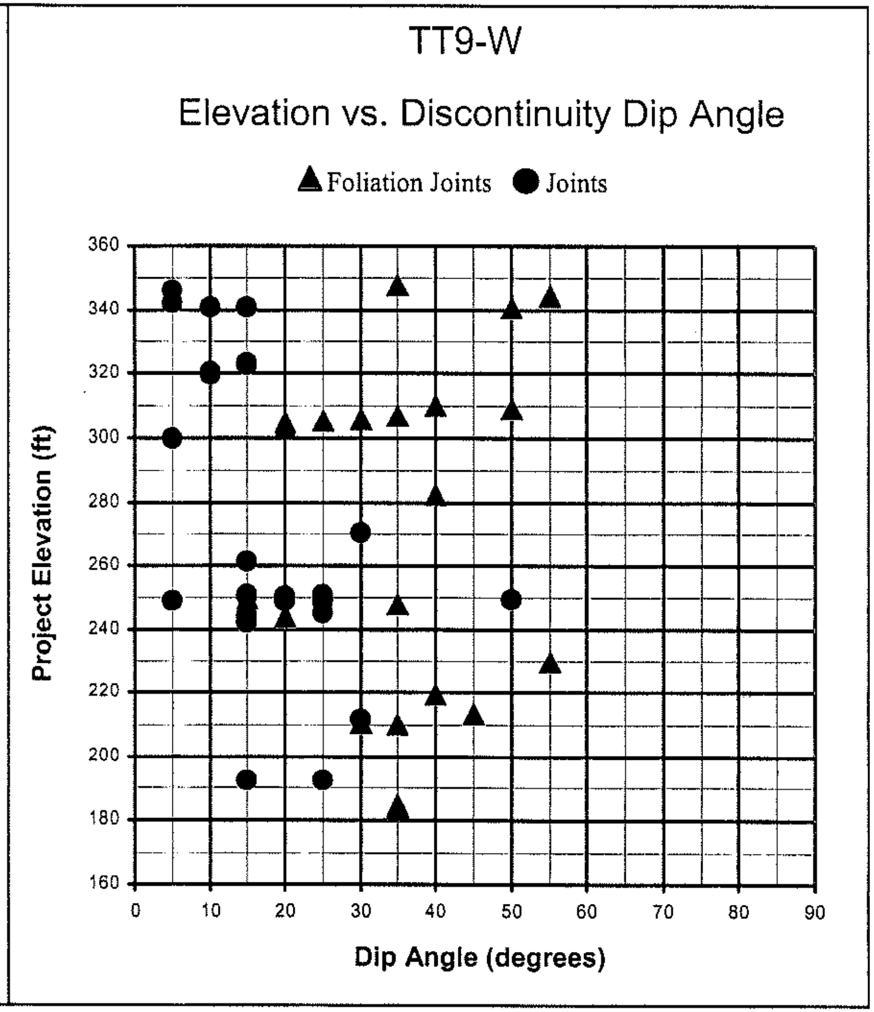




ORIENTED CORE DISCONTINUITY DATA

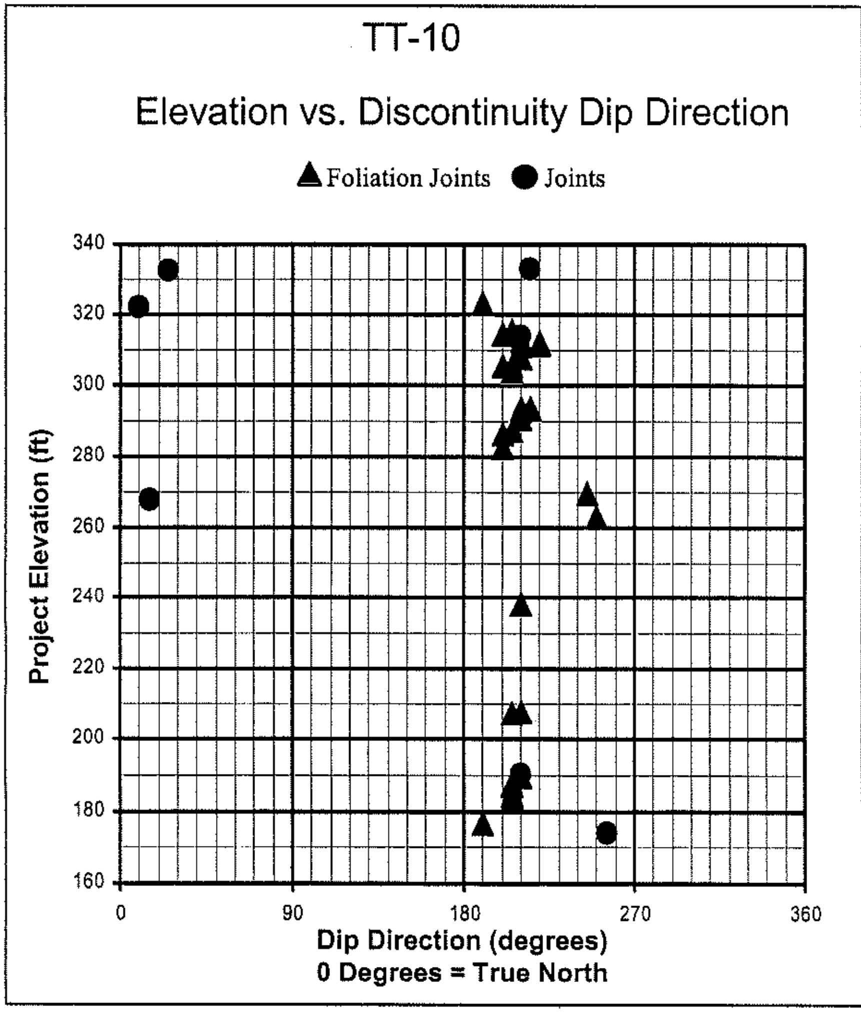
APPENDIX A-1
SHEET 23

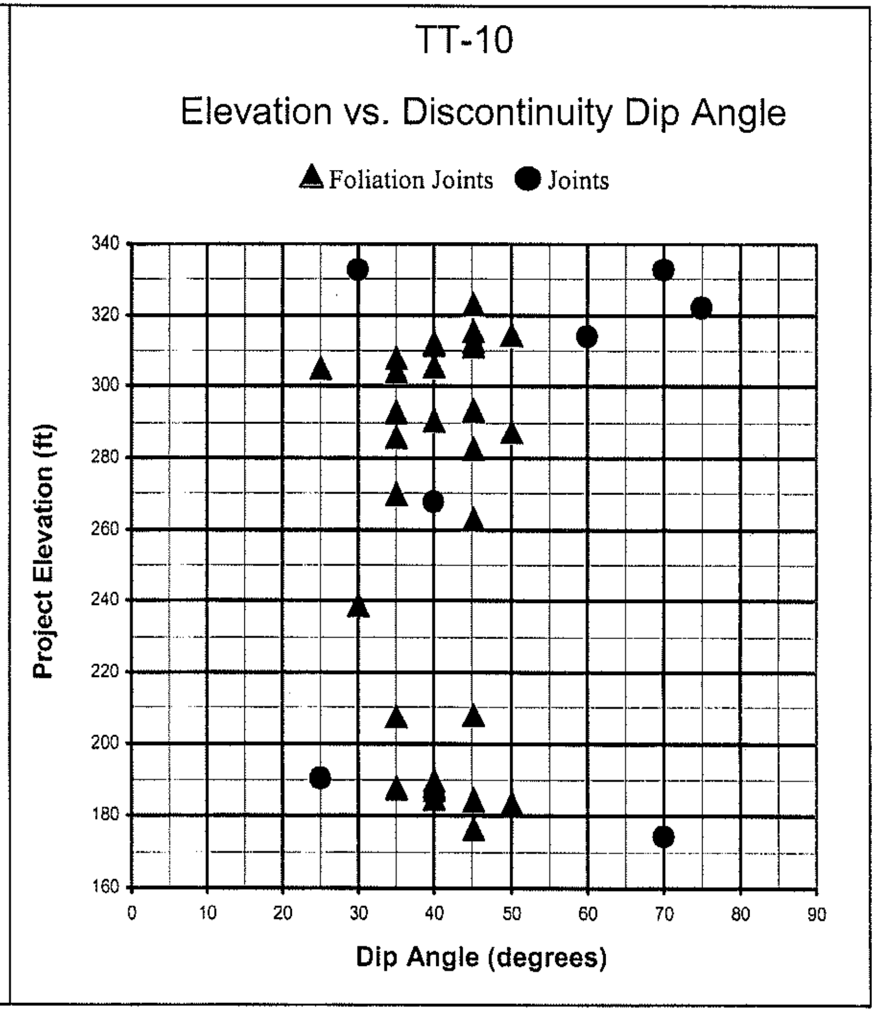




ORIENTED CORE DISCONTINUITY DATA

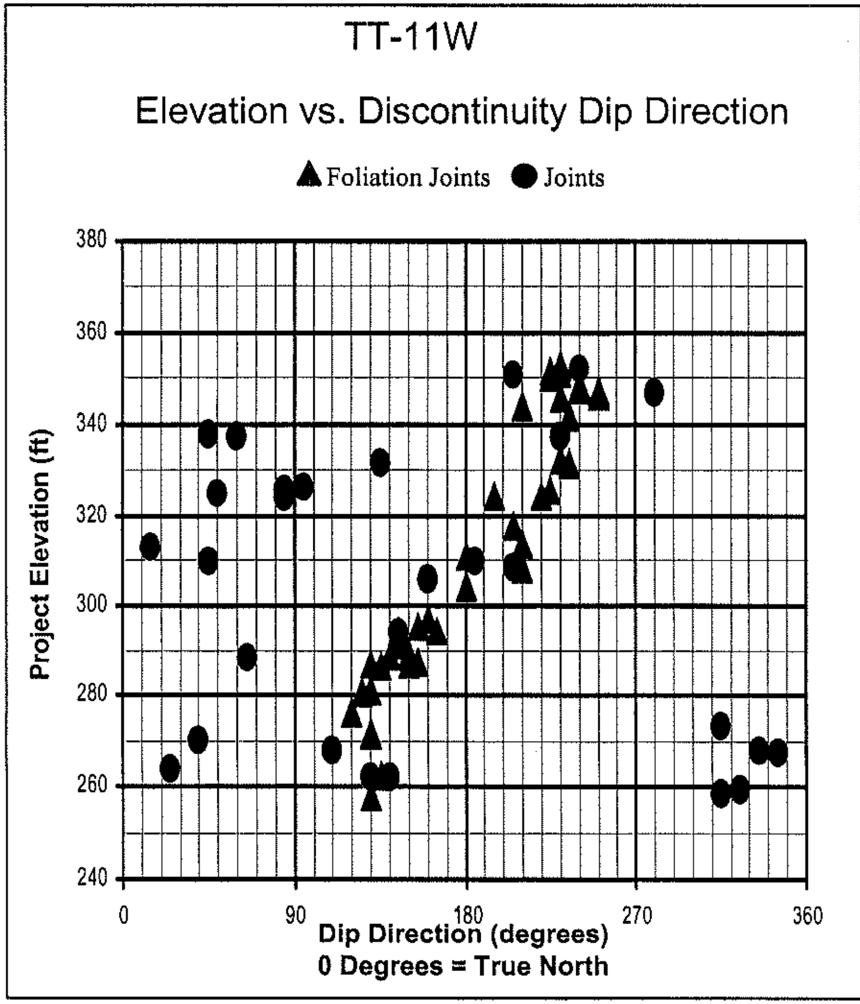
APPENDIX A-1
SHEET 24

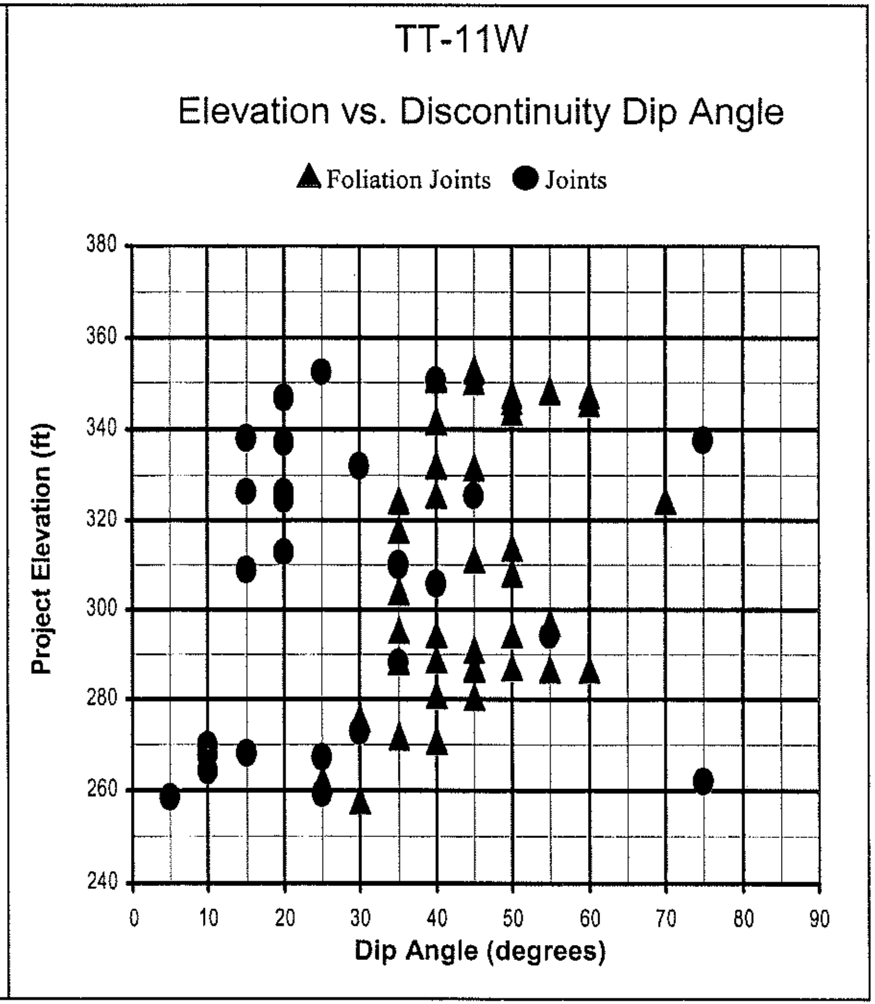




ORIENTED CORE DISCONTINUITY DATA

APPENDIX A-1
SHEET 25





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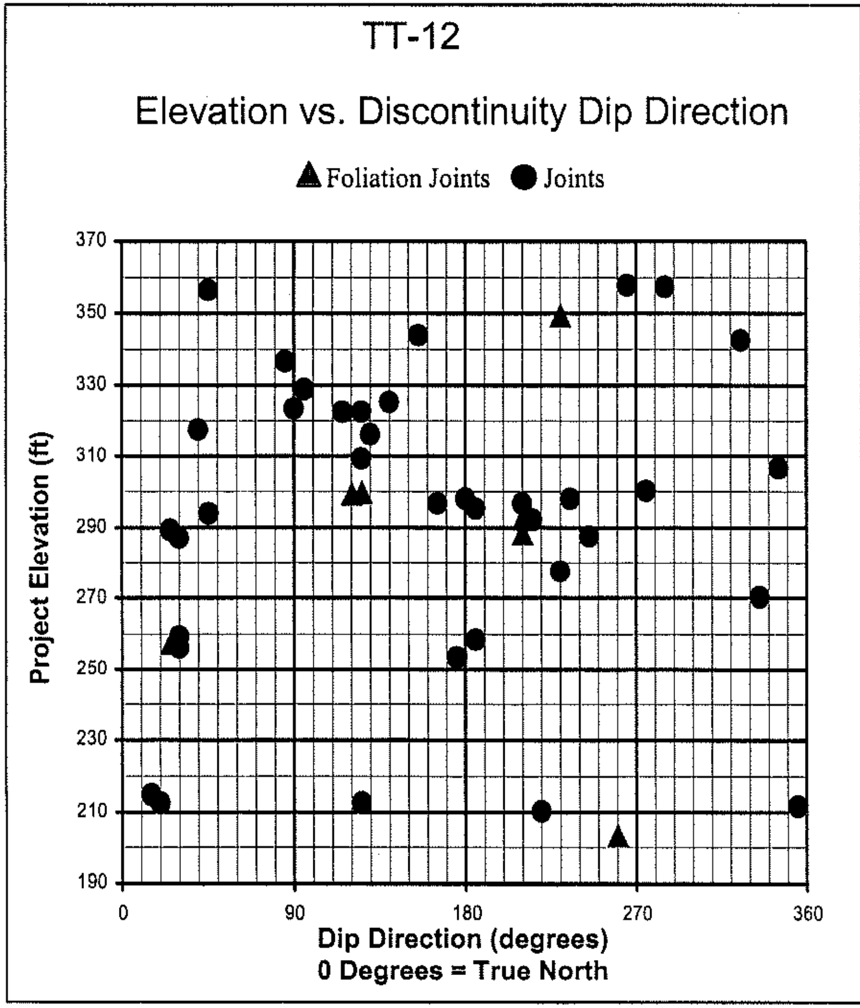

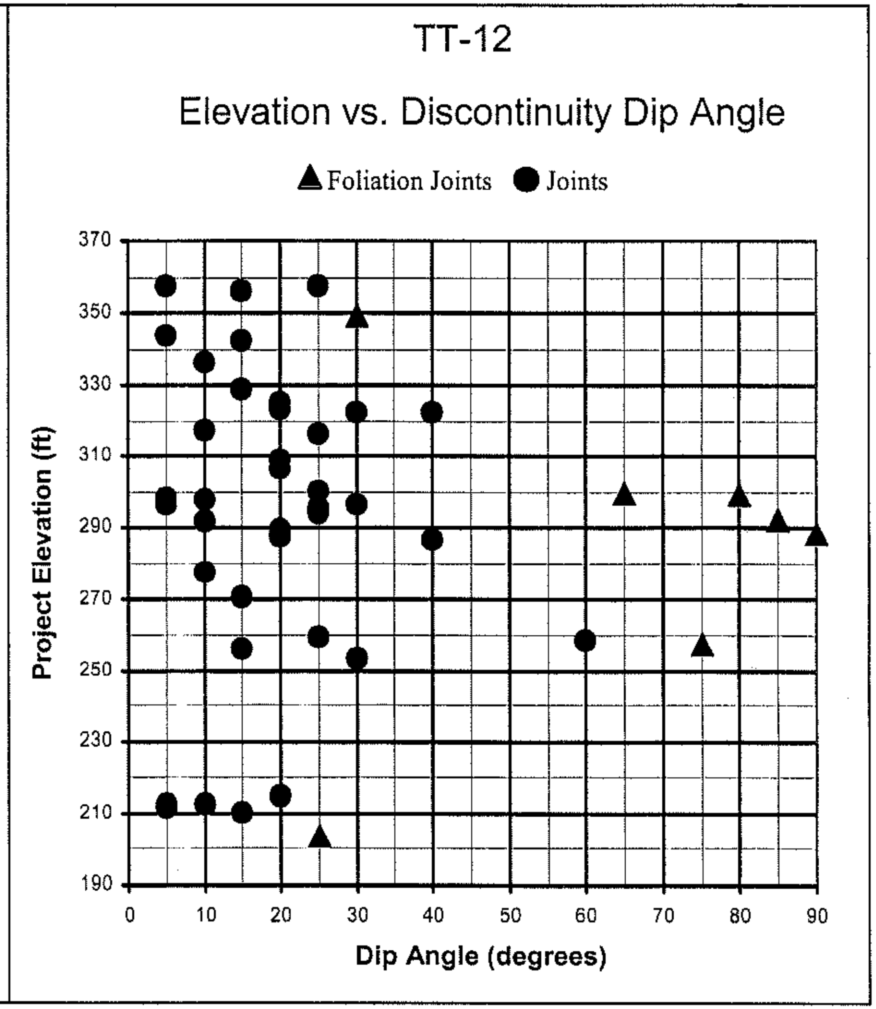

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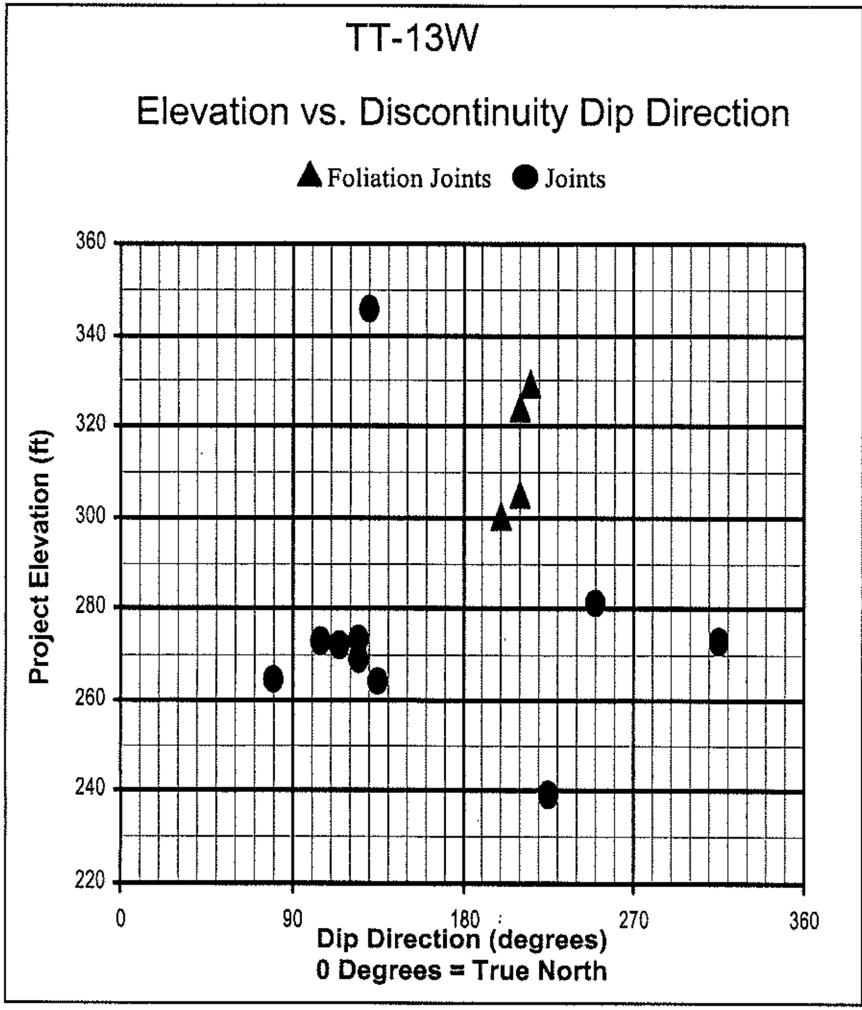
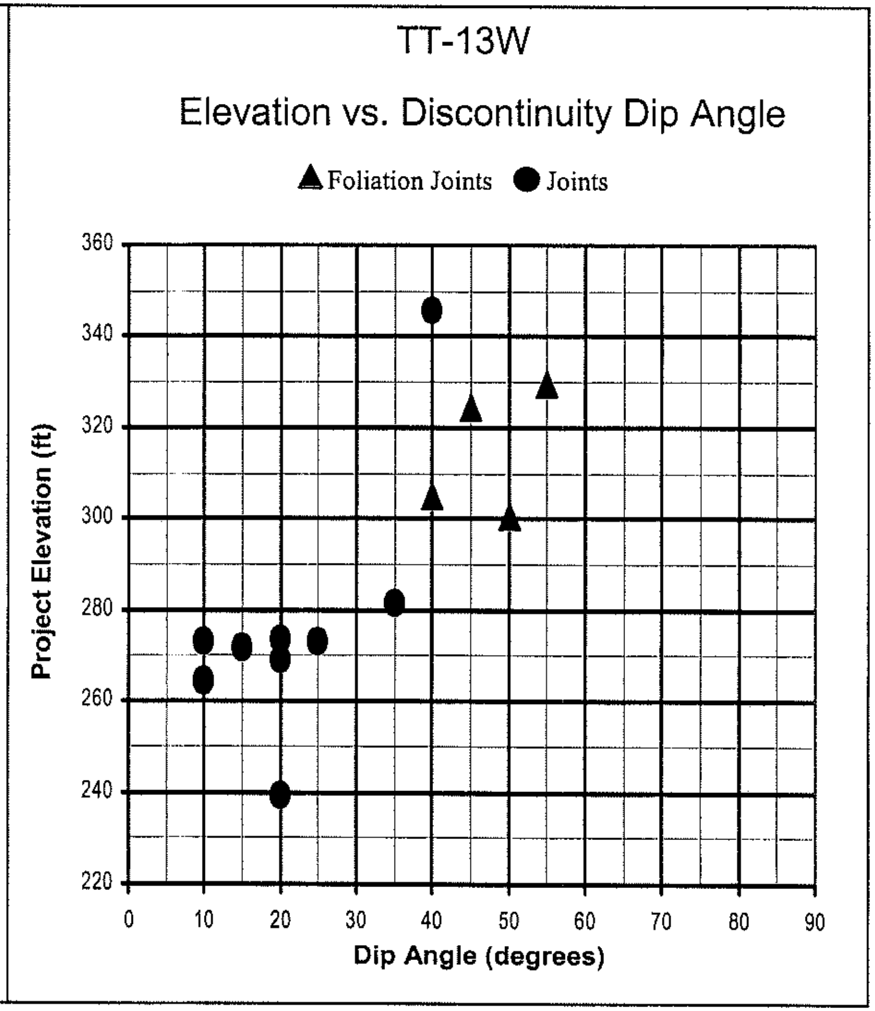
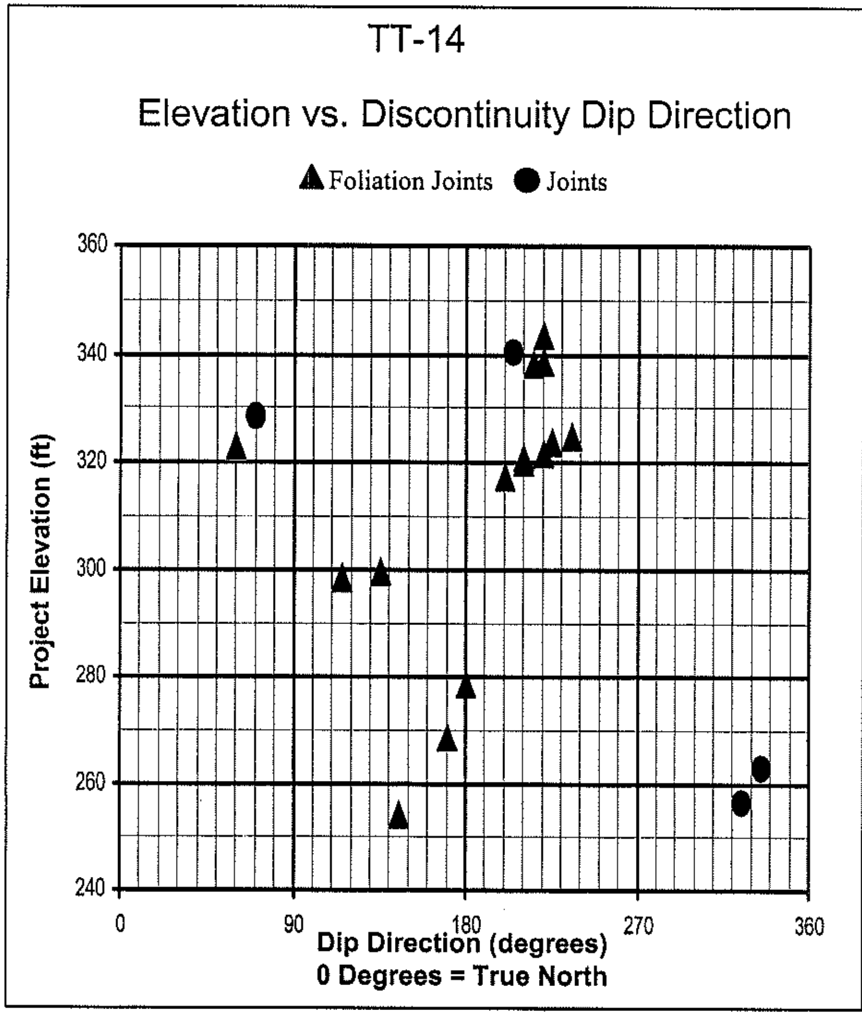
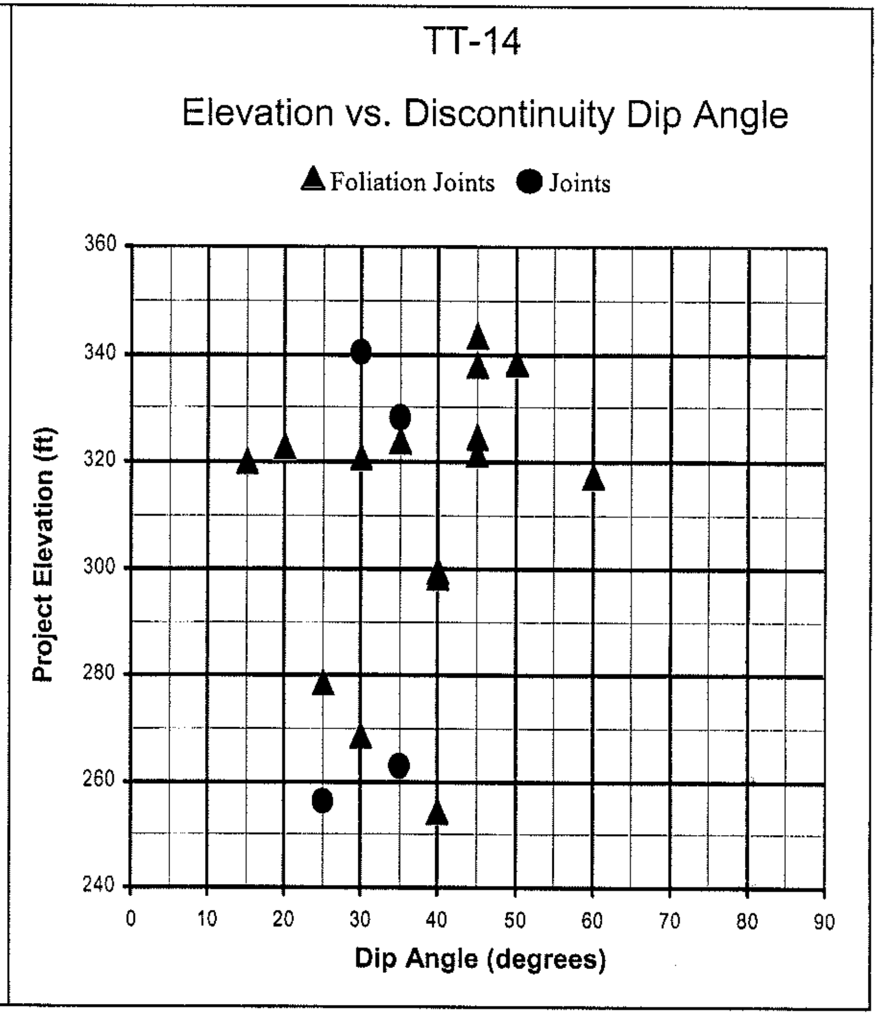




ORIENTED CORE DISCONTINUITY DATA





ORIENTED CORE DISCONTINUITY DATA

APPENDIX A-1
SHEET 29

APPENDIX A-2

FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

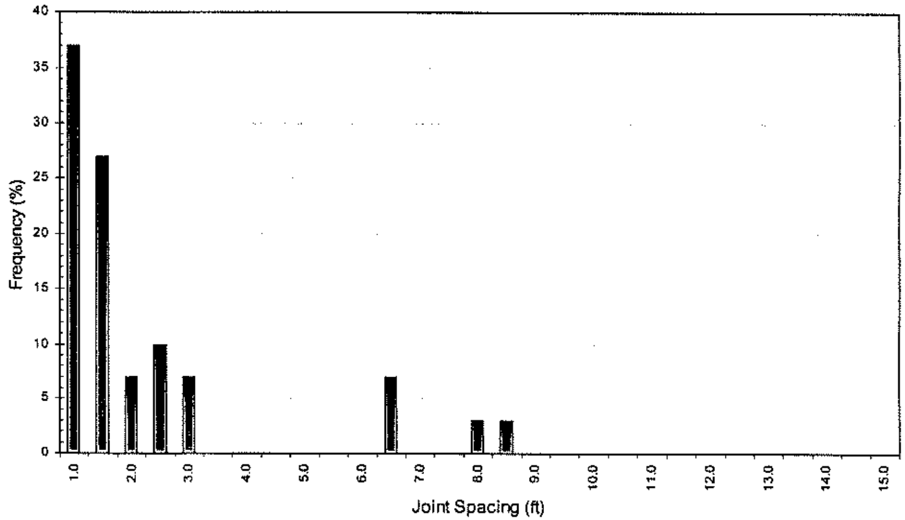
MA-107
Joint Set 1

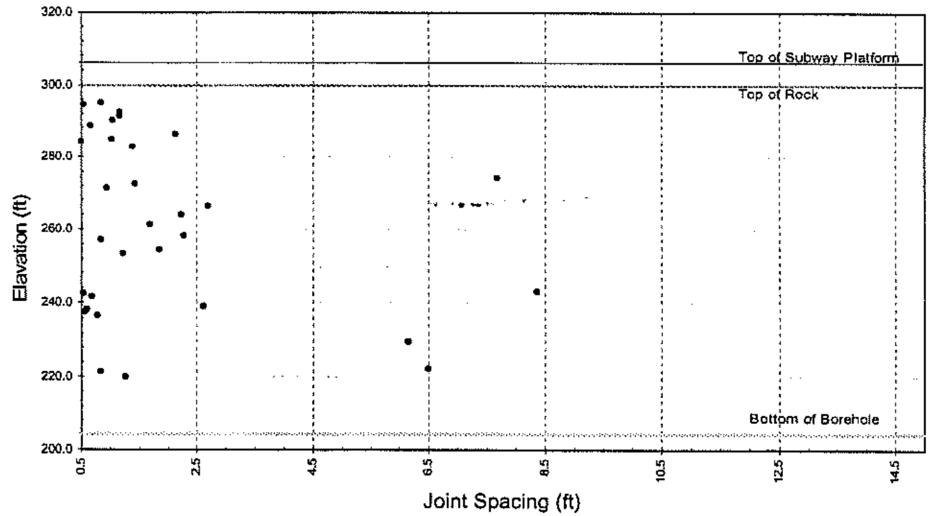
Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
10.0	20	0.0	0.0	296.0
10.2	20	0.2	0.2	295.8
11.1	25	0.9	0.8	294.9
11.7	25	0.6	0.5	294.3
12.1	20	0.4	0.4	293.9
12.6	15	0.5	0.5	293.4
13.8	15	1.2	1.2	292.2
15.0	20	1.2	1.2	291.0
16.1	15	1.1	1.0	289.9
16.5	15	0.4	0.4	289.5
16.7	20	0.2	0.2	289.3
17.0	20	0.3	0.3	289.0
17.7	15	0.7	0.7	288.3
19.9	20	2.2	2.1	286.1
20.3	15	0.4	0.3	285.6
21.3	10	1.1	1.0	284.7
21.8	20	0.5	0.5	284.2
22.0	10	0.2	0.2	284.0
23.4	10	1.4	1.4	282.6
23.7	5	0.3	0.3	282.3
23.9	10	0.2	0.1	282.2
24.1	15	0.2	0.2	282.0
32.0	15	8.0	7.7	274.0
32.3	30	0.3	0.2	273.8
33.9	20	1.7	1.4	272.1
34.9	15	1.0	0.9	271.1
35.2	30	0.3	0.3	270.8
35.7	50	0.5	0.4	270.3
39.9	15	4.2	2.7	266.1
42.2	15	2.3	2.2	263.8
42.5	20	0.3	0.3	263.5
42.9	20	0.4	0.4	263.1
44.7	45	1.8	1.7	261.3
47.9	15	3.2	2.3	258.1
48.2	20	0.3	0.3	257.8
49.1	45	0.9	0.8	256.9
51.7	20	2.6	1.8	254.3
53.0	35	1.3	1.2	253.0
63.2	25	10.2	8.4	242.8
63.8	15	0.6	0.5	242.2
64.5	15	0.7	0.7	241.5
67.2	30	2.7	2.6	238.8
67.9	20	0.7	0.6	238.1
68.5	30	0.6	0.6	237.5
69.4	30	0.9	0.8	236.6
76.5	30	7.1	6.1	229.5
84.0	20	7.5	6.5	222.0
84.9	25	0.9	0.8	221.1
86.3	10	1.4	1.3	219.7
86.6	20	0.3	0.3	219.4

Ground EL. (ft)	306
Top of Rock (ft)	300
Bottom of Hole (ft)	204.3

BIN	Freq.	Freq. (%)
0.5	(Clustering Margin)	
1.0	11	37
1.5	8	27
2.0	2	7
2.5	3	10
3.0	2	7
3.5	0	0
4.0	0	0
4.5	0	0
5.0	0	0
5.5	0	0
6.0	0	0
6.5	2	7
7.0	0	0
7.5	0	0
8.0	1	3
8.5	1	3
9.0	0	0
9.5	0	0
10.0	0	0
10.5	0	0
11.0	0	0
11.5	0	0
12.0	0	0
12.5	0	0
13.0	0	0
13.5	0	0
14.0	0	0
14.5	0	0
15.0	0	0
SUM	30	100

MA-107, Joint Set 1





FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

APPENDIX A-2
SHEET 1

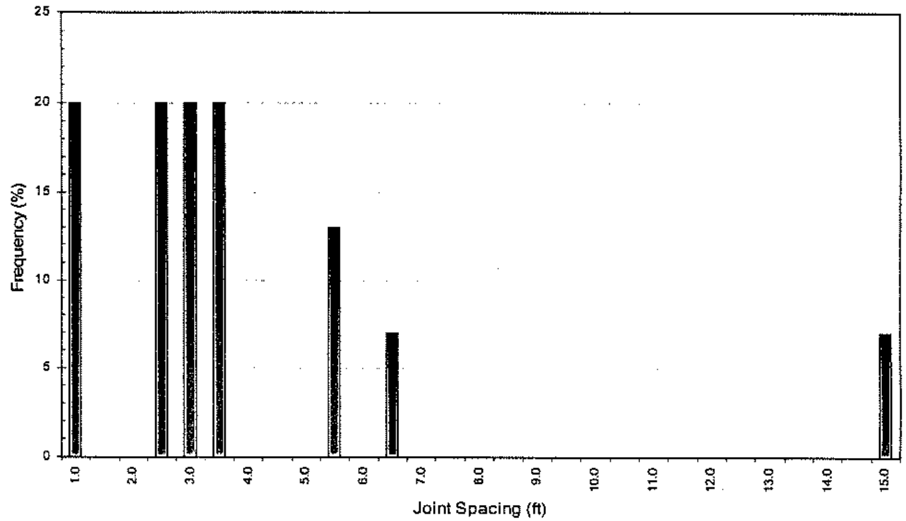
MA-109
Joint Set 1

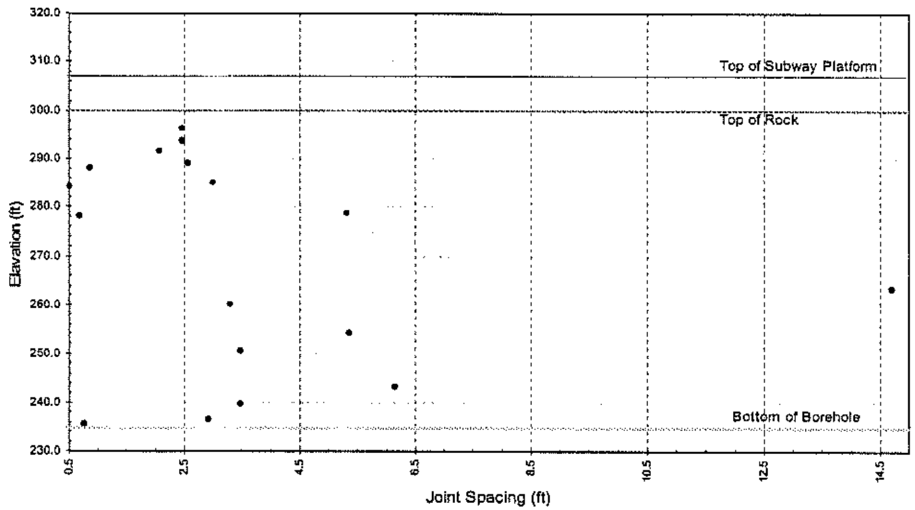
Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
7.9	10	0.0	0.0	299.1
8.3	10	0.4	0.4	298.7
10.8	10	2.5	2.5	296.2
13.3	10	2.5	2.5	293.7
15.4	10	2.1	2.1	291.6
18	30	2.6	2.6	289.0
19	15	1.0	0.9	288.0
22.1	1	3.1	3.0	284.9
22.2	1	0.1	0.1	284.8
22.3	1	0.1	0.1	284.7
22.8	15	0.5	0.5	284.2
28.31	5	5.5	5.3	278.7
29	1	0.7	0.7	278.0
43.7	15	14.7	14.7	263.3
47.1	25	3.4	3.3	259.9
53	20	5.9	5.3	254.0
56.7	30	3.7	3.5	250.3
63.8	20	7.1	6.1	243.2
67.5	10	3.7	3.5	239.5
67.6	20	0.1	0.1	239.4
70.7	20	3.1	2.9	236.3
71.5	15	0.8	0.8	235.5

Ground EL. (ft)	307
Top of Rock (ft)	300
Bottom of Hole (ft)	234.8

BIN	Freq.	Freq. (%)
0.5	(Clustering Margin)	
1.0	3	20
1.5	0	0
2.0	0	0
2.5	3	20
3.0	3	20
3.5	3	20
4.0	0	0
4.5	0	0
5.0	0	0
5.5	2	13
6.0	0	0
6.5	1	7
7.0	0	0
7.5	0	0
8.0	0	0
8.5	0	0
9.0	0	0
9.5	0	0
10.0	0	0
10.5	0	0
11.0	0	0
11.5	0	0
12.0	0	0
12.5	0	0
13.0	0	0
13.5	0	0
14.0	0	0
14.5	0	0
15.0	1	7
SUM	15	100

MA-109, Joint Set 1





FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

APPENDIX A-2
SHEET 2

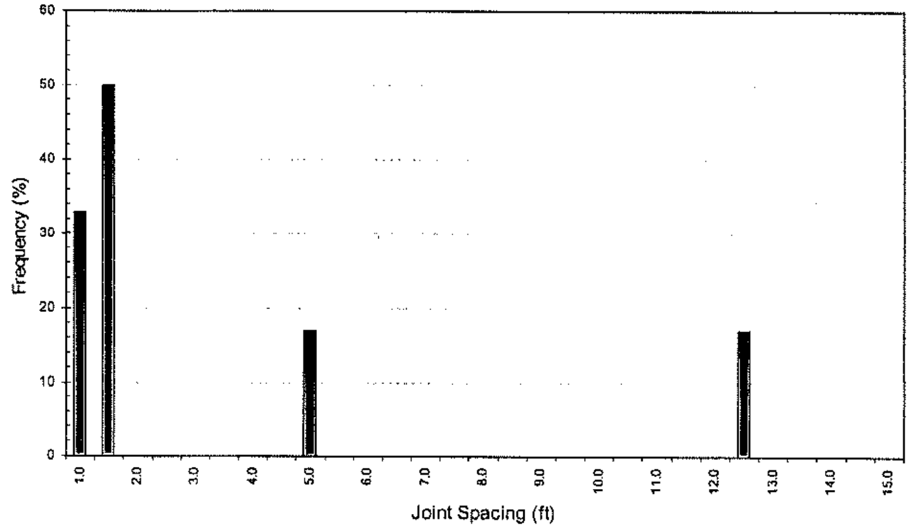
MA-208
Joint Set 1

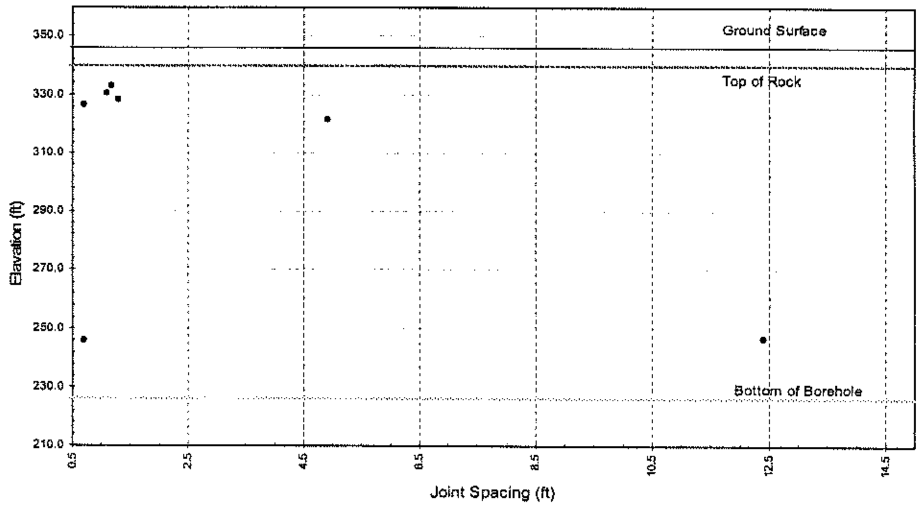
Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
12.1	25	0.0	0.0	333.9
13.4	5	1.3	1.2	332.6
13.5	5	0.1	0.1	332.5
13.7	5	0.2	0.2	332.3
13.8	55	0.1	0.1	332.2
15.7	50	1.9	1.1	330.3
17.7	45	2.0	1.3	328.3
18.1	15	0.4	0.3	327.9
18.4	40	0.3	0.3	327.6
18.9	10	0.5	0.4	327.1
19.6	15	0.7	0.7	326.4
24.7	10	5.1	4.9	321.3
58.8	10	34.1	33.6	287.2
59	10	0.2	0.2	287.0
59.1	10	0.1	0.1	286.9
59.2	10	0.1	0.1	286.8
59.3	10	0.1	0.1	286.7
83.5	40	24.2	23.8	262.5
99.7	5	16.2	12.4	246.3
100.4	20	0.7	0.7	245.6

Ground EL. (ft)	346
Top of Rock (ft)	340
Bottom of Hole (ft)	226.5

BIN	Freq.	Freq. (%)
0.5	(Clustering Margin)	
1.0	2	33
1.5	3	50
2.0	0	0
2.5	0	0
3.0	0	0
3.5	0	0
4.0	0	0
4.5	0	0
5.0	1	17
5.5	0	0
6.0	0	0
6.5	0	0
7.0	0	0
7.5	0	0
8.0	0	0
8.5	0	0
9.0	0	0
9.5	0	0
10.0	0	0
10.5	0	0
11.0	0	0
11.5	0	0
12.0	0	0
12.5	1	17
13.0	0	0
13.5	0	0
14.0	0	0
14.5	0	0
15.0	0	0
SUM	6	100

MA-208, Joint Set 1





FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

APPENDIX A-2
SHEET 3

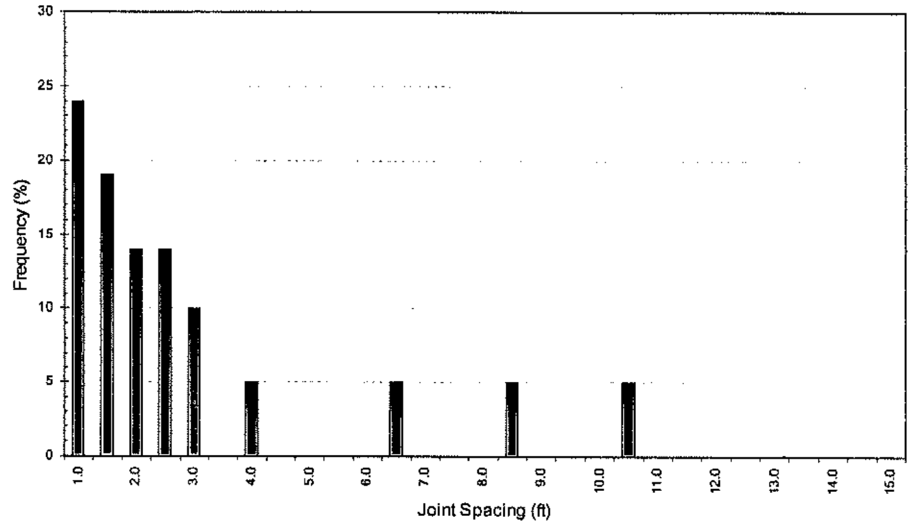
MA-209w
Joint Set 1

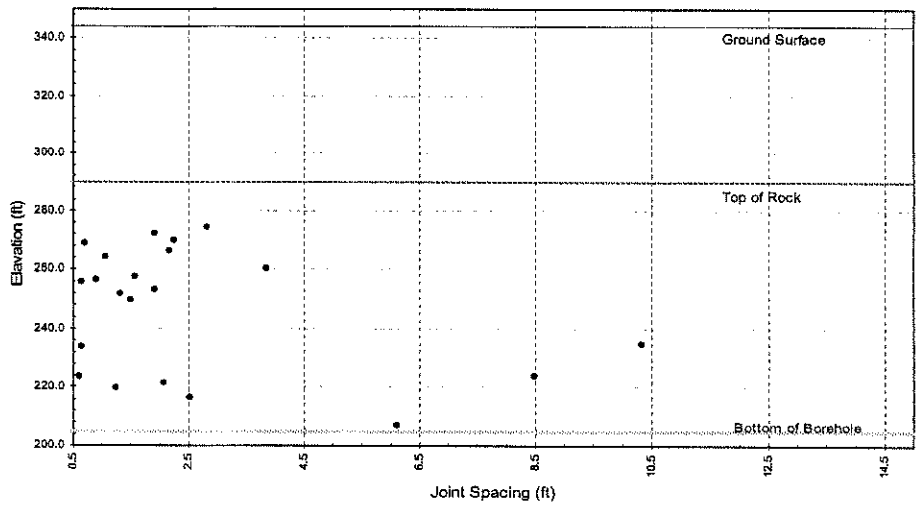
Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
66.6	20	0.0	0.0	277.4
69.6	30	3.0	2.8	274.4
71.8	21	2.2	1.9	272.2
74.2	45	2.4	2.2	269.8
75.2	30	1.0	0.7	268.8
77.7	15	2.5	2.2	266.3
77.9	15	0.2	0.2	266.1
78.3	35	0.4	0.4	265.7
78.4	15	0.1	0.1	265.6
78.6	20	0.2	0.2	265.4
78.7	15	0.1	0.1	265.3
79.8	20	1.1	1.1	264.2
83.9	55	4.1	3.9	260.1
86.65	20	2.8	1.6	257.4
87	45	0.3	0.3	257.0
87.01	5	0.0	0.0	257.0
87.9	25	0.9	0.9	256.1
88.6	30	0.7	0.6	255.4
90.8	40	2.2	1.9	253.2
92.5	45	1.7	1.3	251.5
94.6	45	2.1	1.5	249.4
94.8	45	0.2	0.1	249.2
109.4	50	14.6	10.3	234.6
110.4	30	1.0	0.6	233.6
120.2	10	9.8	8.5	223.8
120.8	10	0.6	0.6	223.2
122.9	40	2.1	2.1	221.1
124.5	40	1.6	1.2	219.5
127.8	50	3.3	2.5	216.2
137.3	60	9.5	6.1	206.7
138.2	50	0.9	0.4	205.8

Ground EL. (ft)	344
Top of Rock (ft)	290
Bottom of Hole (ft)	205

BIN	Freq.	Freq. (%)
0.5	(Clustering Margin)	
1.0	5	24
1.5	4	19
2.0	3	14
2.5	3	14
3.0	2	10
3.5	0	0
4.0	1	5
4.5	0	0
5.0	0	0
5.5	0	0
6.0	0	0
6.5	1	5
7.0	0	0
7.5	0	0
8.0	0	0
8.5	1	5
9.0	0	0
9.5	0	0
10.0	0	0
10.5	1	5
11.0	0	0
11.5	0	0
12.0	0	0
12.5	0	0
13.0	0	0
13.5	0	0
14.0	0	0
14.5	0	0
15.0	0	0
SUM	21	100

MA-209w, Joint Set 1





FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

APPENDIX A-2
SHEET 4

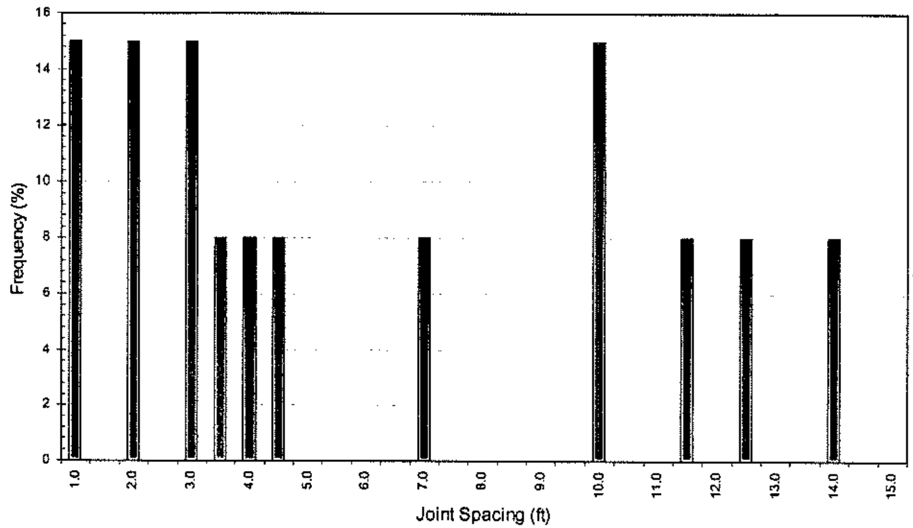
MA-211w
Joint Set 1

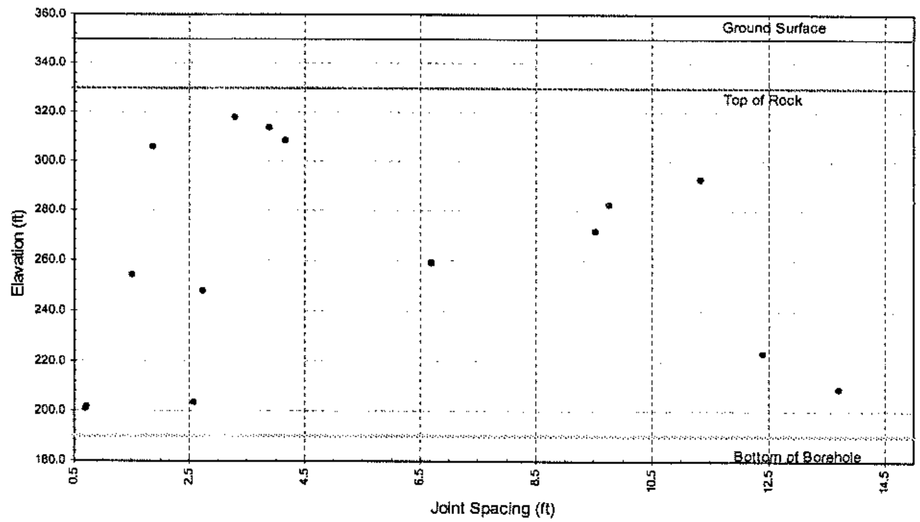
Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
25.7	60	0.0	0.0	324.3
32.3	30	6.6	3.3	317.7
36.8	30	4.5	3.9	313.2
41.6	44	4.8	4.2	308.4
44.2	30	2.6	1.9	305.8
57.3	20	13.1	11.3	292.7
67.7	29	10.4	9.8	282.3
78.6	59	10.9	9.5	271.4
91.6	70	13.0	6.7	258.4
96	75	4.4	1.5	254.0
97	59	1.0	0.3	253.0
102.3	60	5.3	2.7	247.7
127.1	20	24.8	12.4	222.9
141.7	85	14.6	13.7	208.3
142.7	40	1.0	0.1	207.3
143	50	0.3	0.2	207.0
147	65	4.0	2.6	203.0
148.7	75	1.7	0.7	201.3
148.8	70	0.1	0.0	201.2
148.9	40	0.1	0.0	201.1
149.8	65	0.9	0.7	200.2

Ground EL. (ft)	350
Top of Rock (ft)	330
Bottom of Hole (ft)	190

BIN	Freq.	Freq. (%)
0.5	(Clustering Margin)	
1.0	2	15
1.5	0	0
2.0	2	15
2.5	0	0
3.0	2	15
3.5	1	8
4.0	1	8
4.5	1	8
5.0	0	0
5.5	0	0
6.0	0	0
6.5	0	0
7.0	1	8
7.5	0	0
8.0	0	0
8.5	0	0
9.0	0	0
9.5	0	0
10.0	2	15
10.5	0	0
11.0	0	0
11.5	1	8
12.0	0	0
12.5	1	8
13.0	0	0
13.5	0	0
14.0	1	8
14.5	0	0
15.0	0	0
SUM	13	100

MA-211w, Joint Set 1





FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

APPENDIX A-2
SHEET 5

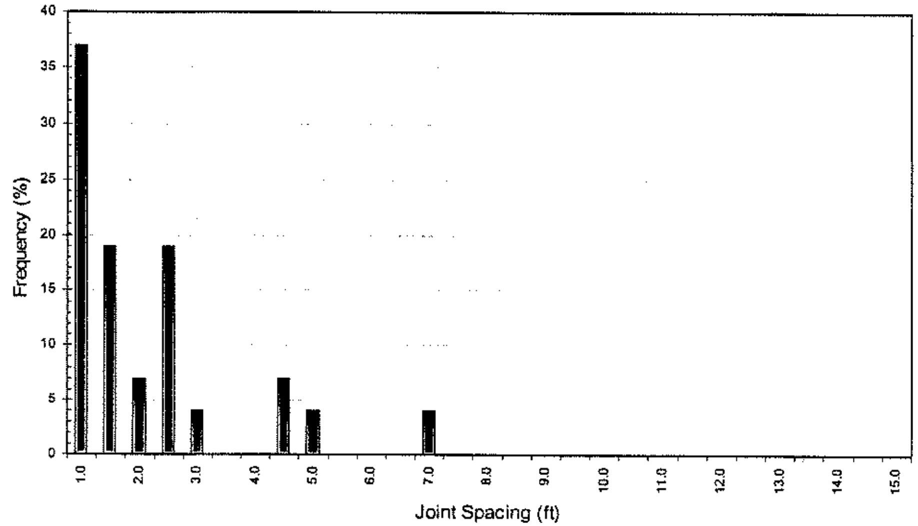
MA-301
Joint Set 1

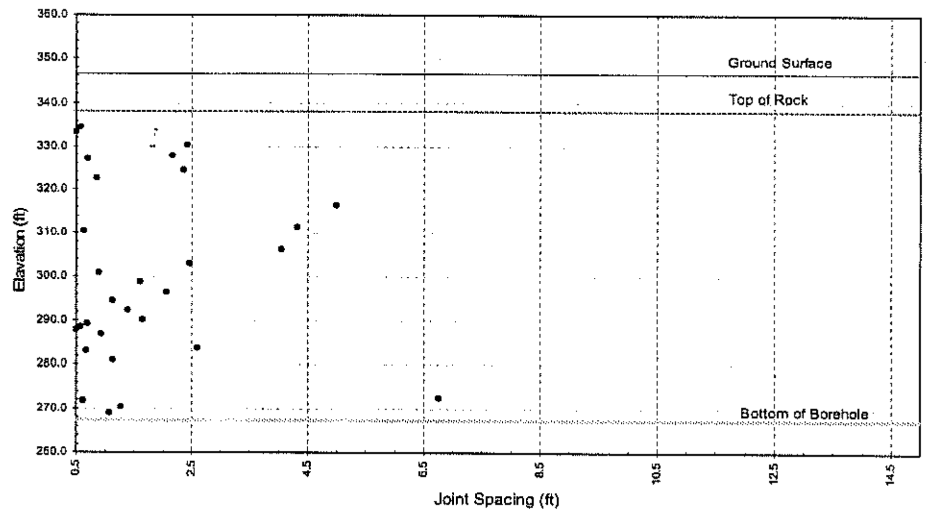
Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
10.1	35	0.0	0.0	336.4
10.3	35	0.2	0.2	336.2
10.75	40	0.4	0.4	335.8
11.1	35	0.4	0.3	335.4
11.3	35	0.2	0.2	335.2
11.6	35	0.3	0.2	334.9
12.3	35	0.7	0.6	334.2
12.4	35	0.1	0.1	334.1
12.7	40	0.3	0.2	333.8
12.9	35	0.2	0.2	333.6
13.5	35	0.6	0.5	333.0
13.6	30	0.1	0.1	332.9
16.4	30	2.8	2.4	330.1
18.9	30	2.5	2.2	327.6
19.7	25	0.8	0.7	326.8
22.3	35	2.6	2.4	324.2
22.8	25	0.5	0.4	323.7
23.1	30	0.3	0.3	323.4
24.1	35	1.0	0.9	322.4
30.2	30	6.1	5.0	316.3
35.2	20	5.0	4.3	311.3
35.5	25	0.3	0.3	311.0
36.2	20	0.7	0.6	310.3
40.5	40	4.3	4.0	306.0
40.6	40	0.1	0.1	305.9
43.8	25	3.2	2.5	302.7
43.9	35	0.1	0.1	302.6
44.1	35	0.2	0.2	302.4
44.3	35	0.2	0.2	302.2
44.6	35	0.3	0.2	301.9
44.7	35	0.1	0.1	301.8
45.8	40	1.1	0.9	300.7
47.9	30	2.1	1.6	298.6
48.1	20	0.2	0.2	298.4
50.3	30	2.2	2.1	296.2
50.5	40	0.2	0.2	296.0
50.8	35	0.3	0.2	295.7
51	20	0.2	0.2	295.5
52.2	30	1.2	1.1	294.3
52.6	35	0.4	0.3	293.9
54.3	35	1.7	1.4	292.2
54.5	30	0.2	0.2	292.0
56.4	50	1.9	1.6	290.1
57.5	35	1.1	0.7	289.0
58.2	35	0.7	0.6	288.3
58.8	20	0.6	0.5	287.7
59.8	30	1.0	0.9	286.7
62.8	15	3.0	2.6	283.7

Ground EL. (ft)	346.5
Top of Rock (ft)	338
Bottom of Hole (ft)	267.5

BIN	Freq.	Freq. (%)
0.5	(Clustering Margin)	
1.0	10	37
1.5	5	19
2.0	2	7
2.5	5	19
3.0	1	4
3.5	0	0
4.0	0	0
4.5	2	7
5.0	1	4
5.5	0	0
6.0	0	0
6.5	0	0
7.0	1	4
7.5	0	0
8.0	0	0
8.5	0	0
9.0	0	0
9.5	0	0
10.0	0	0
10.5	0	0
11.0	0	0
11.5	0	0
12.0	0	0
12.5	0	0
13.0	0	0
13.5	0	0
14.0	0	0
14.5	0	0
15.0	0	0
SUM	27	100

MA-301, Joint Set 1





FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

APPENDIX A-2
SHEET 6

MA-301, Joint Set 1 Data Continued				
63.5	30	0.7	0.7	283.0
63.7	25	0.2	0.2	282.8
64.1	25	0.4	0.4	282.4
64.5	30	0.4	0.4	282.0
65.8	35	1.3	1.1	280.7
66.1	25	0.3	0.2	280.4
66.25	35	0.2	0.1	280.3
66.6	35	0.3	0.3	279.9
66.8	25	0.2	0.2	279.7
74.25	20	7.5	6.8	272.3
74.9	20	0.7	0.6	271.6
76.25	25	1.3	1.3	270.3
76.6	20	0.3	0.3	269.9
77.75	25	1.2	1.1	268.8

FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

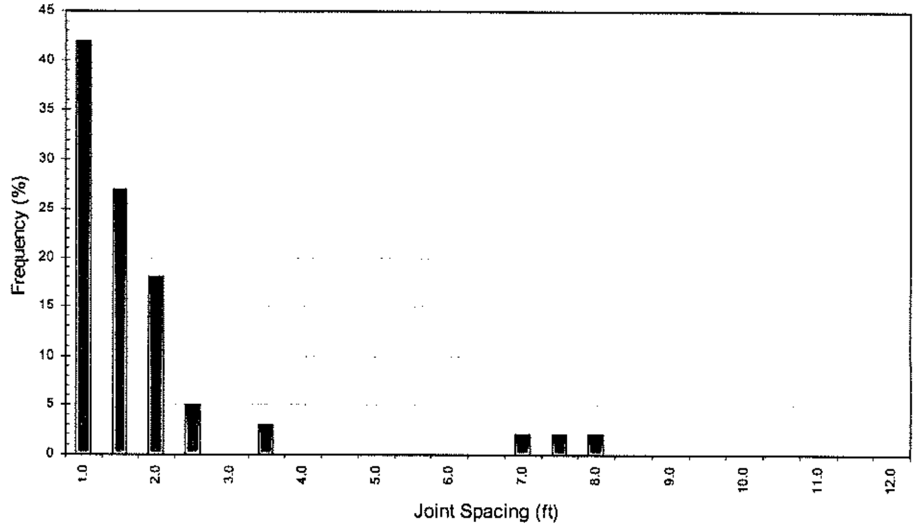
MA-302
Joint Set 1

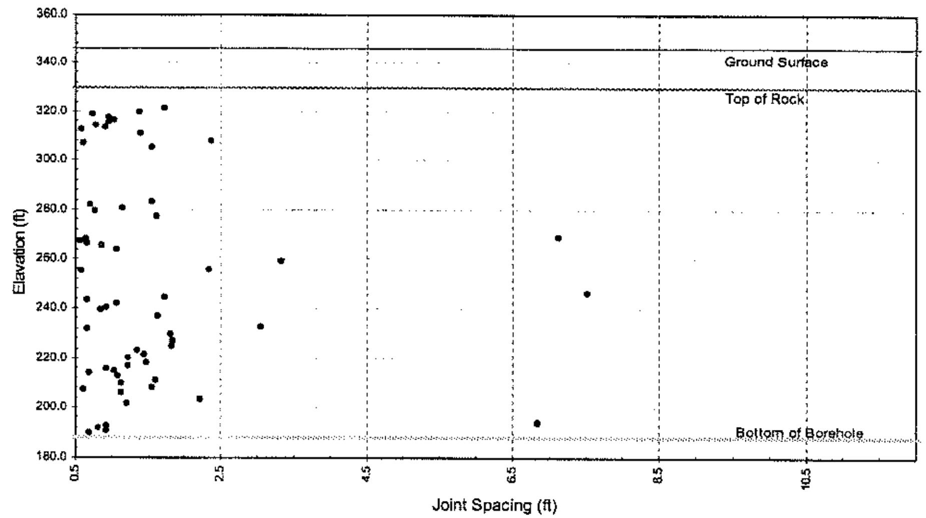
Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
23	25	0.0	0.0	323.0
24.9	30	1.9	1.7	321.1
26.5	35	1.6	1.4	319.5
27.4	30	0.9	0.7	318.6
28.5	30	1.1	1.0	317.5
29.7	30	1.2	1.0	316.3
30.8	35	1.1	1.0	315.2
31.75	30	0.9	0.8	314.3
32.8	35	1.1	0.9	313.2
33.5	35	0.7	0.6	312.5
35.2	40	1.7	1.4	310.8
38.3	30	3.1	2.4	307.7
39	30	0.7	0.6	307.0
40.8	25	1.8	1.6	305.2
61	45	20.2	18.3	285.0
63.2	45	2.2	1.6	282.8
64.2	40	1.0	0.7	281.8
65.7	40	1.5	1.1	280.3
66.7	40	1.0	0.8	279.3
68.8	35	2.1	1.6	277.2
77.5	50	8.7	7.1	268.5
78.5	45	1.0	0.6	267.5
79.3	35	0.8	0.6	266.7
80.1	30	0.8	0.7	265.9
81.1	40	1.0	0.9	264.9
82.5	45	1.4	1.1	263.5
87.2	45	4.7	3.3	258.8
90.5	35	3.3	2.3	255.5
91.21	30	0.7	0.6	254.8
99.9	30	8.7	7.5	246.1
101.9	60	2.0	1.7	244.1
103.2	35	1.3	0.6	242.8
104.5	45	1.3	1.1	241.5
105.8	40	1.3	0.9	240.2
106.9	45	1.1	0.8	239.1
109.2	45	2.3	1.6	236.8
113.5	35	4.3	3.0	232.5
114.3	35	0.8	0.7	231.7
116.5	45	2.2	1.8	229.5
119.1	30	2.6	1.8	226.9
121.2	45	2.1	1.8	224.8
123.1	25	1.9	1.3	222.9
124.7	35	1.6	1.5	221.3
126.2	35	1.5	1.2	219.8
128	20	1.8	1.5	218.0
129.3	40	1.3	1.2	216.7
130.51	30	1.2	0.9	215.5
131.7	30	1.2	1.0	214.3

Ground EL. (ft)	346
Top of Rock (ft)	330
Bottom of Hole (ft)	188

BIN	Freq.	Freq. (%)
0.5	stering Margin)	
1.0	25	42
1.5	16	27
2.0	11	18
2.5	3	5
3.0	0	0
3.5	2	3
4.0	0	0
4.5	0	0
5.0	0	0
5.5	0	0
6.0	0	0
6.5	0	0
7.0	1	2
7.5	1	2
8.0	1	2
8.5	0	0
9.0	0	0
9.5	0	0
10.0	0	0
10.5	0	0
11.0	0	0
11.5	0	0
12.0	0	0
SUM	60	100

MA-302, Joint Set 1





FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

MA-302, Joint Set 1 Data Countined				
132.5	25	0.8	0.7	213.5
133.7	20	1.2	1.1	212.3
135.4	30	1.7	1.6	210.6
136.7	30	1.3	1.1	209.3
138.5	30	1.8	1.6	207.5
139.2	30	0.7	0.6	206.8
140.5	35	1.3	1.1	205.5
143.2	30	2.7	2.2	202.8
144.6	30	1.4	1.2	201.4
152.5	40	7.9	6.8	193.5
153.7	35	1.2	0.9	192.3
154.7	40	1.0	0.8	191.3
155.9	30	1.2	0.9	190.1
156.7	30	0.8	0.7	189.3

FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

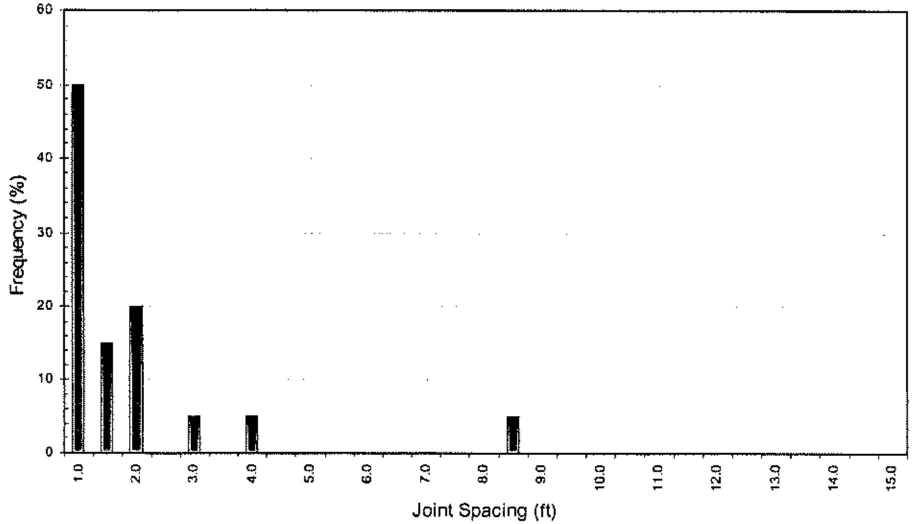
MA-303
Joint Set 1

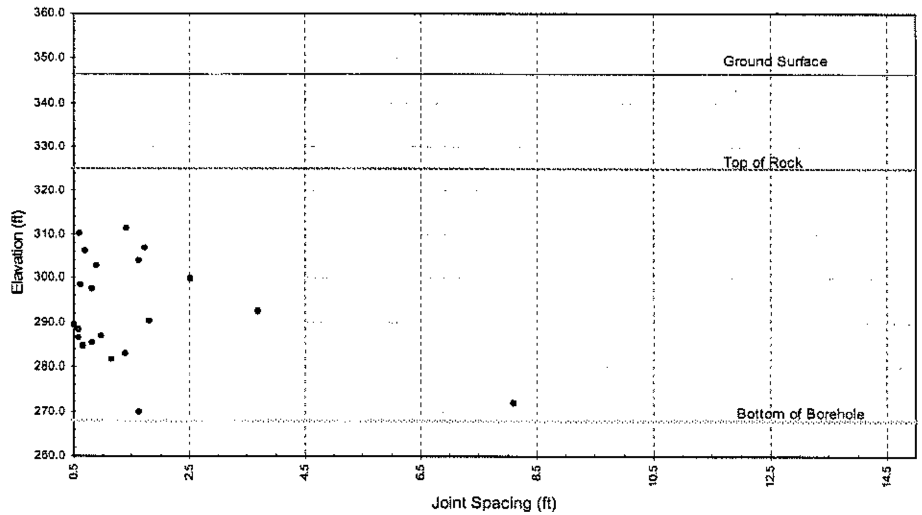
Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
33.7	20	0.0	0.0	312.8
33.8	20	0.1	0.1	312.7
35.3	25	1.5	1.4	311.2
35.7	30	0.4	0.4	310.8
36.4	35	0.7	0.6	310.1
36.7	35	0.3	0.2	309.8
37	35	0.3	0.2	309.5
37.4	35	0.4	0.3	309.1
37.7	35	0.3	0.2	308.8
39.8	30	2.1	1.7	306.7
40.6	35	0.8	0.7	305.9
42.6	35	2.0	1.6	303.9
43.7	35	1.1	0.9	302.8
43.9	30	0.2	0.2	302.6
46.8	35	2.9	2.5	299.7
47	35	0.2	0.2	299.5
47.1	30	0.1	0.1	299.4
47.5	40	0.4	0.3	299.0
48.3	35	0.8	0.6	298.2
49.3	35	1.0	0.8	297.2
49.6	35	0.3	0.2	296.9
54.1	35	4.5	3.7	292.4
56.3	35	2.2	1.8	290.2
56.6	35	0.3	0.2	289.9
57.2	35	0.6	0.5	289.3
57.6	35	0.4	0.3	288.9
58.3	35	0.7	0.6	288.2
59.5	35	1.2	1.0	287.0
60.2	35	0.7	0.6	286.3
61.2	35	1.0	0.8	285.3
62	35	0.8	0.7	284.5
63.7	35	1.7	1.4	282.8
65.1	35	1.4	1.1	281.4
75	25	9.9	8.1	271.5
76.8	35	1.8	1.6	269.7

Ground EL. (ft)	346.5
Top of Rock (ft)	325
Bottom of Hole (ft)	268

BIN	Freq.	Freq. (%)
0.5	(Clustering Margin)	
1.0	10	50
1.5	3	15
2.0	4	20
2.5	0	0
3.0	1	5
3.5	0	0
4.0	1	5
4.5	0	0
5.0	0	0
5.5	0	0
6.0	0	0
6.5	0	0
7.0	0	0
7.5	0	0
8.0	0	0
8.5	1	5
9.0	0	0
9.5	0	0
10.0	0	0
10.5	0	0
11.0	0	0
11.5	0	0
12.0	0	0
12.5	0	0
13.0	0	0
13.5	0	0
14.0	0	0
14.5	0	0
15.0	0	0
SUM	20	100

MA-303, Joint Set 1





FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

APPENDIX A-2
SHEET 10

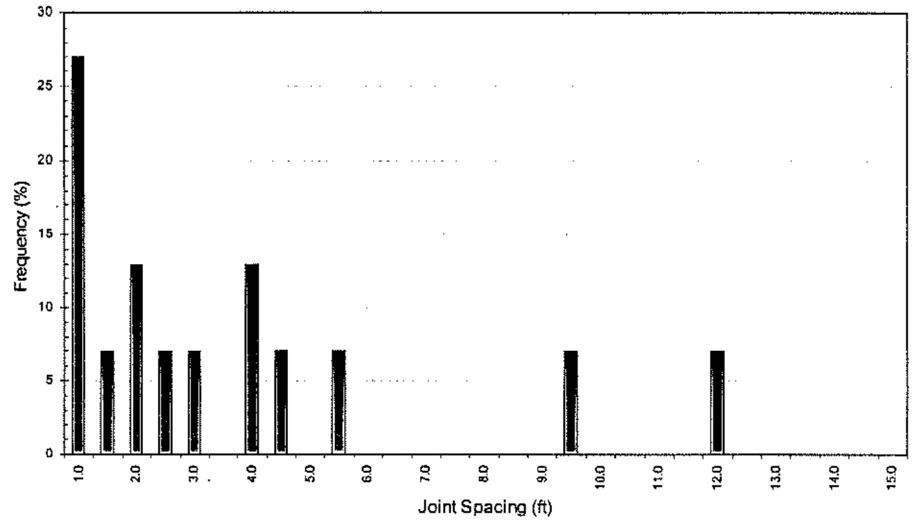
MA-304
Joint Set 1

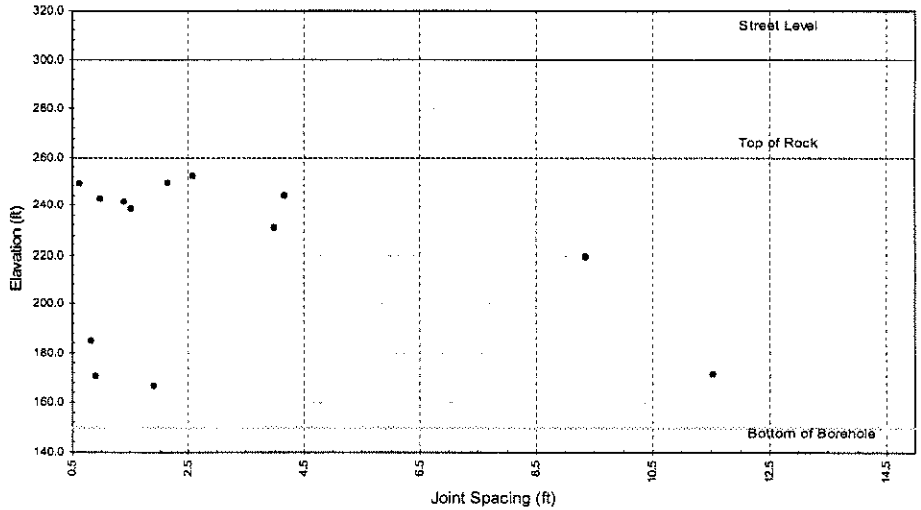
Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
45.2	10			254.8
48.1	45	2.9	2.6	251.9
50.9	35	2.8	2.1	249.1
51.7	45	0.8	0.6	248.3
56.4	10	4.7	4.2	243.6
56.5	5	0.1	0.1	243.5
57.6	50	1.1	1.0	242.4
59.2	10	1.6	1.4	240.8
59.4	10	0.2	0.2	240.6
59.5	10	0.1	0.1	240.5
59.9	25	0.4	0.4	240.1
60.1	20	0.2	0.2	239.9
61.9	45	1.8	1.5	238.1
62	30	0.1	0.1	238.0
62.3	5	0.3	0.3	237.7
62.6	10	0.3	0.3	237.4
62.7	10	0.1	0.1	237.3
62.8	5	0.1	0.1	237.2
62.9	5	0.1	0.1	237.1
63	5	0.1	0.1	237.0
63.2	5	0.2	0.2	236.8
63.3	5	0.1	0.1	236.7
63.4	5	0.1	0.1	236.6
63.5	5	0.1	0.1	236.5
63.7	30	0.2	0.2	236.3
64	10	0.3	0.3	236.0
64.1	5	0.1	0.1	235.9
64.2	5	0.1	0.1	235.8
64.5	5	0.3	0.3	235.5
64.7	5	0.2	0.2	235.3
64.8	10	0.1	0.1	235.2
64.9	20	0.1	0.1	235.1
69.5	40	4.6	4.0	230.5
69.6	40	0.1	0.1	230.4
70.2	40	0.6	0.5	229.8
81	20	10.8	9.4	219.0
81.2	30	0.2	0.2	218.8
81.7	25	0.5	0.4	218.3
114.3	25	32.6	29.5	185.7
115.4	60	1.1	0.8	184.6
115.8	25	0.4	0.3	184.2
116	50	0.2	0.2	184.0
129	5	13.0	11.5	171.0
129.9	10	0.9	0.9	170.1
130.3	10	0.4	0.4	169.7
130.7	20	0.4	0.4	169.3
130.8	10	0.1	0.1	169.2
131.3	15	0.5	0.5	168.7
131.5	20	0.2	0.2	168.5

Ground EL. (ft)	300
Top of Rock (ft)	260
Bottom of Hole (ft)	150

BIN	Freq.	Freq. (%)
0.5	(Clustering Margin)	
1.0	4	27
1.5	1	7
2.0	2	13
2.5	1	7
3.0	1	7
3.5	0	0
4.0	2	13
4.5	1	7
5.0	0	0
5.5	1	7
6.0	0	0
6.5	0	0
7.0	0	0
7.5	0	0
8.0	0	0
8.5	0	0
9.0	0	0
9.5	1	7
10.0	0	0
10.5	0	0
11.0	0	0
11.5	0	0
12.0	1	7
12.5	0	0
13.0	0	0
13.5	0	0
14.0	0	0
14.5	0	0
15.0	0	0
SUM	15	100

MA-304, Joint Set 1





FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

APPENDIX A-2
SHEET 11

MA-304,Joint Set 1 Data Continued				
131.5	20	0.2	0.2	168.5
133.7	40	2.2	1.9	166.3
133.9	30	0.2	0.2	166.1
138.3	20	4.4	4.0	161.7
138.8	20	0.5	0.5	161.2
144.7	25	5.9	5.5	155.3

FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

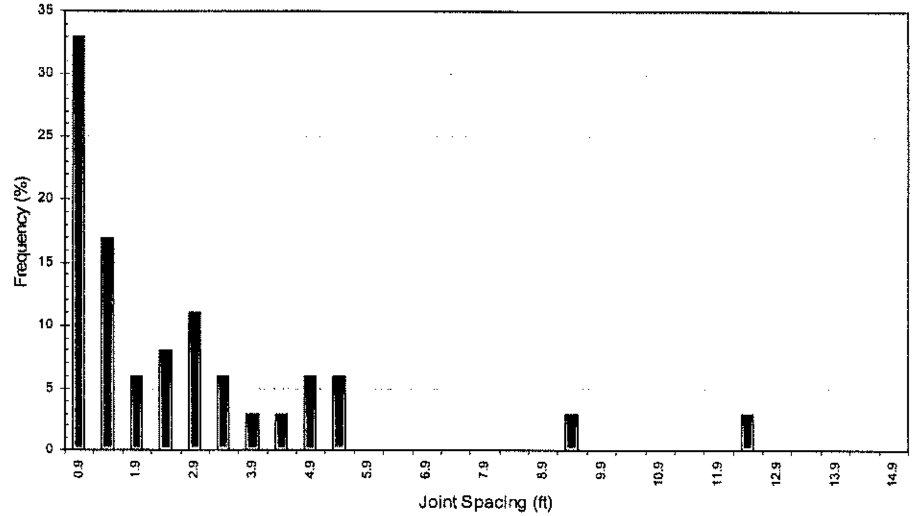
MA-306
Joint Set 1

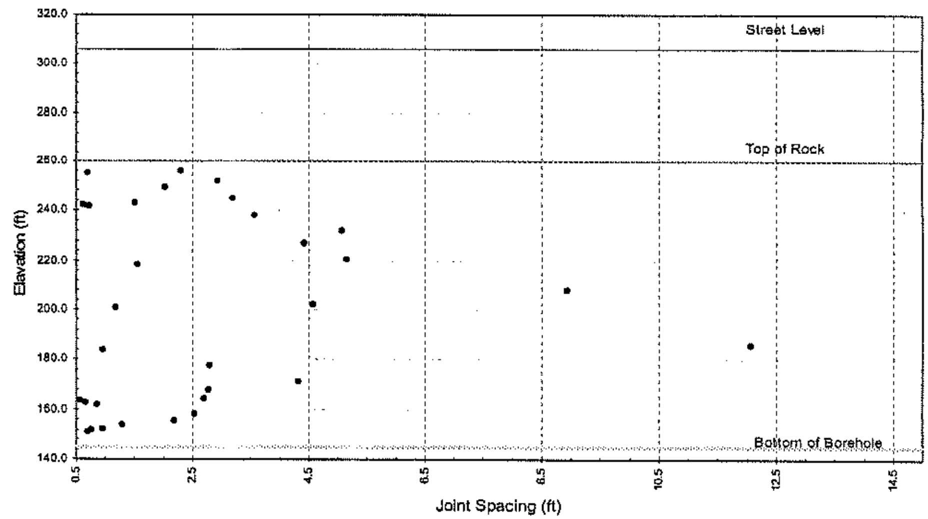
Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
46.95	30			259.1
47.3	30	0.3	0.3	258.7
50.1	40	2.8	2.3	255.9
50.9	20	0.8	0.7	255.1
54.3	40	3.4	2.9	251.7
54.5	30	0.2	0.2	251.5
56.9	35	2.4	2.0	249.1
57.4	30	0.5	0.4	248.6
57.5	30	0.1	0.1	248.5
58	25	0.5	0.4	248.0
61.6	30	3.6	3.2	244.4
63.3	25	1.7	1.5	242.7
64	30	0.7	0.6	242.0
64.8	20	0.8	0.7	241.2
68.5	10	3.7	3.6	237.5
74.1	40	5.6	5.1	231.9
79.5	30	5.4	4.4	226.5
85.8	40	6.3	5.2	220.2
87.7	30	1.9	1.6	218.3
98.6	40	10.9	8.9	207.4
104.2	30	5.6	4.6	201.8
105.6	35	1.4	1.2	200.4
106	20	0.4	0.4	200.0
106.1	25	0.1	0.1	199.9
120.4	40	14.3	12.1	185.6
122.3	60	1.9	0.9	183.7
128.9	50	6.6	2.8	177.1
129.4	40	0.5	0.4	176.6
129.6	35	0.2	0.2	176.4
130	25	0.4	0.3	176.0
135	35	5.0	4.3	171.0
138.5	40	3.5	2.8	167.5
141.9	35	3.4	2.7	164.1
142.6	40	0.7	0.6	163.4
143.4	30	0.8	0.7	162.6
144.4	30	1.0	0.9	161.6
144.5	50	0.1	0.1	161.5
144.8	40	0.3	0.2	161.2
144.9	35	0.1	0.1	161.1
145	40	0.1	0.1	161.0
145.4	30	0.4	0.3	160.6
145.5	30	0.1	0.1	160.5
148.3	20	2.8	2.5	157.7
150.7	30	2.4	2.2	155.3
151.2	25	0.5	0.4	154.8
152.6	20	1.4	1.3	153.4
153	20	0.4	0.4	153.0
154	15	1.0	1.0	152.0
154.8	20	0.8	0.8	151.2
155.6	40	0.8	0.7	150.4

Ground EL. (ft)	306
Top of Rock (ft)	260
Bottom of Hole (ft)	145

BIN	Freq.	Freq. (%)
0.4	(Clustering Margin)	
0.9	12	33
1.4	6	17
1.9	2	6
2.4	3	8
2.9	4	11
3.4	2	6
3.9	1	3
4.4	1	3
4.9	2	6
5.4	2	6
5.9	0	0
6.4	0	0
6.9	0	0
7.4	0	0
7.9	0	0
8.4	0	0
8.9	0	0
9.4	1	3
9.9	0	0
10.4	0	0
10.9	0	0
11.4	0	0
11.9	0	0
12.4	1	3
12.9	0	0
13.4	0	0
13.9	0	0
14.4	0	0
14.9	0	0
SUM	36	100

MA-306, Joint Set 1





FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

APPENDIX A-2
SHEET 13

MA-306, Joint Set 1 Data Continued				
156	20	0.4	0.3	150.0
156.3	5	0.3	0.3	149.7
157.7	30	1.4	1.3	148.3
157.8	25	0.1	0.1	148.2
159.3	30	1.5	1.3	146.7
159.5	35	0.2	0.2	146.5
160.1	30	0.6	0.5	145.9
160.4	25	0.3	0.3	145.6

FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

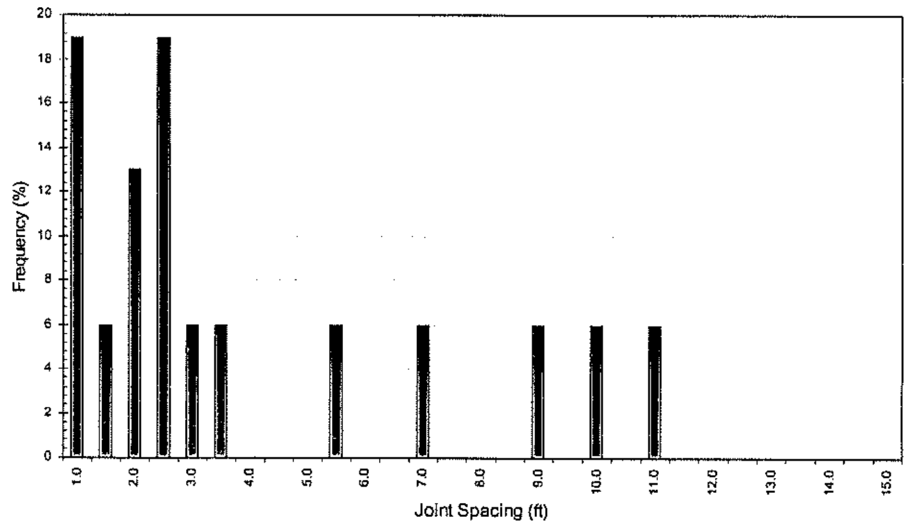
MA-312
Joint Set 1

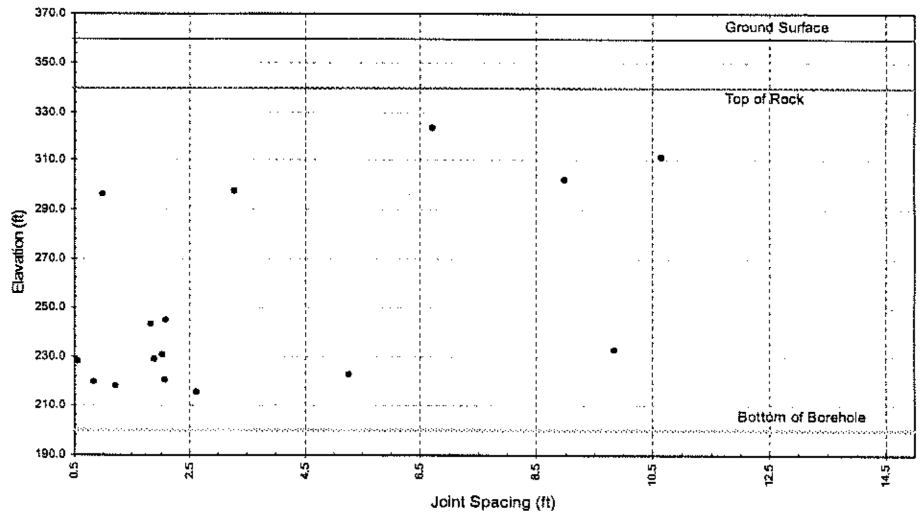
Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
26.1	20	0.0	0.0	333.9
26.5	40	0.4	0.4	333.5
27	45	0.5	0.4	333.0
36.5	30	9.5	6.7	323.5
48.8	15	12.3	10.7	311.2
58.1	30	9.3	9.0	301.9
58.5	35	0.4	0.3	301.5
62.5	40	4.0	3.3	297.5
62.6	55	0.1	0.1	297.4
62.9	20	0.3	0.2	297.1
63.95	15	1.1	1.0	296.1
113.3	25	49.4		
115.6	15	2.3	2.1	244.4
117.5	10	1.9	1.8	242.5
127.5	15	10.0	9.8	232.5
129.6	5	2.1	2.0	230.4
131.5	20	1.9	1.9	228.5
132.1	20	0.6	0.6	227.9
137.7	20	5.6	5.3	222.3
139.9	20	2.2	2.1	220.1
140.8	30	0.9	0.8	219.2
142.2	25	1.4	1.2	217.8
145.1	15	2.9	2.6	214.9

Ground EL. (ft)	360
Top of Rock (ft)	340
Bottom of Hole (ft)	200

BIN	Freq.	Freq. (%)
0.5	(Clustering Margin)	
1.0	3	19
1.5	1	6
2.0	2	13
2.5	3	19
3.0	1	6
3.5	1	6
4.0	0	0
4.5	0	0
5.0	0	0
5.5	1	6
6.0	0	0
6.5	0	0
7.0	1	6
7.5	0	0
8.0	0	0
8.5	0	0
9.0	1	6
9.5	0	0
10.0	1	6
10.5	0	0
11.0	1	6
11.5	0	0
12.0	0	0
12.5	0	0
13.0	0	0
13.5	0	0
14.0	0	0
14.5	0	0
15.0	0	0
SUM	16	100

MA-312, Joint Set 1





FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

APPENDIX A-2
SHEET 15

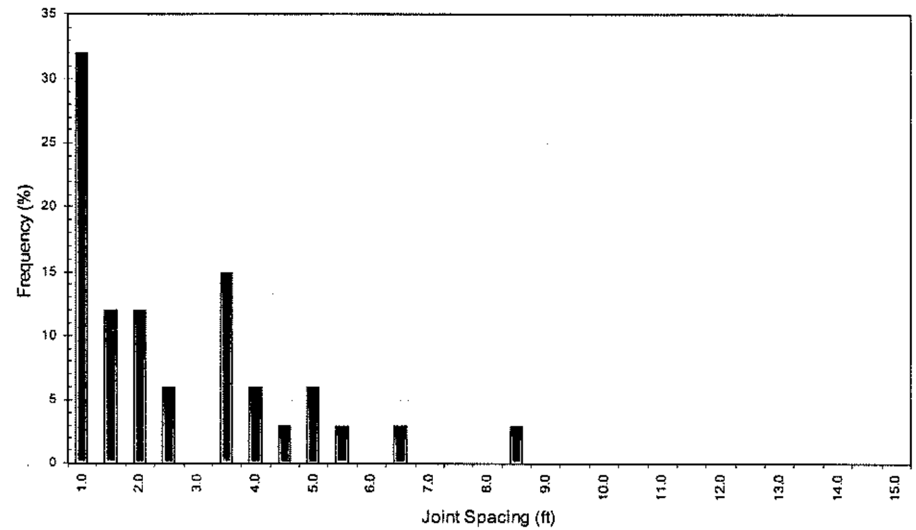
MA-313
Joint Set 1

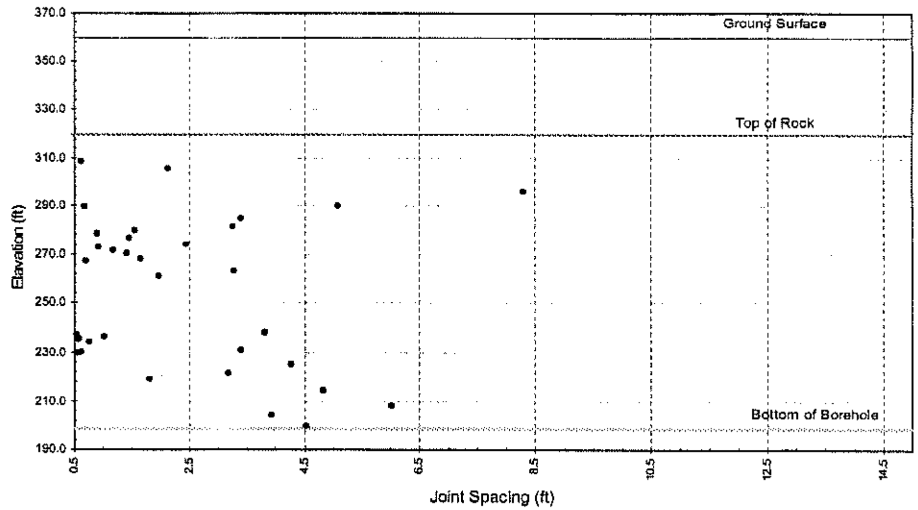
Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
51.25	20	0.0	0.0	308.8
51.9	30	0.6	0.6	308.1
52.4	15	0.5	0.4	307.6
54.6	45	2.2	2.1	305.4
54.8	35	0.2	0.1	305.2
55.25	25	0.5	0.4	304.8
64.4	35	9.2	8.3	295.6
64.7	25	0.3	0.2	295.3
70.3	15	5.6	5.1	289.7
71	25	0.7	0.7	289.0
71.35	35	0.3	0.3	288.7
75.5	10	4.2	3.4	284.5
78.8	30	3.3	3.2	281.2
80.6	20	1.8	1.6	279.4
81	25	0.4	0.4	279.0
82	25	1.0	0.9	278.0
83.6	25	1.6	1.5	276.4
86.3	15	2.7	2.4	273.7
87.25	20	1.0	0.9	272.8
88.5	20	1.3	1.2	271.5
90	40	1.5	1.4	270.0
92.15	20	2.2	1.6	267.9
92.9	35	0.8	0.7	267.1
93	35	0.1	0.1	267.0
97	35	4.0	3.3	263.0
99.4	30	2.4	2.0	260.6
99.9	30	0.5	0.4	260.1
118.35	15	18.5	16.0	241.7
122.3	10	4.0	3.8	237.7
122.85	15	0.5	0.5	237.2
123.9	15	1.1	1.0	236.1
124.5	20	0.6	0.6	235.5
125.1	20	0.6	0.6	234.9
125.9	10	0.8	0.8	234.1
129.35	20	3.4	3.4	230.7
130	20	0.7	0.6	230.0
130.6	25	0.6	0.6	229.4
135.3	25	4.7	4.3	224.7
138.8	35	3.5	3.2	221.2
141.01	10	2.2	1.8	219.0
145.9	10	4.9	4.8	214.1
152	10	6.1	6.0	208.0
156	10	4.0	3.9	204.0
160.6	15	4.6	4.5	199.4

Ground EL. (ft)	360
Top of Rock (ft)	320
Bottom of Hole (ft)	199

BIN	Freq.	Freq. (%)
0.5	(Clustering Margin)	
1.0	11	32
1.5	4	12
2.0	4	12
2.5	2	6
3.0	0	0
3.5	5	15
4.0	2	6
4.5	1	3
5.0	2	6
5.5	1	3
6.0	0	0
6.5	1	3
7.0	0	0
7.5	0	0
8.0	0	0
8.5	1	3
9.0	0	0
9.5	0	0
10.0	0	0
10.5	0	0
11.0	0	0
11.5	0	0
12.0	0	0
12.5	0	0
13.0	0	0
13.5	0	0
14.0	0	0
14.5	0	0
15.0	0	0
SUM	34	100

MA-313, Joint Set 1





FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

APPENDIX A-2
SHEET 16

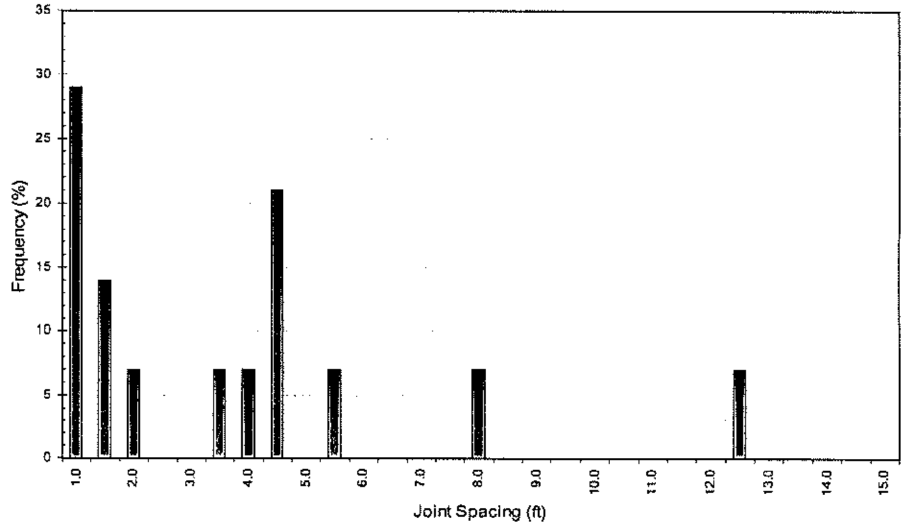
MA-314
Joint Set 1

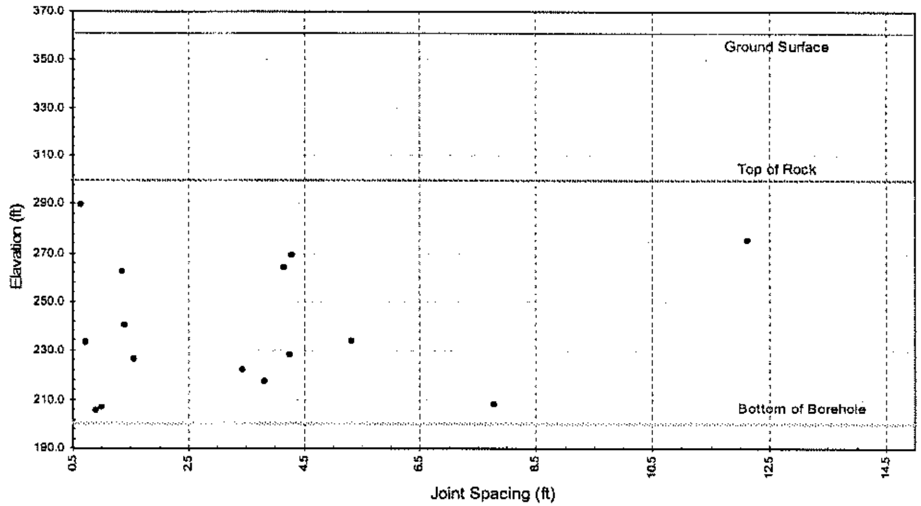
Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
70.8	25	0.0	0.0	289.9
71.5	20	0.7	0.6	289.2
72	30	0.5	0.5	288.7
86	40	14.0	12.1	274.7
91.6	30	5.6	4.3	269.1
92.1	30	0.5	0.4	268.6
96.9	25	4.8	4.2	263.8
98.4	30	1.5	1.4	262.3
119	35	20.6	17.8	241.7
120.7	35	1.7	1.4	240.0
127.2	25	6.5	5.3	233.5
128	30	0.8	0.7	232.7
132.9	30	4.9	4.2	227.8
134.7	30	1.8	1.6	226.0
135.2	25	0.5	0.4	225.5
139	30	3.8	3.4	221.7
143.4	35	4.4	3.8	217.3
152.9	45	9.5	7.8	207.8
154.3	35	1.4	1.0	206.4
155.4	65	1.1	0.9	205.3

Ground EL. (ft)	360.7
Top of Rock (ft)	300
Bottom of Hole (ft)	200.7

BIN	Freq.	Freq. (%)
0.5	(Clustering Margin)	
1.0	4	29
1.5	2	14
2.0	1	7
2.5	0	0
3.0	0	0
3.5	1	7
4.0	1	7
4.5	3	21
5.0	0	0
5.5	1	7
6.0	0	0
6.5	0	0
7.0	0	0
7.5	0	0
8.0	1	7
8.5	0	0
9.0	0	0
9.5	0	0
10.0	0	0
10.5	0	0
11.0	0	0
11.5	0	0
12.0	0	0
12.5	1	7
13.0	0	0
13.5	0	0
14.0	0	0
14.5	0	0
15.0	0	0
SUM	14	100

MA-314, Joint Set 1





FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

APPENDIX A-2
SHEET 17

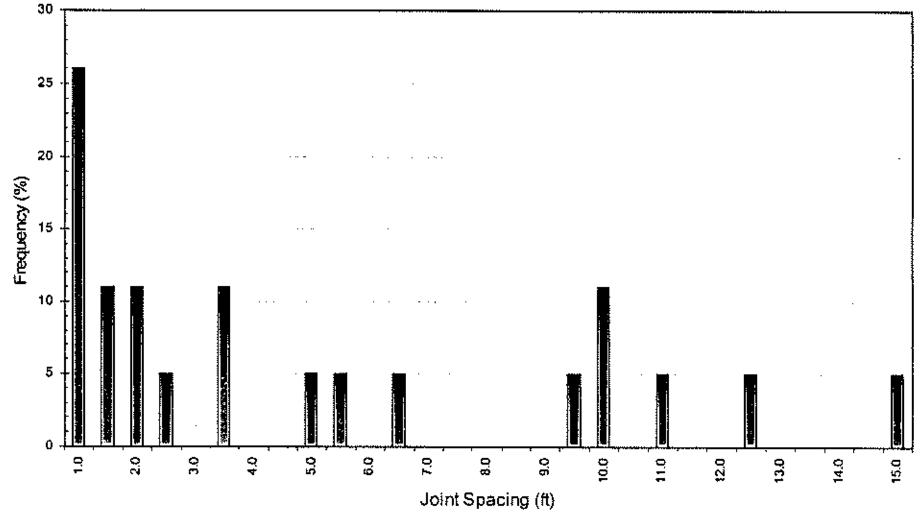
MA-318w
Joint Set 1

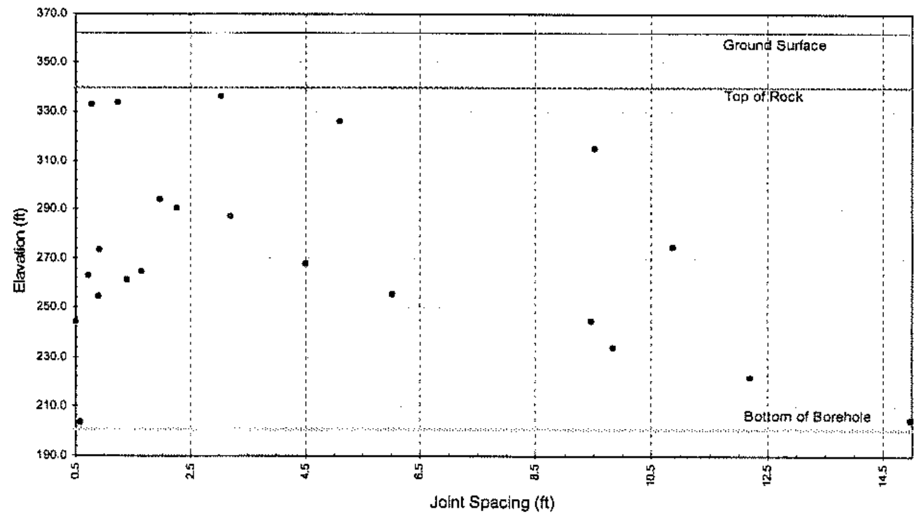
Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
21.3	30	0.0	0.0	340.7
21.7	40	0.4	0.3	340.3
21.8	35	0.1	0.1	340.2
22	35	0.2	0.2	340.0
22.2	30	0.2	0.2	339.8
22.4	30	0.2	0.2	339.6
22.5	30	0.1	0.1	339.5
26	40	3.5	3.0	336.0
26.4	45	0.4	0.3	335.6
26.6	35	0.2	0.1	335.4
26.8	35	0.2	0.2	335.2
28.3	30	1.5	1.2	333.7
29.2	20	0.9	0.8	332.8
29.5	30	0.3	0.3	332.5
29.9	30	0.4	0.3	332.1
30.2	30	0.3	0.3	331.8
36.1	30	5.9	5.1	325.9
47.1	30	11.0	9.5	314.9
66.2	10	19.1	16.5	295.8
66.3	35	0.1	0.1	295.7
68.7	45	2.4	2.0	293.3
71.9	30	3.2	2.3	290.1
75.6	25	3.7	3.2	286.4
87.6	45	12.0	10.9	274.4
88.9	35	1.3	0.9	273.1
94.4	60	5.5	4.5	267.6
97.7	65	3.3	1.7	264.3
99.4	35	1.7	0.7	262.6
101.1	10	1.7	1.4	260.9
107.2	5	6.1	6.0	254.8
108.1	15	0.9	0.9	253.9
117.9	10	9.8	9.5	244.1
118.4	10	0.5	0.5	243.6
128.4	10	10.0	9.8	233.6
140.8	30	12.4	12.2	221.2
158.1	15	17.3	15.0	203.9
158.7	25	0.6	0.6	203.3

Ground EL. (ft)	362
Top of Rock (ft)	340
Bottom of Hole (ft)	201.2

BIN	Freq.	Freq. (%)
0.5	(Clustering Margin)	
1.0	5	26
1.5	2	11
2.0	2	11
2.5	1	5
3.0	0	0
3.5	2	11
4.0	0	0
4.5	0	0
5.0	1	5
5.5	1	5
6.0	0	0
6.5	1	5
7.0	0	0
7.5	0	0
8.0	0	0
8.5	0	0
9.0	0	0
9.5	1	5
10.0	2	11
10.5	0	0
11.0	1	5
11.5	0	0
12.0	0	0
12.5	1	5
13.0	0	0
13.5	0	0
14.0	0	0
14.5	0	0
15.0	1	5
SUM	19	100

MA-318w, Joint Set 1





FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

APPENDIX A-2
SHEET 18

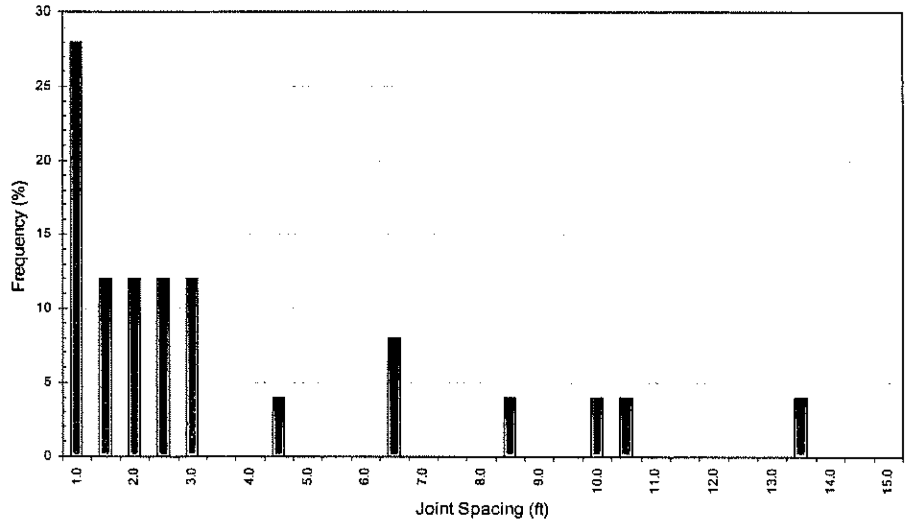
MA-320
Joint Set 1

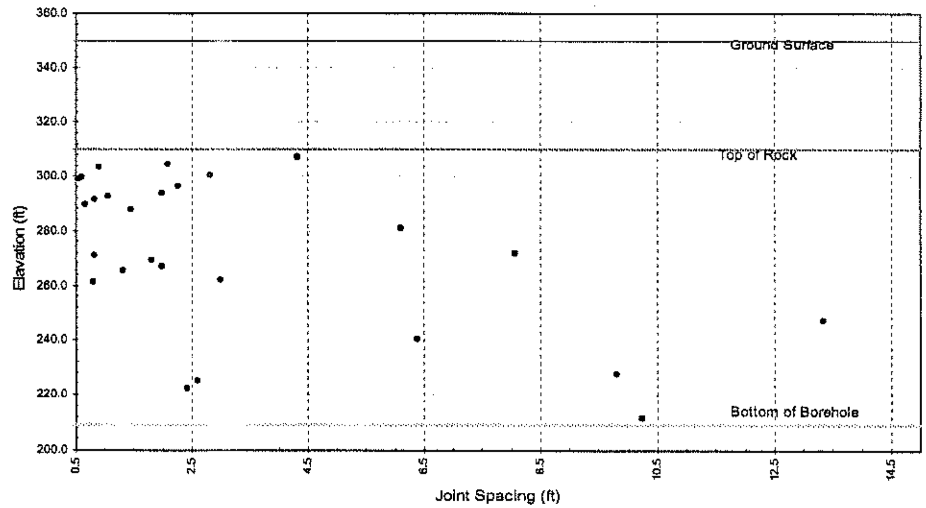
Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
37.8	40	0.0	0.0	312.2
37.9	30	0.1	0.1	312.1
42.9	35	5.0	4.3	307.1
43.3	30	0.4	0.3	306.7
43.6	25	0.3	0.3	306.4
45.9	35	2.3	2.1	304.1
47	20	1.1	0.9	303.0
50	30	3.0	2.8	300.0
50.7	30	0.7	0.6	299.3
50.9	25	0.2	0.2	299.1
51.5	25	0.6	0.5	298.5
54	25	2.5	2.3	296.0
54.3	25	0.3	0.3	295.7
56.5	15	2.2	2.0	293.5
57.6	20	1.1	1.1	292.4
57.65	20	0.0	0.0	292.4
58	25	0.4	0.3	292.0
58.9	20	0.9	0.8	291.1
59.3	15	0.4	0.4	290.7
59.8	20	0.5	0.5	290.2
60.2	20	0.4	0.4	289.8
60.9	20	0.7	0.7	289.1
61.1	25	0.2	0.2	288.9
62.7	25	1.6	1.5	287.3
62.8	20	0.1	0.1	287.2
62.9	20	0.1	0.1	287.1
69.4	25	6.5	6.1	280.6
78.3	25	8.9	8.1	271.7
79.2	25	0.9	0.8	270.8
81.2	25	2.0	1.8	268.8
83.4	20	2.2	2.0	266.6
84.8	25	1.4	1.3	265.2
88.1	5	3.3	3.0	261.9
88.9	25	0.8	0.8	261.1
89.4	15	0.5	0.5	260.6
103.2	20	13.8	13.3	246.8
110	40	6.8	6.4	240.0
122.8	15	12.8	9.8	227.2
125.5	15	2.7	2.6	224.5
128	15	2.5	2.4	222.0
138.6	10	10.6	10.2	211.4

Ground EL. (ft)	350
Top of Rock (ft)	310
Bottom of Hole (ft)	209.5

BIN	Freq.	Freq. (%)
0.5	(Clustering Margin)	
1.0	7	28
1.5	3	12
2.0	3	12
2.5	3	12
3.0	3	12
3.5	0	0
4.0	0	0
4.5	1	4
5.0	0	0
5.5	0	0
6.0	0	0
6.5	2	8
7.0	0	0
7.5	0	0
8.0	0	0
8.5	1	4
9.0	0	0
9.5	0	0
10.0	1	4
10.5	1	4
11.0	0	0
11.5	0	0
12.0	0	0
12.5	0	0
13.0	0	0
13.5	1	4
14.0	0	0
14.5	0	0
15.0	0	0
SUM	25	100

MA-320, Joint Set 1





FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

APPENDIX A-2
SHEET 19

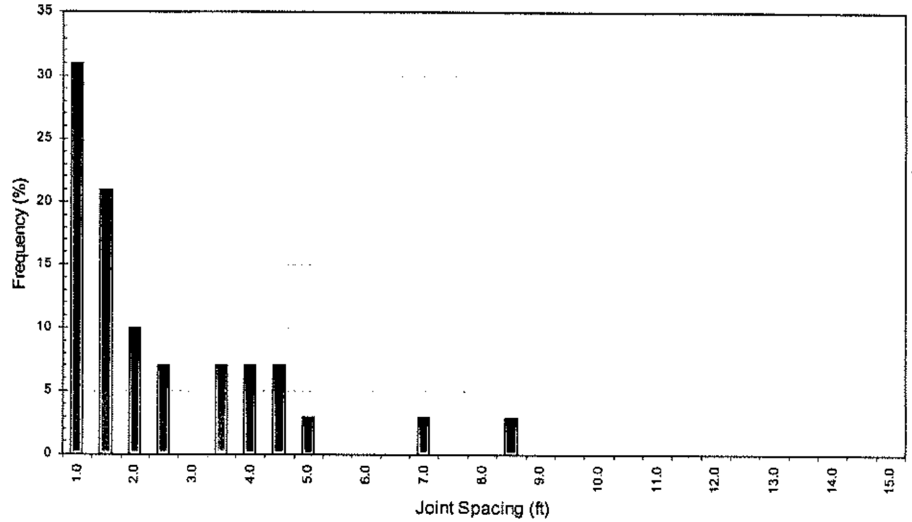
MA-321w
Joint Set 1

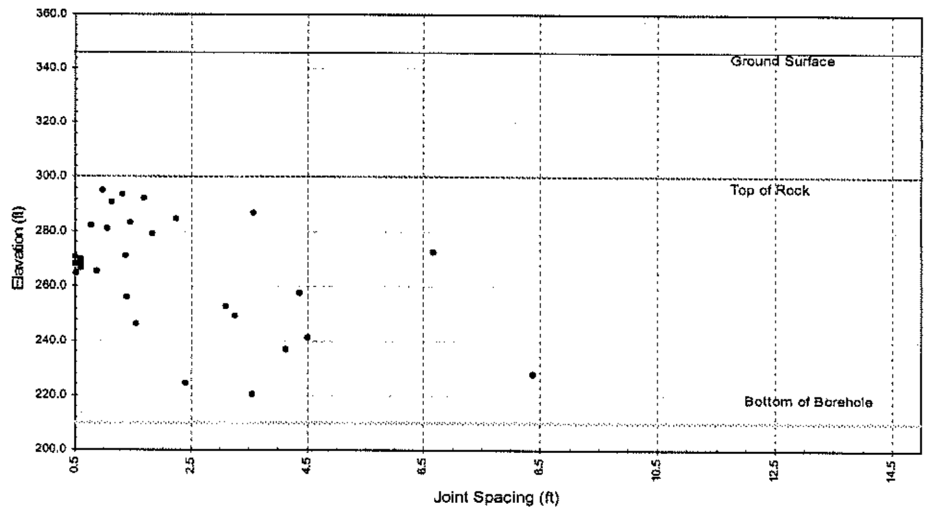
Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
49.9	35	0.0	0.0	296.1
51.1	20	1.2	1.0	294.9
52.5	20	1.4	1.3	293.5
54.3	20	1.8	1.7	291.7
55.5	20	1.2	1.1	290.5
59.3	20	3.8	3.6	286.7
61.7	15	2.4	2.3	284.3
63.2	15	1.5	1.4	282.8
63.4	15	0.2	0.2	282.6
64.2	15	0.8	0.8	281.8
65.3	15	1.1	1.1	280.7
67.2	15	1.9	1.8	278.8
74.1	10	6.9	6.7	271.9
75.5	5	1.4	1.4	270.5
76	5	0.5	0.5	270.0
76.6	5	0.6	0.6	269.4
76.8	10	0.2	0.2	269.2
77.4	10	0.6	0.6	268.6
78	10	0.6	0.6	268.0
78.5	5	0.5	0.5	267.5
79.1	5	0.6	0.6	266.9
79.3	5	0.2	0.2	266.7
79.7	5	0.4	0.4	266.3
80.3	10	0.6	0.6	265.7
81.2	10	0.9	0.9	264.8
81.5	30	0.3	0.3	264.5
82.1	50	0.6	0.5	263.9
88.9	5	6.8	4.4	257.1
90.3	20	1.4	1.4	255.7
93.6	10	3.3	3.1	252.4
96.9	30	3.3	3.2	249.1
97.4	50	0.5	0.4	248.6
98.1	30	0.7	0.4	247.9
99.9	30	1.8	1.6	246.1
105.1	20	5.2	4.5	240.9
109.5	20	4.4	4.1	236.5
110	10	0.5	0.5	236.0
118.5	45	8.5	8.4	227.5
121.9	30	3.4	2.4	224.1
126	10	4.1	3.6	220.0

Ground EL. (ft)	346
Top of Rock (ft)	300
Bottom of Hole (ft)	210

BIN	Freq.	Freq. (%)
0.5	(Clustering Margin)	
1.0	9	31
1.5	6	21
2.0	3	10
2.5	2	7
3.0	0	0
3.5	2	7
4.0	2	7
4.5	2	7
5.0	1	3
5.5	0	0
6.0	0	0
6.5	0	0
7.0	1	3
7.5	0	0
8.0	0	0
8.5	1	3
9.0	0	0
9.5	0	0
10.0	0	0
10.5	0	0
11.0	0	0
11.5	0	0
12.0	0	0
12.5	0	0
13.0	0	0
13.5	0	0
14.0	0	0
14.5	0	0
15.0	0	0
SUM	29	100

MA-321w, Joint Set 1





FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

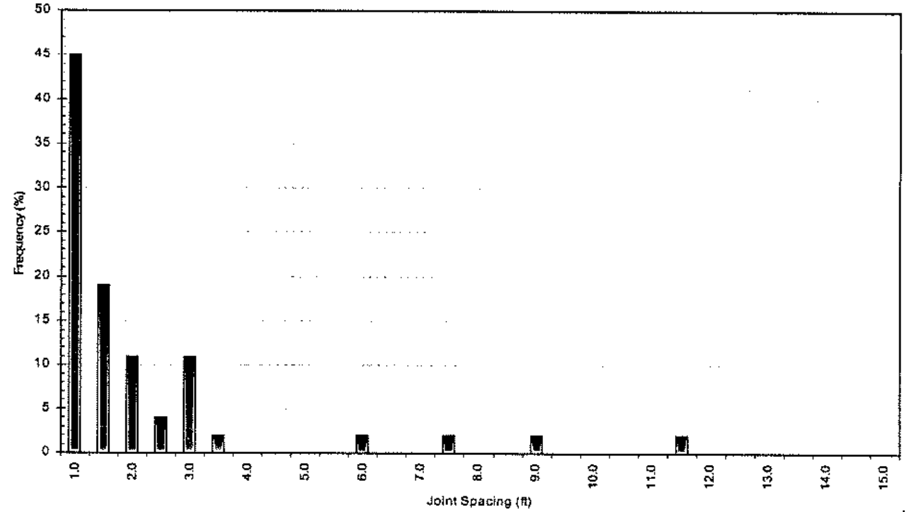
MA-322
Joint Set 1

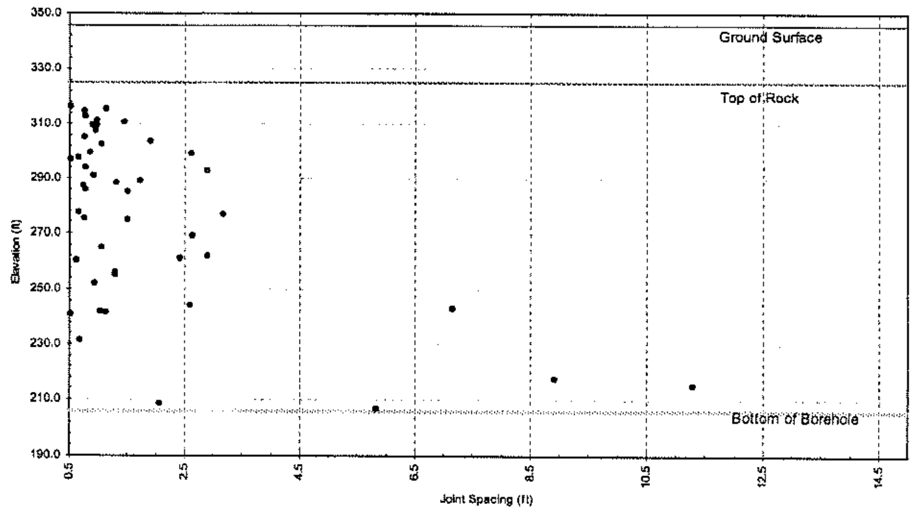
Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
28.3	30	0.0	0.0	317.7
28.9	20	0.6	0.5	317.1
30.1	20	1.2	1.1	315.9
30.9	15	0.8	0.8	315.1
31.4	15	0.5	0.5	314.6
32.2	15	0.8	0.8	313.8
33.2	15	1.0	1.0	312.8
34.7	15	1.5	1.4	311.3
35.7	10	1.0	1.0	310.3
36.6	30	0.9	0.9	309.4
36.9	30	0.3	0.3	309.1
38	20	1.1	1.0	308.0
38.8	30	0.8	0.8	307.2
41	45	2.2	1.9	305.0
42.5	30	1.5	1.1	303.5
43.5	25	1.0	0.9	302.5
46.4	25	2.9	2.6	299.6
46.8	20	0.4	0.4	299.2
47.5	55	0.7	0.7	298.5
48.4	30	0.9	0.5	297.6
49.3	15	0.9	0.8	296.7
52.3	25	3.0	2.9	293.7
53.3	35	1.0	0.9	292.7
55.4	40	2.1	1.7	290.6
57.1	35	1.7	1.3	288.9
58	30	0.9	0.7	288.0
58.9	20	0.9	0.8	287.1
60.5	35	1.6	1.5	285.5
61.3	65	0.8	0.7	284.7
68.8	20	7.5	3.2	277.2
69.6	20	0.8	0.8	276.4
71.2	25	1.6	1.5	274.8
71.6	25	0.4	0.4	274.4
72.1	30	0.5	0.5	273.9
72.6	25	0.5	0.4	273.4
73	25	0.4	0.4	273.0
73.3	20	0.3	0.3	272.7
73.4	20	0.1	0.1	272.6
76.2	15	2.8	2.6	269.8
77.3	45	1.1	1.1	268.7
81.4	30	4.1	2.9	264.6
84.2	40	2.8	2.4	261.8
85	60	0.8	0.6	261.0
85.9	60	0.9	0.5	260.1
88.5	30	2.6	1.3	257.5
90	20	1.5	1.3	256.0
91	30	1.0	0.9	255.0
94	25	3.0	2.6	252.0
101.9	20	7.9	7.2	244.1

Ground EL. (ft)	346
Top of Rock (ft)	325
Bottom of Hole (ft)	206

BIN	Freq.	Freq. (%)
0.5	(Clustering Margin)	
1.0	21	45
1.5	9	19
2.0	5	11
2.5	2	4
3.0	5	11
3.5	1	2
4.0	0	0
4.5	0	0
5.0	0	0
5.5	0	0
6.0	1	2
6.5	0	0
7.0	0	0
7.5	1	2
8.0	0	0
8.5	0	0
9.0	1	2
9.5	0	0
10.0	0	0
10.5	0	0
11.0	0	0
11.5	1	2
12.0	0	0
12.5	0	0
13.0	0	0
13.5	0	0
14.0	0	0
14.5	0	0
15.0	0	0
SUM	47	100

MA-322, Joint Set 1





FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

APPENDIX A-2
SHEET 21

MA-322, Joint Set 1 Data Continued				
103	20	1.1	1.0	243.0
104.2	30	1.2	1.1	241.8
104.8	15	0.6	0.5	241.2
105.5	20	0.7	0.7	240.5
115	35	9.5	8.9	231.0
128.8	40	13.8	11.3	217.2
131.5	20	2.7	2.1	214.5
137.7	20	6.2	5.8	208.3
139.6	40	1.9	1.8	206.4

FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

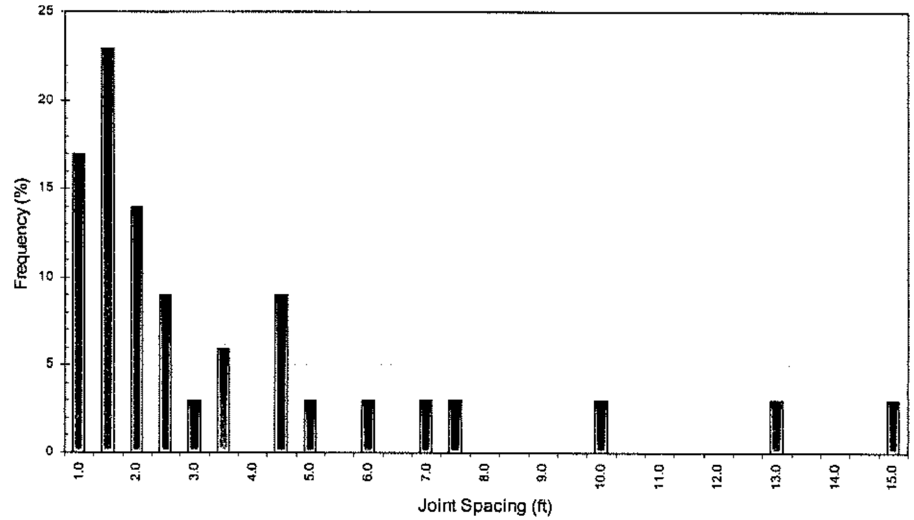
MA-325w
Joint Set 1

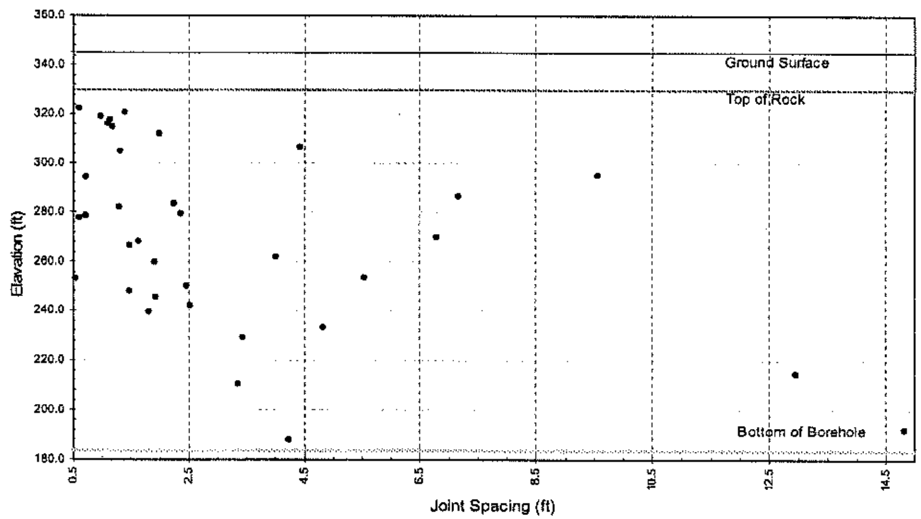
Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
21.8	30	0.0	0.0	323.2
22	30	0.2	0.2	323.0
22.7	35	0.7	0.6	322.3
24.4	35	1.7	1.4	320.6
24.9	35	0.5	0.4	320.1
26.1	30	1.2	1.0	318.9
27.4	35	1.3	1.1	317.6
27.8	30	0.4	0.3	317.2
27.9	25	0.1	0.1	317.1
29.1	25	1.2	1.1	315.9
30.4	40	1.3	1.2	314.6
33	35	2.6	2.0	312.0
38.4	35	5.4	4.4	306.6
40	30	1.6	1.3	305.0
40.5	15	0.5	0.4	304.5
50.4	25	9.9	9.6	294.6
51.2	25	0.8	0.7	293.8
59.1	30	7.9	7.2	285.9
59.3	30	0.2	0.2	285.7
61.9	30	2.6	2.3	283.1
63.4	25	1.5	1.3	281.6
66	25	2.6	2.4	279.0
66.8	30	0.8	0.7	278.2
67.5	25	0.7	0.6	277.5
75	25	7.5	6.8	270.0
76.8	30	1.8	1.6	268.2
78.5	35	1.7	1.5	266.5
83.4	25	4.9	4.0	261.6
85.5	25	2.1	1.9	259.5
91.6	30	6.1	5.5	253.4
91.7	25	0.1	0.1	253.3
92.3	35	0.6	0.5	252.7
95.3	25	3.0	2.5	249.7
95.511	35	0.2	0.2	249.5
97.3	35	1.8	1.5	247.7
99.65	35	2.4	1.9	245.4
99.7	40	0.0	0.0	245.3
103	30	3.3	2.5	242.0
103.1	30	0.1	0.1	241.9
103.6	35	0.5	0.4	241.4
105.8	35	2.2	1.8	239.2
106	35	0.2	0.2	239.0
111.9	35	5.9	4.8	233.1
116.1	20	4.2	3.4	228.9
116.5	25	0.4	0.4	228.5
130.8	35	14.3	13.0	214.2
134.9	35	4.1	3.4	210.1
153	20	18.1	14.8	192.0
157.5	15	4.5	4.2	187.5

Ground EL. (ft)	345
Top of Rock (ft)	330
Bottom of Hole (ft)	184

BIN	Freq.	Freq. (%)
0.5	(Clustering Margin)	
1.0	6	17
1.5	8	23
2.0	5	14
2.5	3	9
3.0	1	3
3.5	2	6
4.0	0	0
4.5	3	9
5.0	1	3
5.5	0	0
6.0	1	3
6.5	0	0
7.0	1	3
7.5	1	3
8.0	0	0
8.5	0	0
9.0	0	0
9.5	0	0
10.0	1	3
10.5	0	0
11.0	0	0
11.5	0	0
12.0	0	0
12.5	0	0
13.0	1	3
13.5	0	0
14.0	0	0
14.5	0	0
15.0	1	3
SUM	35	100

MA-325w, Joint Set 1





FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

APPENDIX A-2
SHEET 23

MD-7

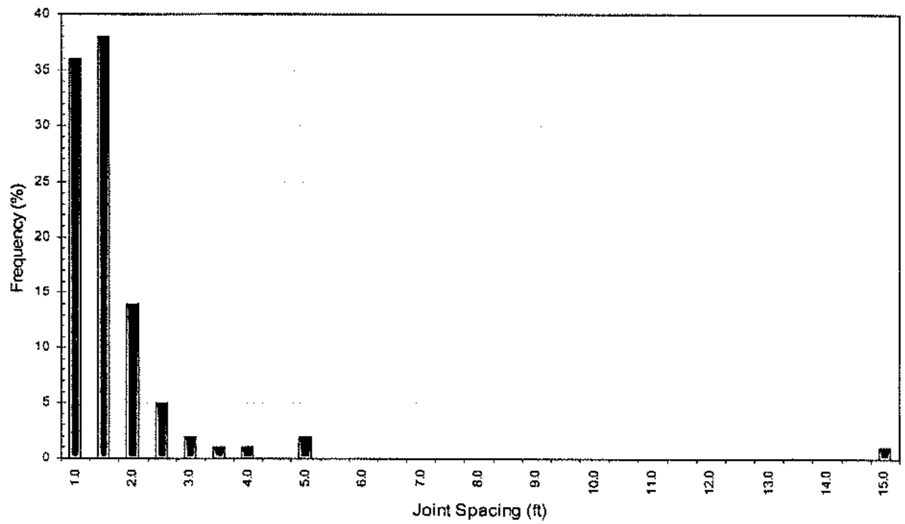
Joint Set 1

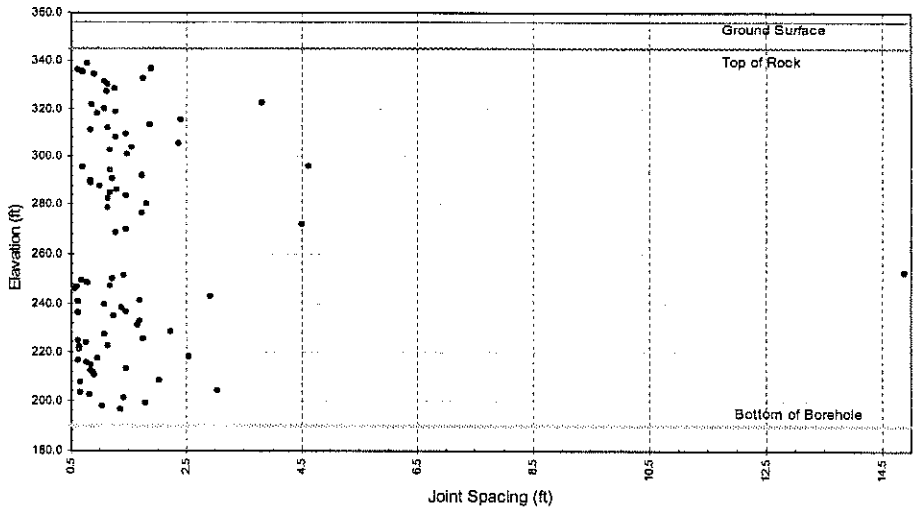
Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
16.6	15	0.0	0.0	339.6
17.4	15	0.8	0.8	338.8
19.4	20	2.0	1.9	336.9
20.0	20	0.6	0.6	336.2
20.8	20	0.8	0.7	335.5
21.7	20	0.9	0.9	334.5
23.6	30	1.9	1.7	332.7
24.8	30	1.3	1.1	331.4
26.1	30	1.3	1.1	330.1
27.6	40	1.5	1.3	328.7
29.0	30	1.5	1.1	327.2
33.4	45	4.4	3.8	322.8
34.6	35	1.2	0.8	321.6
35.9	25	1.3	1.1	320.3
37.3	25	1.4	1.3	318.9
38.4	20	1.1	1.0	317.9
40.9	30	2.6	2.4	315.3
43.1	25	2.2	1.9	313.2
44.3	20	1.3	1.1	311.9
45.2	20	0.9	0.8	311.0
46.8	20	1.6	1.5	309.5
48.1	10	1.4	1.3	308.1
50.5	30	2.4	2.4	305.7
52.3	10	1.8	1.6	303.9
53.5	10	1.2	1.2	302.7
55.0	25	1.5	1.5	301.2
60.1	30	5.1	4.6	296.1
60.9	25	0.8	0.7	295.3
62.2	30	1.3	1.2	294.0
64.2	20	2.0	1.7	292.0
65.5	20	1.3	1.2	290.7
66.4	20	0.9	0.8	289.8
67.3	25	0.9	0.8	288.9
68.4	30	1.1	1.0	287.8
69.9	30	1.5	1.3	286.3
71.3	20	1.3	1.2	285.0
72.8	25	1.6	1.5	283.4
74.1	25	1.3	1.1	282.2
76.1	50	2.0	1.8	280.2
77.8	35	1.8	1.1	278.4
79.9	20	2.1	1.7	276.3
84.7	45	4.8	4.5	271.5
86.8	20	2.1	1.4	269.5
88.1	15	1.3	1.3	268.1
103.5	20	15.4	14.9	252.7
105.0	20	1.5	1.4	251.2
106.3	15	1.3	1.2	249.9
107.0	15	0.7	0.7	249.2

Ground EL. (ft)	356.2
Top of Rock (ft)	345
Bottom of Hole (ft)	190

BIN	Freq.	Freq. (%)
0.5	(Clustering Margin)	
1.0	31	36
1.5	33	38
2.0	12	14
2.5	4	5
3.0	2	2
3.5	1	1
4.0	1	1
4.5	0	0
5.0	2	2
5.5	0	0
6.0	0	0
6.5	0	0
7.0	0	0
7.5	0	0
8.0	0	0
8.5	0	0
9.0	0	0
9.5	0	0
10.0	0	0
10.5	0	0
11.0	0	0
11.5	0	0
12.0	0	0
12.5	0	0
13.0	0	0
13.5	0	0
14.0	0	0
14.5	0	0
15.0	1	1
SUM	86	100

MD-7, Joint Set 1





FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

APPENDIX A-2
SHEET 24

MD-7, Joint Set 1 Data continued				
107.0	15	0.7	0.7	249.2
107.8	10	0.8	0.8	248.4
109.0	10	1.2	1.2	247.2
109.6	20	0.6	0.8	246.6
110.2	20	0.6	0.6	246.0
113.3	15	3.1	2.9	242.9
115.1	15	1.8	1.7	241.2
115.7	10	0.7	0.6	240.5
116.8	10	1.1	1.1	239.4
118.2	15	1.4	1.4	238.0
119.7	15	1.5	1.4	236.5
120.4	10	0.6	0.6	235.9
121.6	15	1.3	1.2	234.6
123.4	20	1.8	1.7	232.9
125.1	20	1.8	1.6	231.1
125.5	15	0.4	0.3	230.8
127.8	20	2.3	2.2	228.5
128.9	15	1.2	1.1	227.3
130.7	40	1.8	1.7	225.5

FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

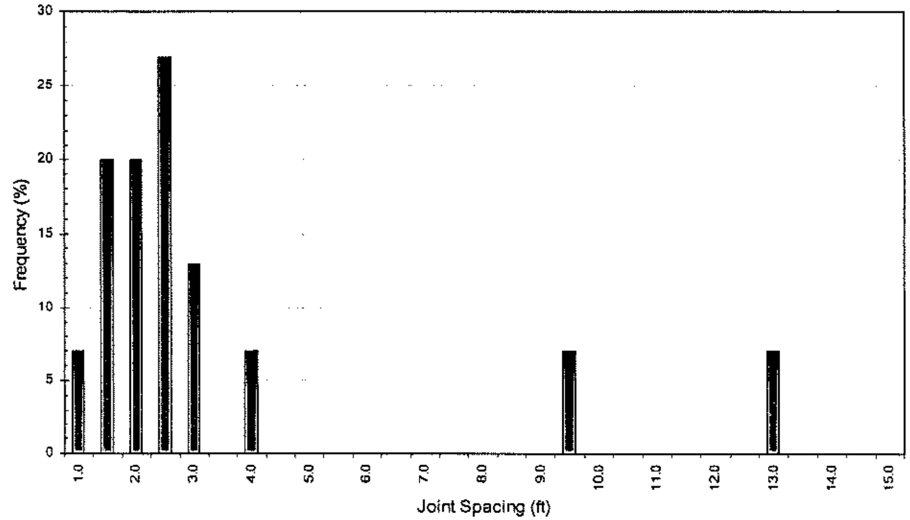
MG-201
Joint Set 1

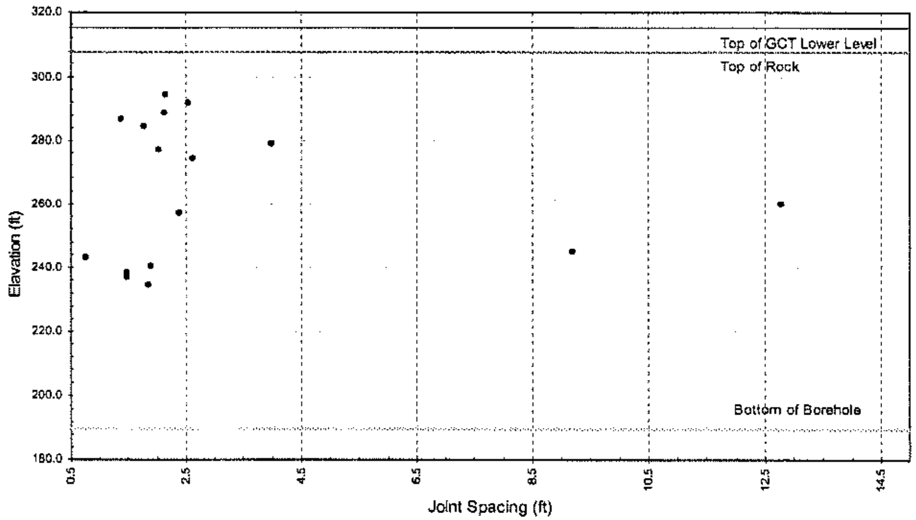
Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
17.8	40	0.0	0.0	297.1
20.6	20	2.8	2.1	294.3
23.3	35	2.7	2.5	291.6
23.75	30	0.4	0.4	291.2
26.2	50	2.5	2.1	288.7
26.4	40	0.2	0.1	288.5
28.2	40	1.8	1.4	286.7
28.71	20	0.5	0.4	286.2
30.6	40	1.9	1.8	284.3
35.8	15	5.2	4.0	279.1
37.9	25	2.1	2.0	277.0
40.8	25	2.9	2.6	274.1
54.9	40	14.1	12.8	260.0
58	40	3.1	2.4	256.9
70	45	12.0	9.2	244.9
70.2	45	0.2	0.1	244.7
70.8	40	0.6	0.4	244.1
71.8	25	1.0	0.8	243.1
72.2	35	0.4	0.4	242.7
74.5	35	2.3	1.9	240.4
76.3	35	1.8	1.5	238.6
78.1	40	1.8	1.5	236.8
80.5	30	2.4	1.8	234.4

Ground EL. (ft)	314.9
Top of Rock (ft)	307.9
Bottom of Hole (ft)	189.9

BIN	Freq.	Freq. (%)
0.5	(Clustering Margin)	
1.0	1	7
1.5	3	20
2.0	3	20
2.5	4	27
3.0	2	13
3.5	0	0
4.0	1	7
4.5	0	0
5.0	0	0
5.5	0	0
6.0	0	0
6.5	0	0
7.0	0	0
7.5	0	0
8.0	0	0
8.5	0	0
9.0	0	0
9.5	1	7
10.0	0	0
10.5	0	0
11.0	0	0
11.5	0	0
12.0	0	0
12.5	0	0
13.0	1	7
13.5	0	0
14.0	0	0
14.5	0	0
15.0	0	0
SUM	15	100

MG-201, Joint Set 1





FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

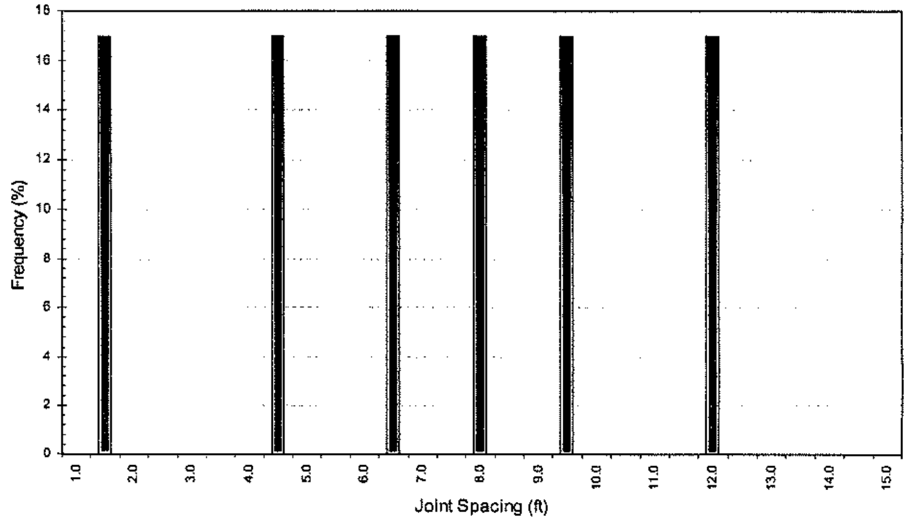
MG-202
Joint Set 1

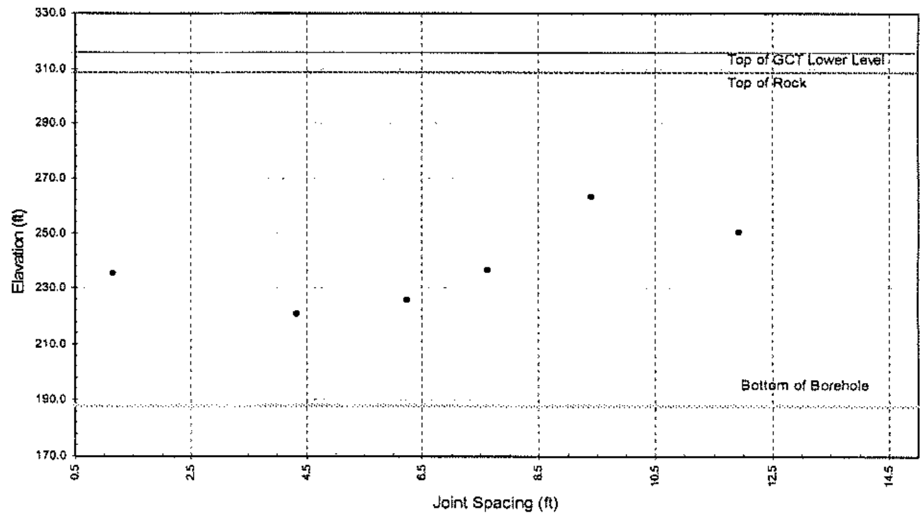
Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
39.7	45	0.0	0.0	276.4
53	20	13.3	9.4	263.1
65.7	35	12.7	11.9	250.4
65.9	40	0.2	0.2	250.2
66.3	55	0.4	0.3	249.8
79.6	35	13.3	7.6	236.5
81	50	1.4	1.1	235.1
90.7	30	9.7	6.2	225.4
95.7	35	5.0	4.3	220.4

Ground EL. (ft)	316.1
Top of Rock (ft)	309
Bottom of Hole (ft)	188.1

BIN	Freq.	Freq. (%)
0.5	(Clustering Margin)	
1.0	0	0
1.5	1	17
2.0	0	0
2.5	0	0
3.0	0	0
3.5	0	0
4.0	0	0
4.5	1	17
5.0	0	0
5.5	0	0
6.0	0	0
6.5	1	17
7.0	0	0
7.5	0	0
8.0	1	17
8.5	0	0
9.0	0	0
9.5	1	17
10.0	0	0
10.5	0	0
11.0	0	0
11.5	0	0
12.0	1	17
12.5	0	0
13.0	0	0
13.5	0	0
14.0	0	0
14.5	0	0
15.0	0	0
SUM	6	100

MG-202, Joint Set 1





FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

APPENDIX A-2
SHEET 27

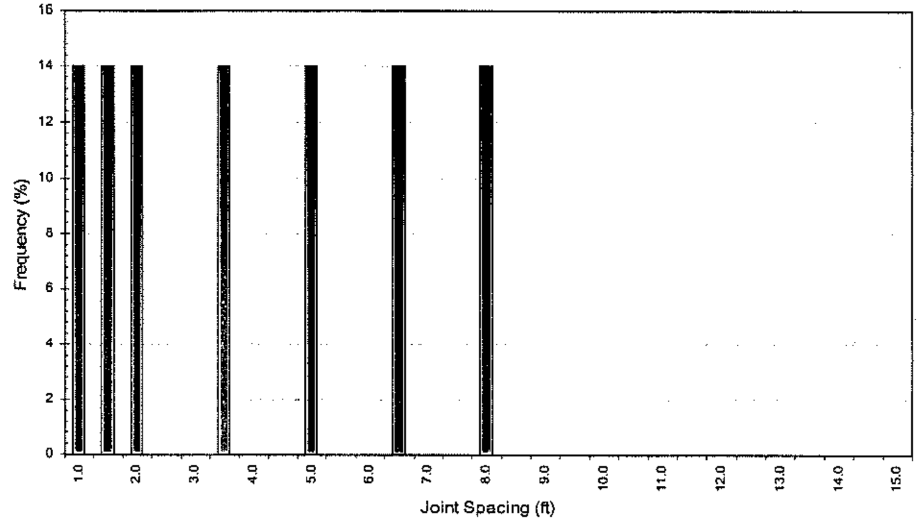
MG-204
Joint Set 1

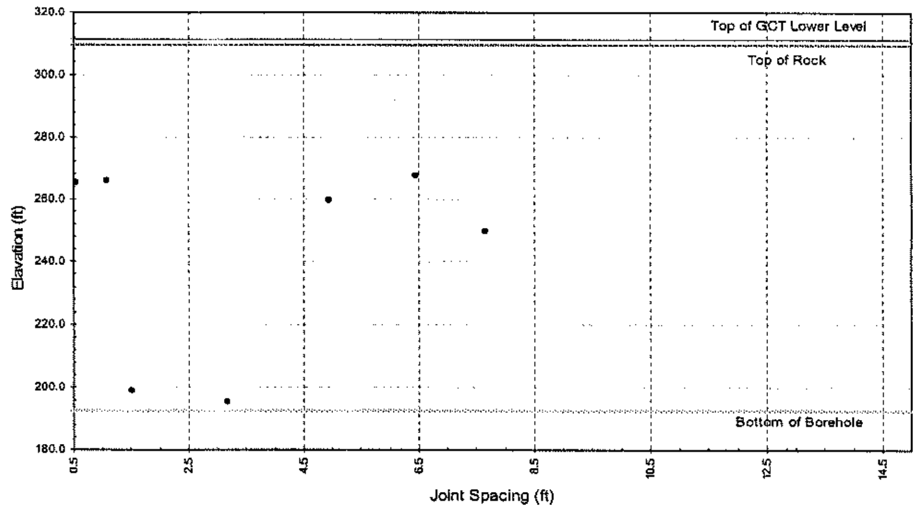
Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
36.8	25	0.0	0.0	274.7
43.9	40	7.1	6.4	267.6
44.2	35	0.3	0.2	267.3
45.5	40	1.3	1.1	266.0
46.2	30	0.7	0.5	265.3
51.9	40	5.7	4.9	259.6
61.9	45	10.0	7.7	249.6
110.8	20	48.9	34.6	200.7
110.9	25	0.1	0.1	200.6
111.1	25	0.2	0.2	200.4
111.2	20	0.1	0.1	200.3
112.8	25	1.6	1.5	198.7
112.9	25	0.1	0.1	198.6
116.4	30	3.5	3.2	195.1

Ground EL. (ft)	311.5
Top of Rock (ft)	309.5
Bottom of Hole (ft)	192.7

BIN	Freq.	Freq. (%)
0.5	(Clustering Margin)	
1.0	1	14
1.5	1	14
2.0	1	14
2.5	0	0
3.0	0	0
3.5	1	14
4.0	0	0
4.5	0	0
5.0	1	14
5.5	0	0
6.0	0	0
6.5	1	14
7.0	0	0
7.5	0	0
8.0	1	14
8.5	0	0
9.0	0	0
9.5	0	0
10.0	0	0
10.5	0	0
11.0	0	0
11.5	0	0
12.0	0	0
12.5	0	0
13.0	0	0
13.5	0	0
14.0	0	0
14.5	0	0
15.0	0	0
SUM	7	100

MG-204, Joint Set 1





FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

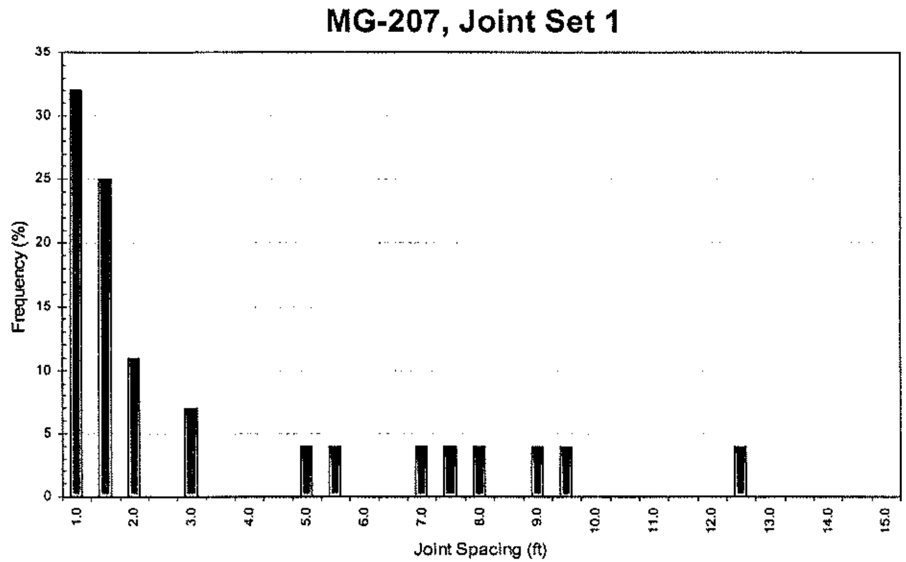
APPENDIX A-2
SHEET 28

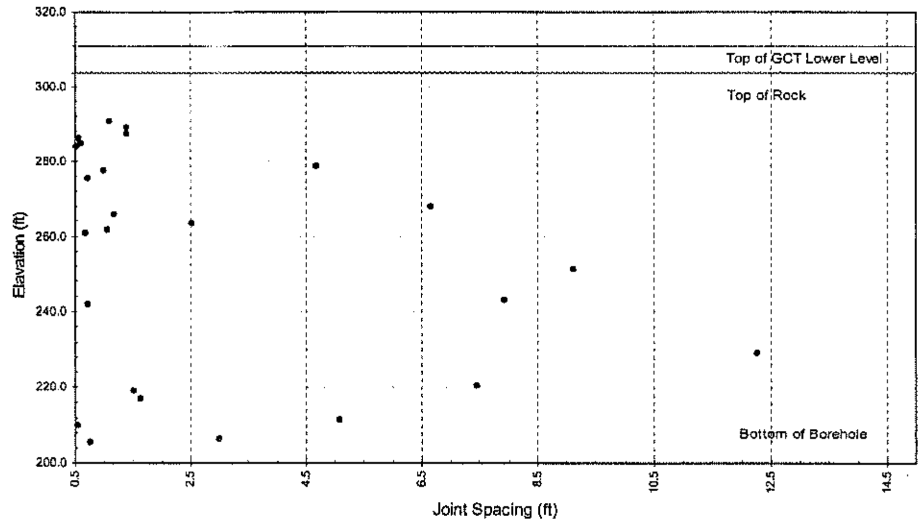
MG-207
Joint Set 1

Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
19.3	25	0.0	0.0	291.7
20.5	30	1.2	1.1	290.5
22.1	30	1.6	1.4	288.9
23.7	25	1.6	1.4	287.3
24.2	20	0.5	0.5	286.8
24.8	30	0.6	0.6	286.2
25.3	30	0.5	0.4	285.7
25.7	30	0.4	0.3	285.3
26.4	30	0.7	0.6	284.6
27	30	0.6	0.5	284.0
32.4	25	5.4	4.7	278.6
33.5	20	1.1	1.0	277.5
34	25	0.5	0.5	277.0
34.3	35	0.3	0.3	276.7
34.7	25	0.4	0.3	276.3
35.5	30	0.8	0.7	275.5
43.2	20	7.7	6.7	267.8
43.5	25	0.3	0.3	267.5
43.9	25	0.4	0.4	267.1
45.2	15	1.3	1.2	265.8
47.8	30	2.6	2.5	263.2
48.3	15	0.5	0.4	262.7
48.4	15	0.1	0.1	262.6
49.5	15	1.1	1.1	261.5
50.2	20	0.7	0.7	260.8
59.9	15	9.7	9.1	251.1
68.1	10	8.2	7.9	242.9
68.5	25	0.4	0.4	242.5
69.3	15	0.8	0.7	241.7
82	30	12.7	12.3	229.0
90.6	20	8.6	7.4	220.4
92.2	35	1.6	1.5	218.8
94.2	20	2.0	1.6	216.8
99.6	20	5.4	5.1	211.4
100	20	0.4	0.4	211.0
100.3	35	0.3	0.3	210.7
100.4	25	0.1	0.1	210.6
101	30	0.6	0.5	210.0
101.4	30	0.4	0.3	209.6
101.5	25	0.1	0.1	209.5
104.8	20	3.3	3.0	206.2
105.6	25	0.8	0.8	205.4
105.7	20	0.1	0.1	205.3
114.9	20	9.2	8.6	196.1
116	30	1.1	1.0	195.0
117.6	20	1.6	1.4	193.4
119.7	30	2.1	2.0	191.3

Ground EL. (ft)	311
Top of Rock (ft)	304
Bottom of Hole (ft)	191

BIN	Freq.	Freq. (%)
0.5	(Clustering Margin)	
1.0	9	32
1.5	7	25
2.0	3	11
2.5	0	0
3.0	2	7
3.5	0	0
4.0	0	0
4.5	0	0
5.0	1	4
5.5	1	4
6.0	0	0
6.5	0	0
7.0	1	4
7.5	1	4
8.0	1	4
8.5	0	0
9.0	1	4
9.5	1	4
10.0	0	0
10.5	0	0
11.0	0	0
11.5	0	0
12.0	0	0
12.5	1	4
13.0	0	0
13.5	0	0
14.0	0	0
14.5	0	0
15.0	0	0
SUM	28	100





FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

APPENDIX A-2
SHEET 29

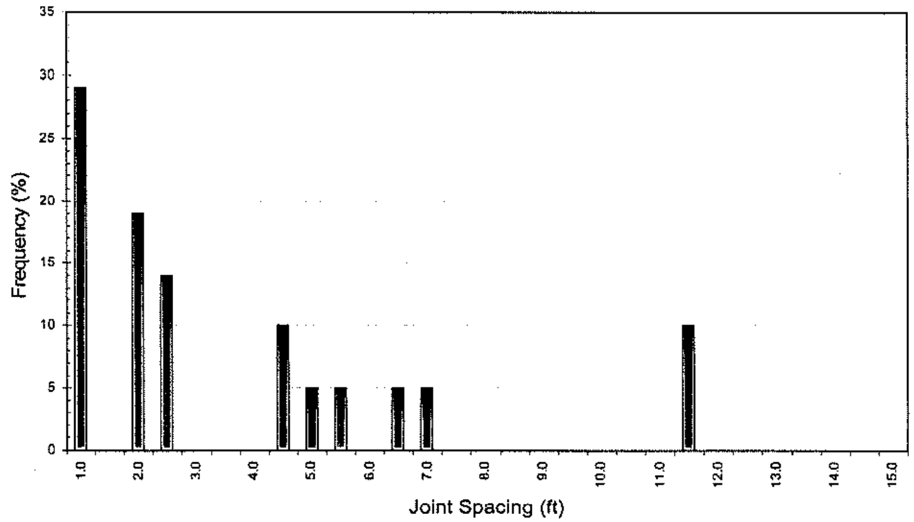
TT-9w
Joint Set 1

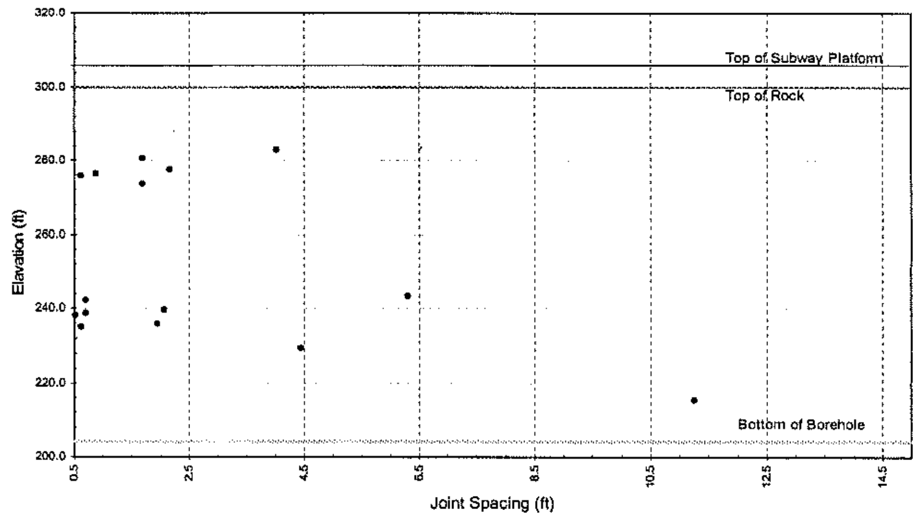
Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
17.4	50			288.6
23.1	40	5.7	4.0	282.9
25.3	40	2.2	1.7	280.7
28.5	55	3.2	2.2	277.5
29.6	20	1.1	0.9	276.4
30.3	35	0.7	0.6	275.7
32.6	50	2.3	1.7	273.4
55.4	10	22.8	19.7	250.6
55.9	15	0.5	0.5	250.1
63	40	7.1	6.3	243.0
64	50	1.0	0.7	242.0
66.6	25	2.6	2.1	239.4
67.4	35	0.8	0.7	238.6
68	25	0.6	0.5	238.0
68.2	30	0.2	0.2	237.8
70.3	15	2.1	1.9	235.7
71	40	0.7	0.6	235.0
76.6	35	5.6	4.4	229.4
90.8	40	14.2	11.3	215.2
123.2	25	32.4	27.3	182.8
129.1	20	5.9	5.5	176.9
143.3	55	14.2	11.3	162.7
153.3	40	10.0	6.8	152.7
159.9	45	6.6	4.9	146.1
162.7	25	2.8	2.3	143.3
163	35	0.3	0.3	143.0
188.9	40	25.9	20.5	117.1
190.9	35	2.0	1.6	115.1

Ground EL. (ft)	306
Top of Rock (ft)	300
Bottom of Hole (ft)	204.3

BIN	Freq.	Freq. (%)
0.5	(Clustering Margin)	
1.0	6	29
1.5	0	0
2.0	4	19
2.5	3	14
3.0	0	0
3.5	0	0
4.0	0	0
4.5	2	10
5.0	1	5
5.5	1	5
6.0	0	0
6.5	1	5
7.0	1	5
7.5	0	0
8.0	0	0
8.5	0	0
9.0	0	0
9.5	0	0
10.0	0	0
10.5	0	0
11.0	0	0
11.5	2	10
12.0	0	0
12.5	0	0
13.0	0	0
13.5	0	0
14.0	0	0
14.5	0	0
15.0	0	0
SUM	21	100

TT-9w, Joint Set 1





FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

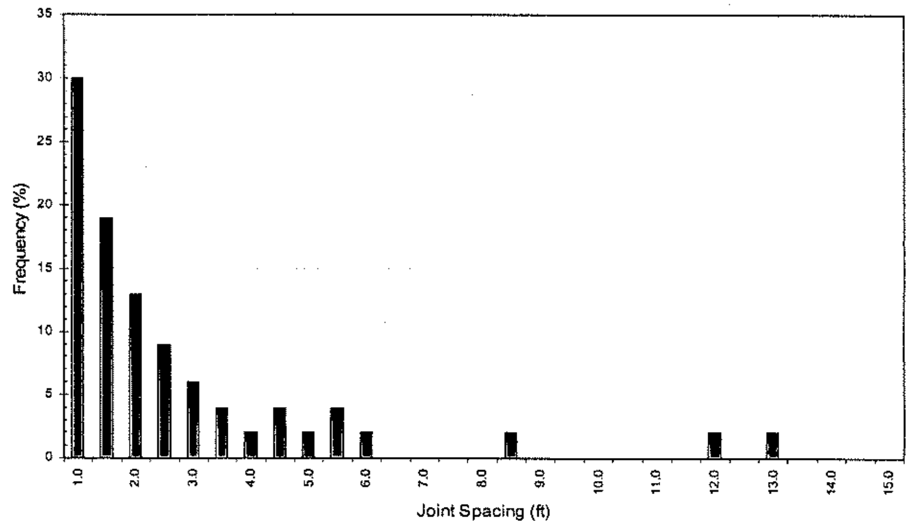
TT-10
Joint Set 1

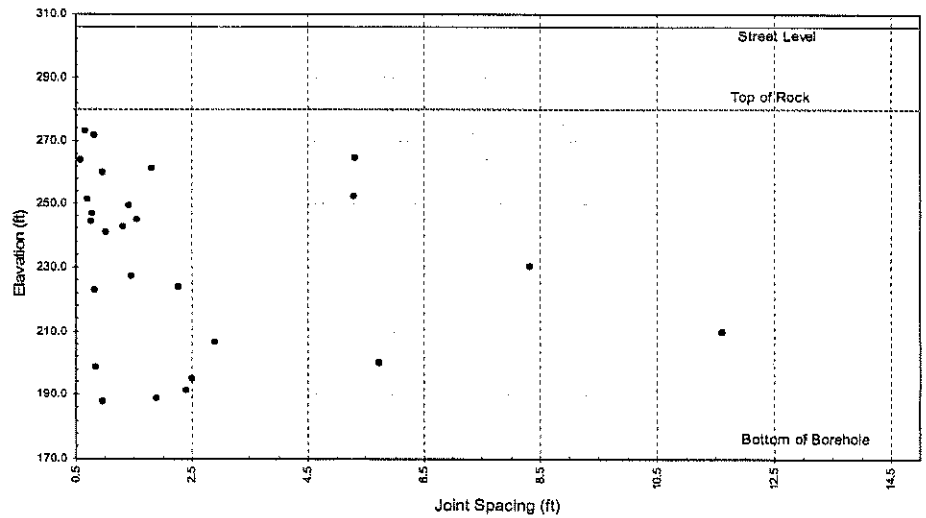
Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
31	25			275.0
31.3	35	0.3	0.3	274.7
31.35	40	0.1	0.0	274.7
31.4	40	0.0	0.0	274.6
31.45	45	0.1	0.0	274.6
32	40	0.6	0.4	274.0
32.8	30	0.8	0.7	273.2
33.3	10	0.5	0.5	272.7
34.2	40	0.9	0.8	271.8
34.4	30	0.2	0.2	271.6
34.5	30	0.1	0.1	271.5
34.7	30	0.2	0.2	271.3
35	35	0.3	0.3	271.0
41.3	30	6.3	5.3	264.7
42	40	0.7	0.6	264.0
42.1	40	0.1	0.1	263.9
44.65	50	2.6	1.8	261.4
44.7	55	0.1	0.0	261.3
44.9	40	0.2	0.1	261.1
46.2	45	1.3	1.0	259.8
53.7	45	7.5	5.3	252.3
54.7	45	1.0	0.7	251.3
56.7	45	2.0	1.4	249.3
57.1	45	0.4	0.3	248.9
57.6	45	0.5	0.4	248.4
58.1	45	0.5	0.4	247.9
59.2	45	1.1	0.8	246.8
61.1	25	1.9	1.6	244.9
62	40	0.9	0.8	244.0
63.6	30	1.6	1.3	242.4
63.9	30	0.3	0.3	242.1
65.1	35	1.2	1.0	240.9
75.6	40	10.5	8.3	230.4
75.7	40	0.1	0.1	230.3
76.2	30	0.5	0.4	229.8
76.55	55	0.3	0.3	229.5
78.7	40	2.2	1.5	227.3
81.9	50	3.2	2.3	224.1
83	35	1.1	0.8	223.0
96.1	20	13.1	11.6	209.9
99.3	30	3.2	2.9	206.7
106.1	35	6.8	5.7	199.9
107.2	45	1.1	0.8	198.8
110.9	50	3.7	2.5	195.1
111.2	45	0.3	0.2	194.8
111.35	40	0.1	0.1	194.7
114.6	45	3.3	2.4	191.4
114.9	35	0.3	0.2	191.1

Ground EL. (ft)	306
Top of Rock (ft)	280
Bottom of Hole (ft)	110

BIN	Freq.	Freq. (%)
0.5	(Clustering Margin)	
1.0	14	30
1.5	9	19
2.0	6	13
2.5	4	9
3.0	3	6
3.5	2	4
4.0	1	2
4.5	2	4
5.0	1	2
5.5	2	4
6.0	1	2
6.5	0	0
7.0	0	0
7.5	0	0
8.0	0	0
8.5	1	2
9.0	0	0
9.5	0	0
10.0	0	0
10.5	0	0
11.0	0	0
11.5	0	0
12.0	1	2
12.5	0	0
13.0	1	2
13.5	0	0
14.0	0	0
14.5	0	0
15.0	0	0
SUM	47	100

TT-10, Joint Set 1





FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

APPENDIX A-2
SHEET 31

TT-10, Joint Set 1 Data Continued				
145.4	50	3.5	2.7	160.6
151	25	5.6	4.4	155.0
152.9	20	1.9	1.8	153.1
154.5	25	1.6	1.5	151.5
156	30	1.5	1.3	150.0
160.9	40	4.9	4.0	145.1
161.7	40	0.8	0.6	144.3
178.5	40	16.8	12.9	127.5
179.1	40	0.6	0.5	126.9
180.9	35	1.8	1.4	125.1
181.1	30	0.2	0.2	124.9
181.6	40	0.5	0.4	124.4
184	40	2.4	1.8	122.0
184.3	45	0.3	0.2	121.7
185.1	45	0.8	0.6	120.9
187.9	45	2.8	2.0	118.1
192.2	40	4.3	3.2	113.8
193.7	30	1.5	1.2	112.3

FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

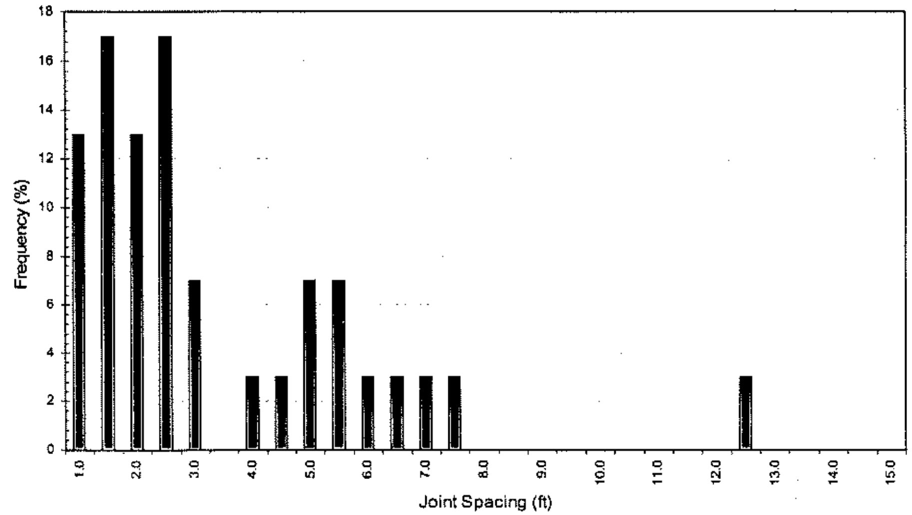
TT-11w
Joint Set 1

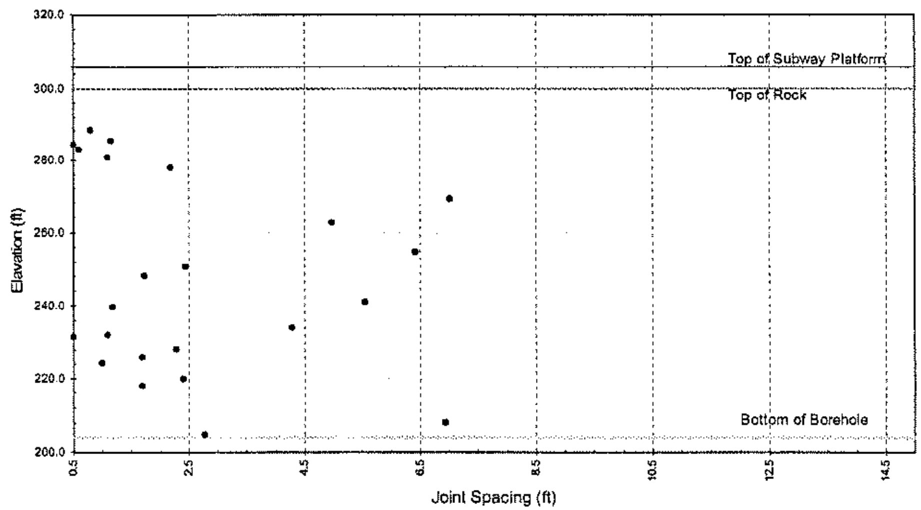
Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
16.4	45			289.6
16.8	45	0.4	0.3	289.2
17.8	30	1.0	0.8	288.2
18.3	40	0.5	0.4	287.7
18.9	45	0.6	0.4	287.1
20.8	60	1.9	1.2	285.2
21.8	60	1.0	0.5	284.2
22.1	55	0.3	0.2	283.9
23.2	60	1.1	0.6	282.8
23.5	75	0.3	0.1	282.5
23.6	65	0.1	0.0	282.4
25.5	45	1.9	1.1	280.5
28.25	30	2.8	2.2	277.8
37.1	45	8.9	7.0	268.9
37.6	35	0.5	0.4	268.4
43.5	30	5.9	5.0	262.5
51.6	45	8.1	6.4	254.4
55.4	55	3.8	2.4	250.6
58.1	45	2.7	1.7	247.9
65.1	30	7.0	5.6	240.9
66.4	20	1.3	1.2	239.6
72.2	65	5.8	4.3	233.8
74	40	1.8	1.1	232.0
74.7	50	0.7	0.5	231.3
74.8	40	0.1	0.1	231.2
75	40	0.2	0.2	231.0
78.1	45	3.1	2.3	227.9
80.3	35	2.2	1.7	225.7
80.6	35	0.3	0.2	225.4
82	55	1.4	1.0	224.0
82.1	50	0.1	0.1	223.9
82.2	45	0.1	0.1	223.8
82.4	50	0.2	0.1	223.6
82.6	55	0.2	0.1	223.4
82.7	55	0.1	0.1	223.3
86.1	35	3.4	2.4	219.9
88.3	45	2.2	1.7	217.7
88.6	45	0.3	0.2	217.4
98.0	40	9.4	6.9	208.0
101.4	30	3.4	2.8	204.6
106.8	30	5.4	4.7	199.2
111.4	30	4.6	4.0	194.6
111.6	5	0.2	0.2	194.4
111.7	35	0.1	0.1	194.3
112.7	10	1.0	0.9	193.3
112.8	40	0.1	0.1	193.2
113.2	35	0.4	0.3	192.8
116.4	35	3.2	2.6	189.6
122.6	35	6.2	5.1	183.4

Ground EL. (ft)	306
Top of Rock (ft)	300
Bottom of Hole (ft)	204.3

BIN	Freq.	Freq. (%)
0.5	(Clustering Margin)	
1.0	4	13
1.5	5	17
2.0	4	13
2.5	5	17
3.0	2	7
3.5	0	0
4.0	1	3
4.5	1	3
5.0	2	7
5.5	2	7
6.0	1	3
6.5	1	3
7.0	1	3
7.5	1	3
8.0	0	0
8.5	0	0
9.0	0	0
9.5	0	0
10.0	0	0
10.5	0	0
11.0	0	0
11.5	0	0
12.0	0	0
12.5	1	3
13.0	0	0
13.5	0	0
14.0	0	0
14.5	0	0
15.0	0	0
SUM	30	100

TT-11w, Joint Set 1





FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

TT-11w, Joint Set 1 Data Continued				
128.7	25	6.1	5.3	177.3
175.0	20	46.3	42.8	131.0
175.4	30	0.4	0.4	130.6
190.2	35	14.8	12.5	115.8
192.8	40	2.6	2.1	113.2
194.2	40	1.4	1.1	111.8
196.4	30	2.2	1.8	109.6
196.5	30	0.1	0.1	109.5
196.9	35	0.4	0.3	109.1

FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

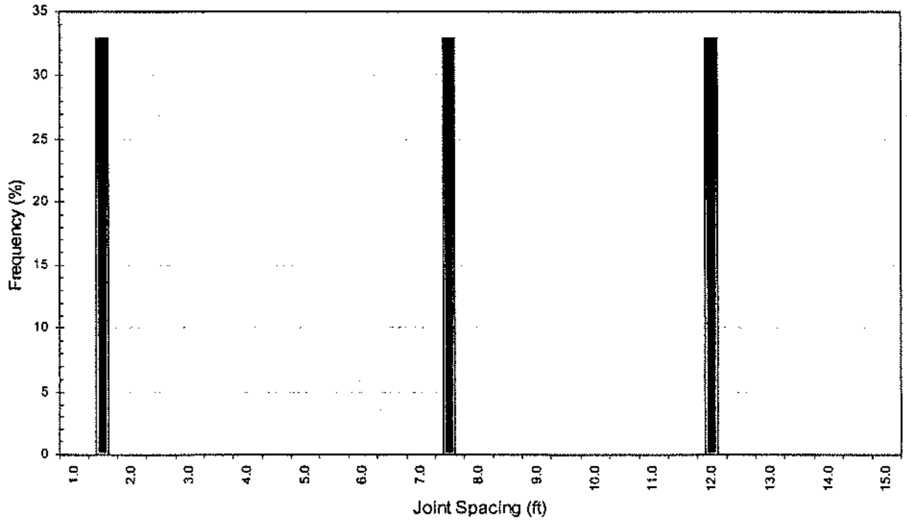
TT-12
Joint Set 1

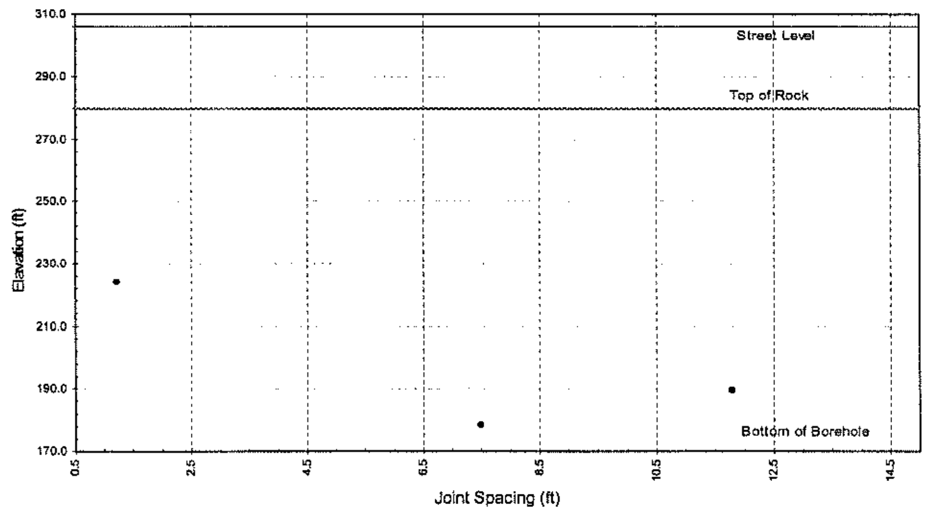
Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
25	30			281.0
74.5	70	49.5	31.8	231.5
75	75	0.5	0.2	231.0
82	85	7.0	1.2	224.0
85.9	90	3.9	0.2	220.1
116.7	45	30.8	11.8	189.3
127.8	50	11.1	7.5	178.2
170.7	15	42.9	36.2	135.3

Ground EL. (ft)	306
Top of Rock (ft)	280
Bottom of Hole (ft)	110

BIN	Freq.	Freq. (%)
0.5	(Clustering Margin)	
1.0	0	0
1.5	1	33
2.0	0	0
2.5	0	0
3.0	0	0
3.5	0	0
4.0	0	0
4.5	0	0
5.0	0	0
5.5	0	0
6.0	0	0
6.5	0	0
7.0	0	0
7.5	1	33
8.0	0	0
8.5	0	0
9.0	0	0
9.5	0	0
10.0	0	0
10.5	0	0
11.0	0	0
11.5	0	0
12.0	1	33
12.5	0	0
13.0	0	0
13.5	0	0
14.0	0	0
14.5	0	0
15.0	0	0
SUM	3	100

TT-12, Joint Set 1





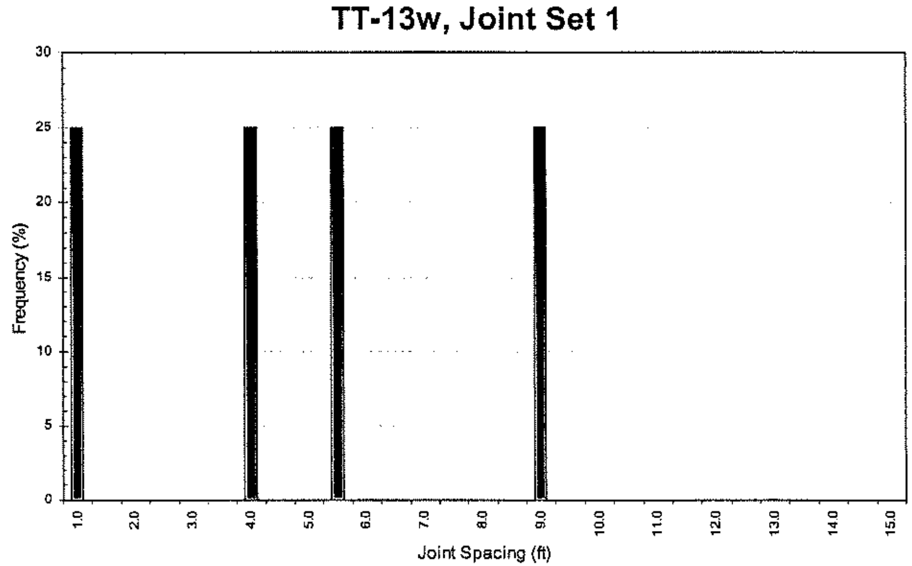
FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

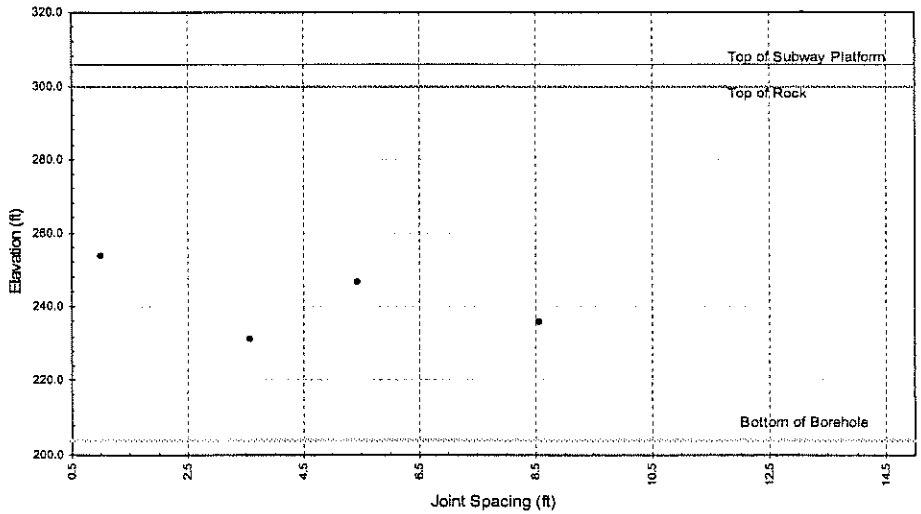
TT-13w
Joint Set 1

Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
51	45			255.0
52.3	35	1.3	1.0	253.7
59.4	45	7.1	5.4	246.6
70.2	30	10.8	8.6	235.8
74.7	45	4.5	3.6	231.3
189.7	50	115.0	77.7	116.3

Ground EL. (ft)	306
Top of Rock (ft)	300
Bottom of Hole (ft)	204.3

BIN	Freq.	Freq. (%)
0.5	(Clustering Margin)	
1.0	1	25
1.5	0	0
2.0	0	0
2.5	0	0
3.0	0	0
3.5	0	0
4.0	1	25
4.5	0	0
5.0	0	0
5.5	1	25
6.0	0	0
6.5	0	0
7.0	0	0
7.5	0	0
8.0	0	0
8.5	0	0
9.0	1	25
9.5	0	0
10.0	0	0
10.5	0	0
11.0	0	0
11.5	0	0
12.0	0	0
12.5	0	0
13.0	0	0
13.5	0	0
14.0	0	0
14.5	0	0
15.0	0	0
SUM	4	100





FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

APPENDIX A-2
SHEET 36

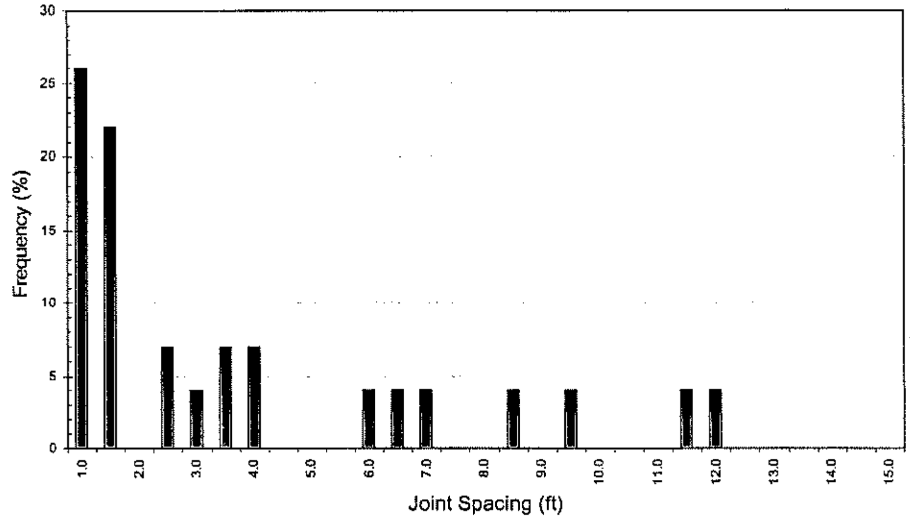
TT-14
Joint Set 1

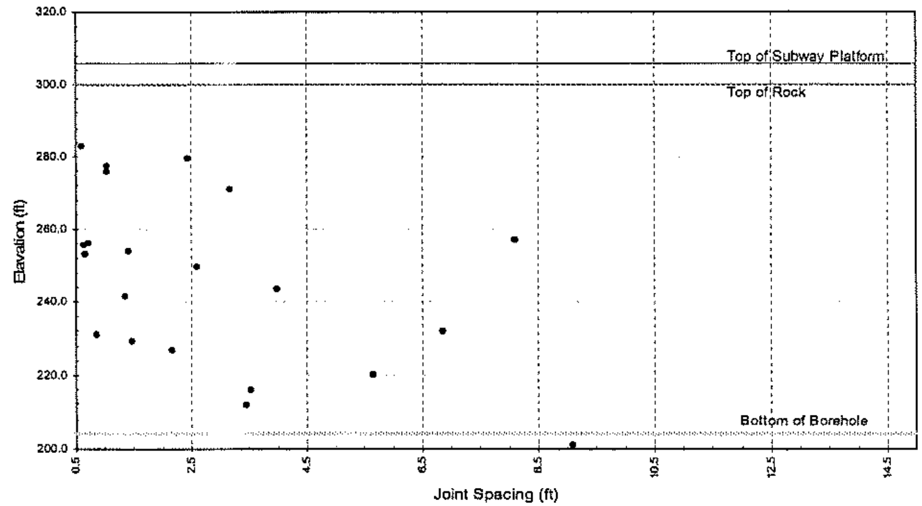
Depth	Angle	Vertical Distance	TRUE Spacing	EL (ft)
21.7	40			284.3
21.8	50	0.1	0.1	284.2
22	40	0.2	0.1	284.0
22.2	50	0.2	0.1	283.8
23.1	45	0.9	0.6	282.9
26.7	50	3.6	2.4	279.3
28.5	60	1.8	1.0	277.5
30.3	50	1.8	1.0	275.7
35	45	4.7	3.2	271.0
35.5	50	0.5	0.3	270.5
35.7	45	0.2	0.1	270.3
36.4	55	0.7	0.4	269.6
49	45	12.6	8.1	257.0
49.9	30	0.9	0.7	256.1
50.6	15	0.7	0.6	255.4
52.2	40	1.6	1.4	253.8
53	30	0.8	0.7	253.0
56.4	50	3.4	2.6	249.6
62.6	50	6.2	4.0	243.4
64.6	45	2.0	1.4	241.4
65.15	50	0.6	0.4	240.9
74.1	30	8.9	6.9	231.9
75.1	30	1.0	0.9	230.9
76.8	30	1.7	1.5	229.2
79.3	30	2.5	2.2	226.7
86	35	6.7	5.7	220.0
90.3	35	4.3	3.5	215.7
94.4	30	4.1	3.5	211.6
94.9	30	0.5	0.4	211.1
105.15	25	10.3	9.1	200.9
105.2	25	0.0	0.0	200.8
119.4	40	14.2	12.0	186.6
120.8	45	1.4	1.0	185.2
121.4	45	0.6	0.4	184.6
135.3	30	13.9	11.0	170.7
136.3	30	1.0	0.9	169.7
157.4	40	21.1	17.3	148.6
167.3	60	9.9	6.4	138.7
168.4	30	1.1	0.8	137.6

Ground EL. (ft)	306
Top of Rock (ft)	300
Bottom of Hole (ft)	204.3

BIN	Freq.	Freq. (%)
0.5	(Clustering Margin)	
1.0	7	26
1.5	6	22
2.0	0	0
2.5	2	7
3.0	1	4
3.5	2	7
4.0	2	7
4.5	0	0
5.0	0	0
5.5	0	0
6.0	1	4
6.5	1	4
7.0	1	4
7.5	0	0
8.0	0	0
8.5	1	4
9.0	0	0
9.5	1	4
10.0	0	0
10.5	0	0
11.0	0	0
11.5	1	4
12.0	1	4
12.5	0	0
13.0	0	0
13.5	0	0
14.0	0	0
14.5	0	0
15.0	0	0
SUM	27	100

TT-14, Joint Set 1



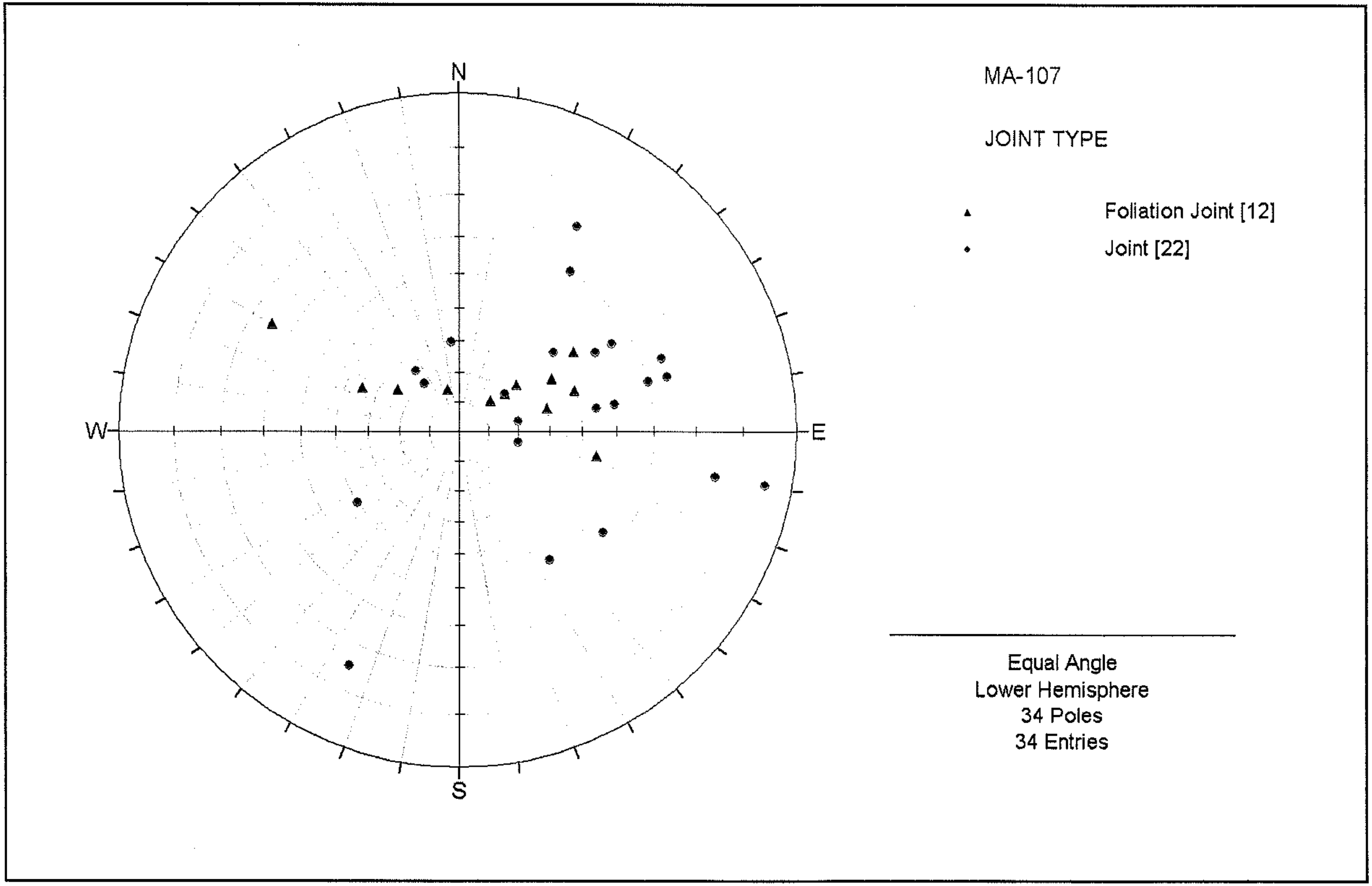


FREQUENCY HISTOGRAMS OF FOLIATION FRACTURES

APPENDIX A-2
SHEET 37

APPENDIX A-3

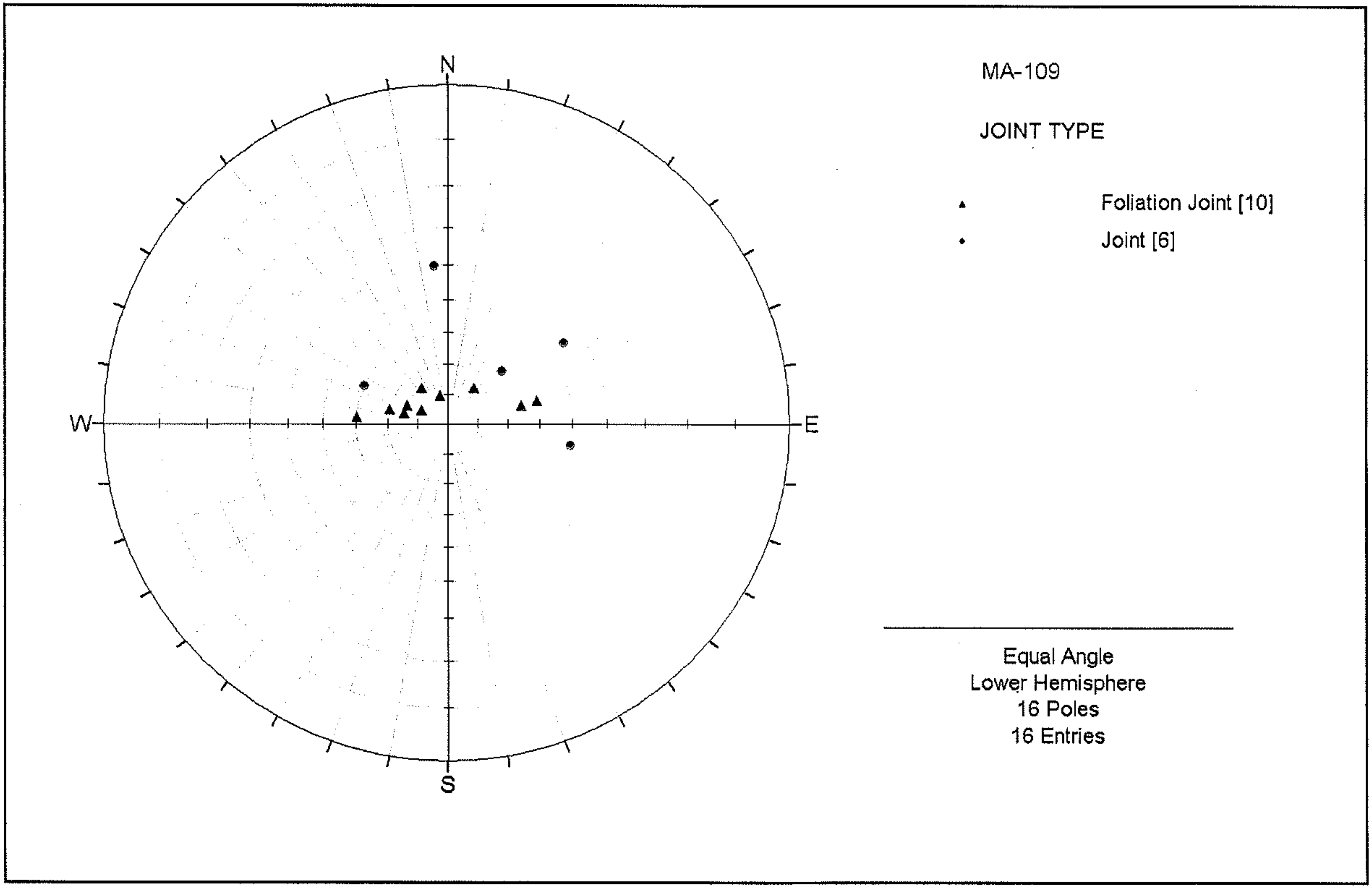
EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC POLE PLOTS OF DISCONTINUITY DATA



EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC
POLE PLOTS OF DISCONTINUITY DATA

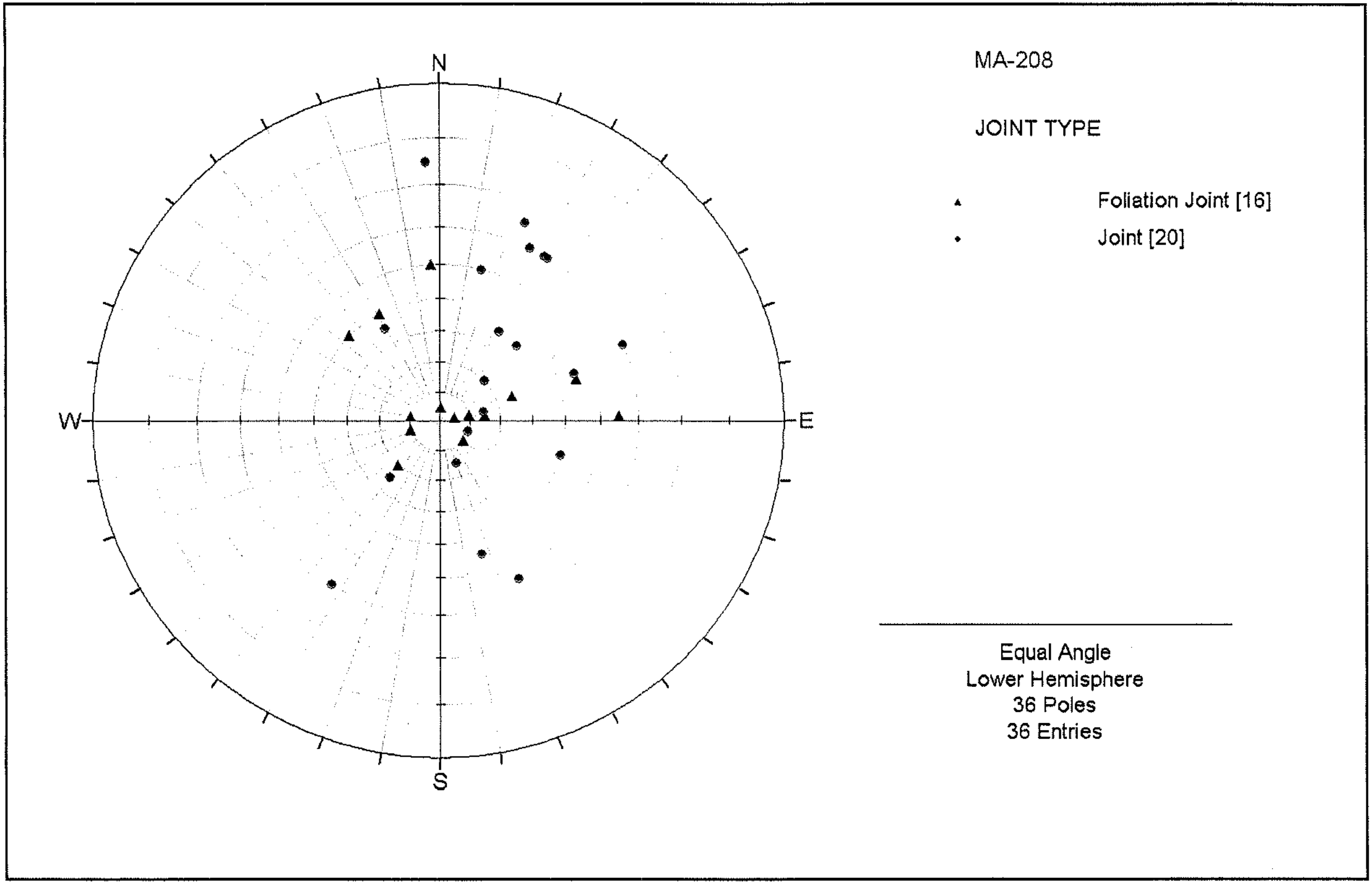
APPENDIX A-3

SHEET 1



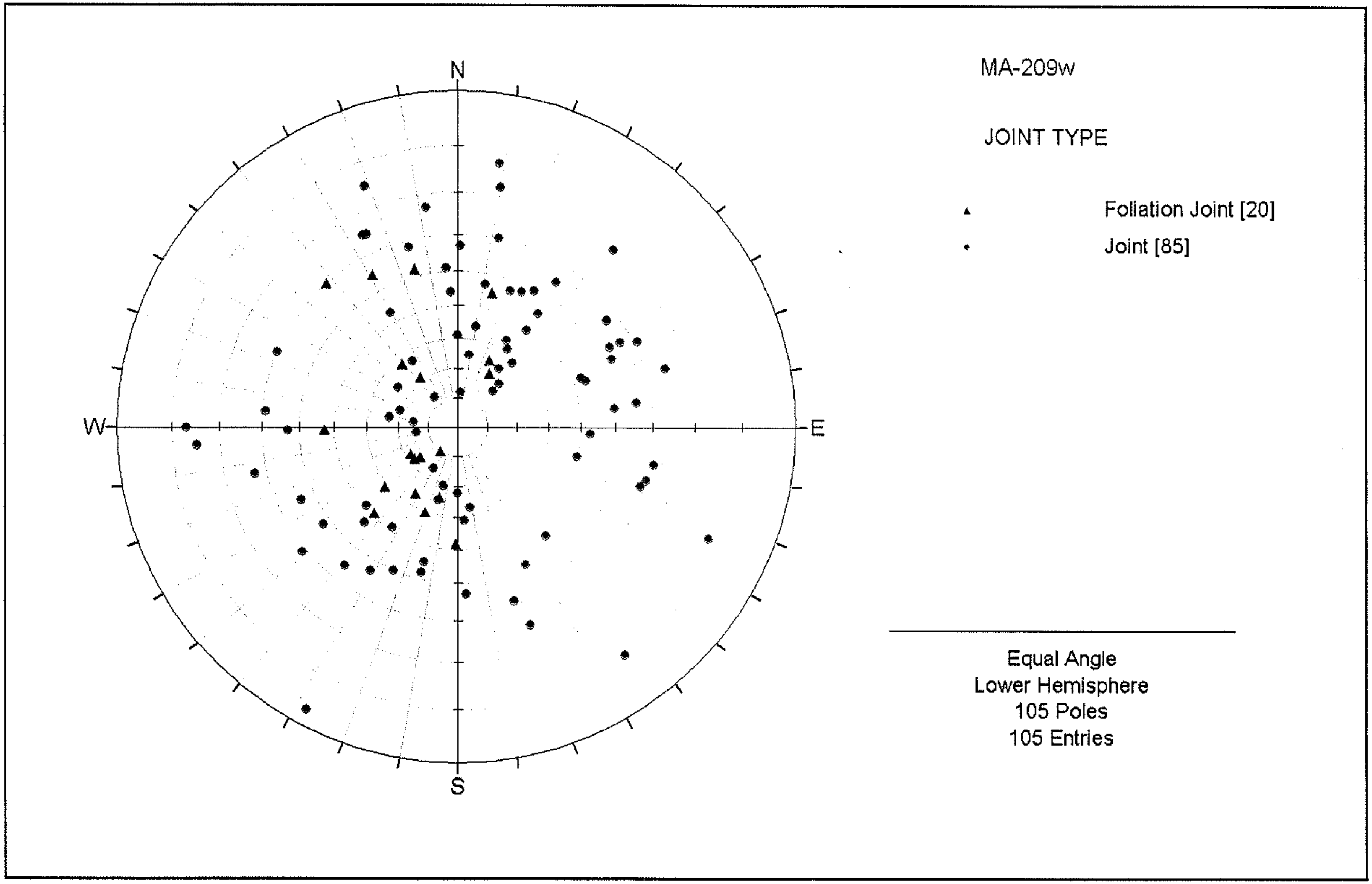
EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC
POLE PLOTS OF DISCONTINUITY DATA

APPENDIX A-3



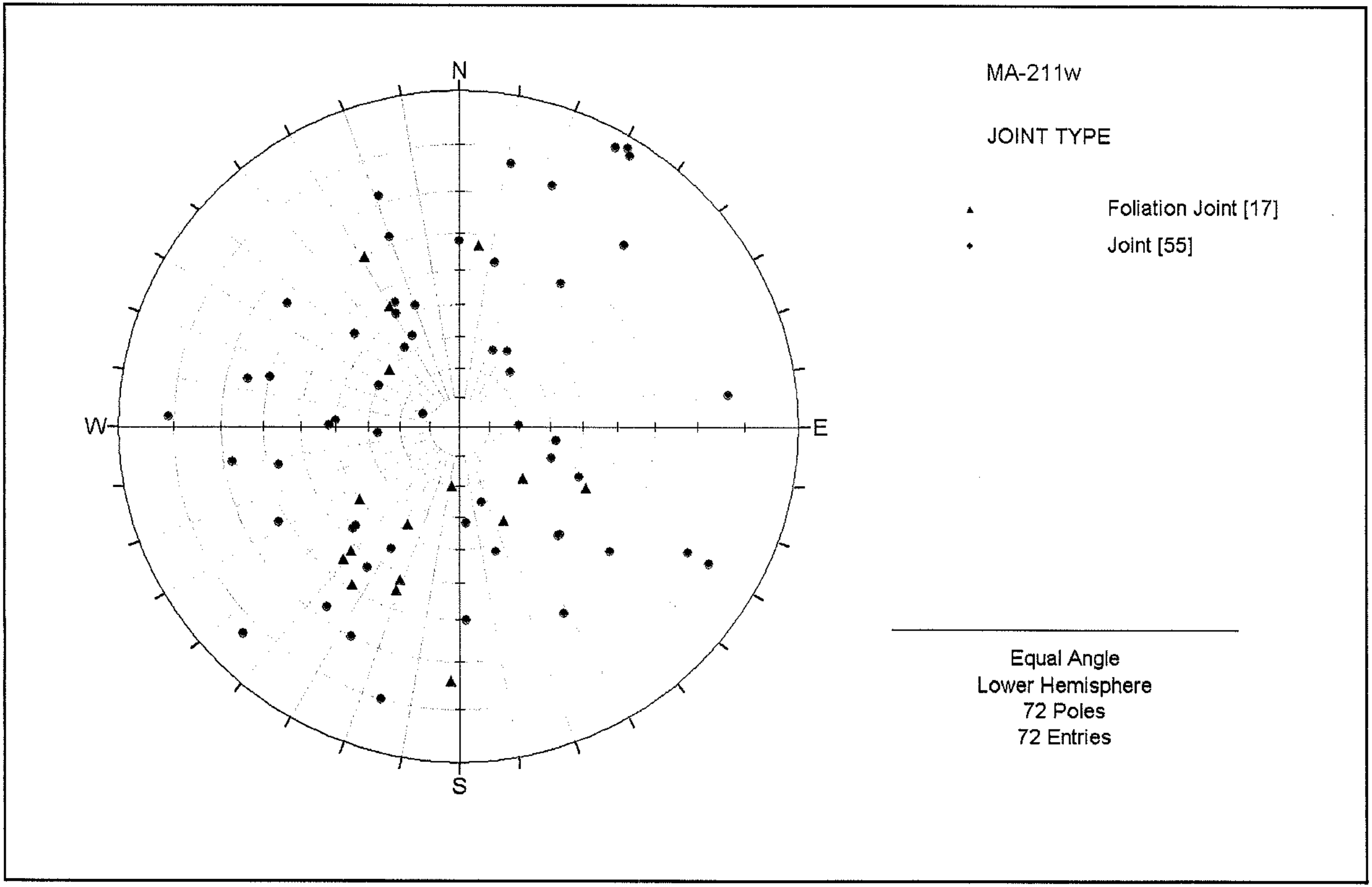
EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC
POLE PLOTS OF DISCONTINUITY DATA

APPENDIX A-3



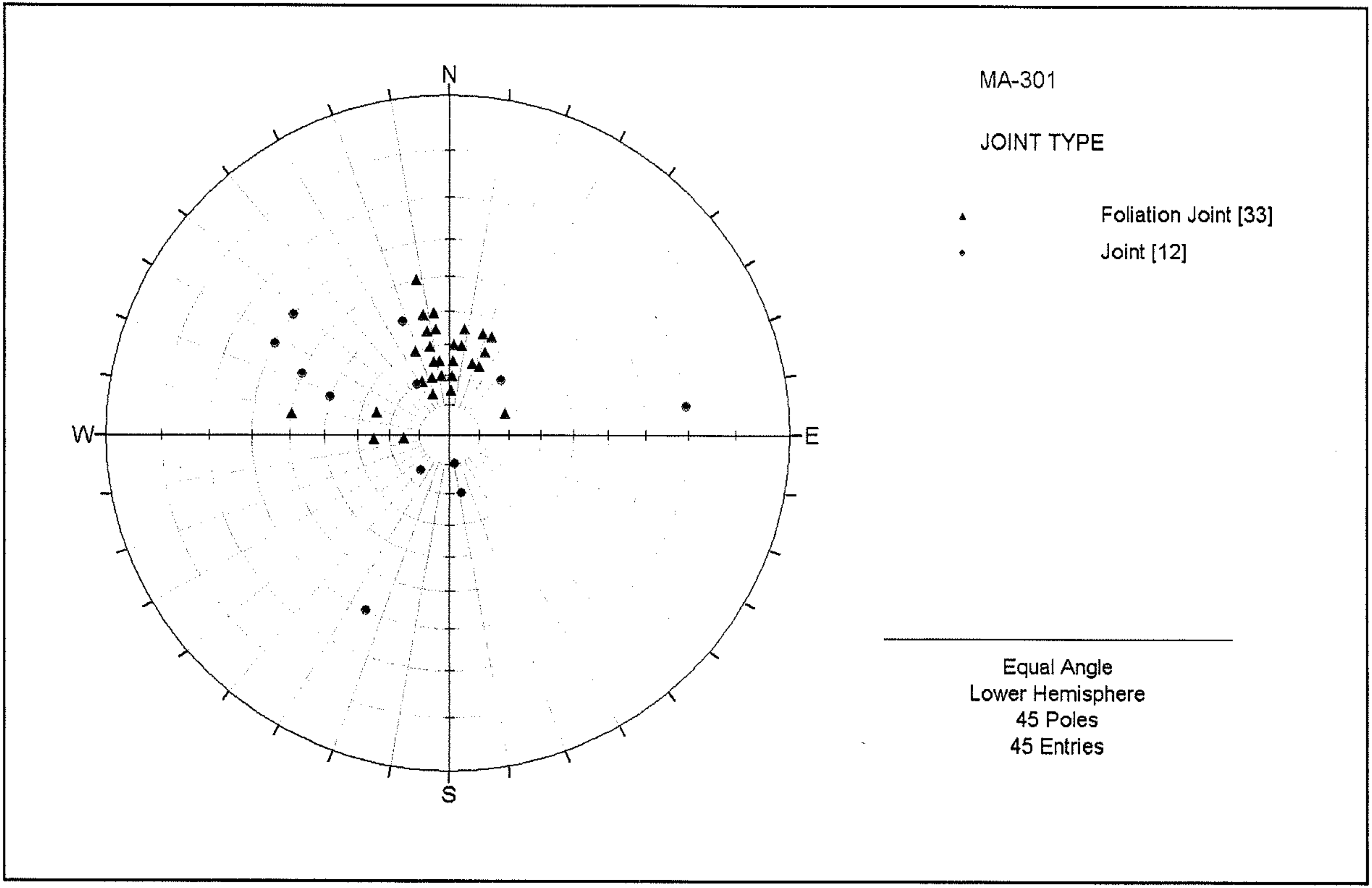
EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC
POLE PLOTS OF DISCONTINUITY DATA

APPENDIX A-3



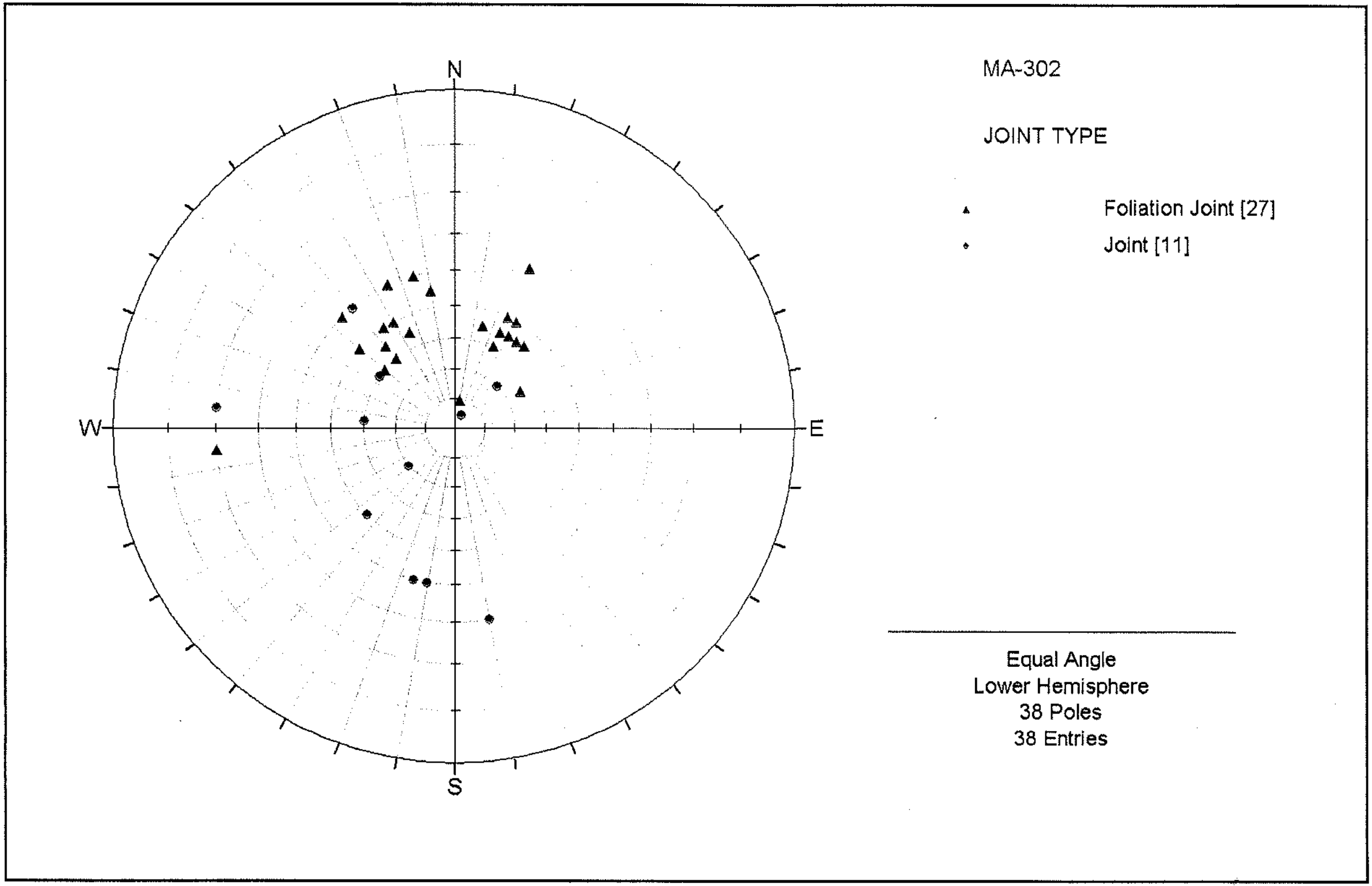
EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC
POLE PLOTS OF DISCONTINUITY DATA

APPENDIX A-3



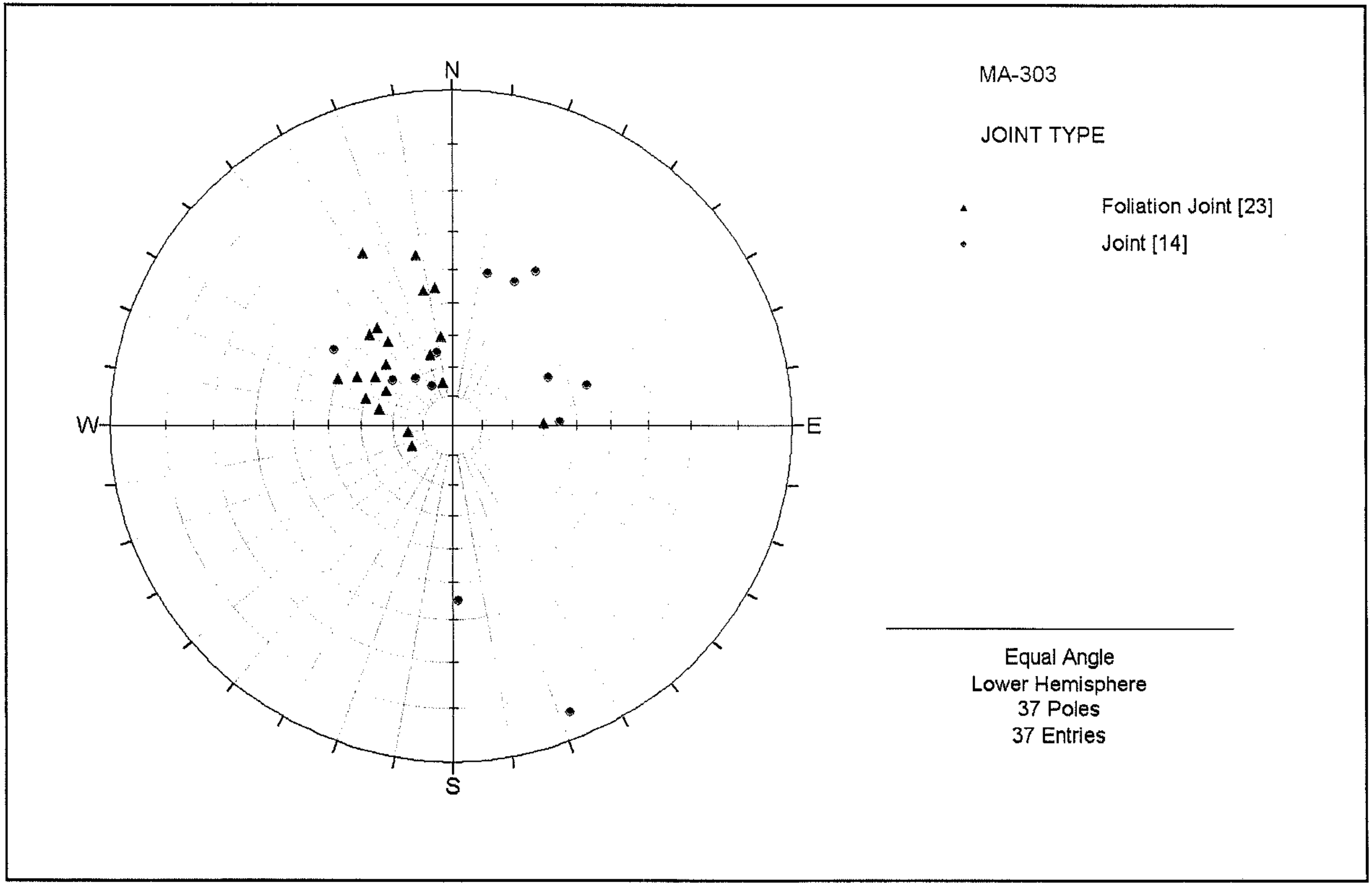
EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC
POLE PLOTS OF DISCONTINUITY DATA

APPENDIX A-3



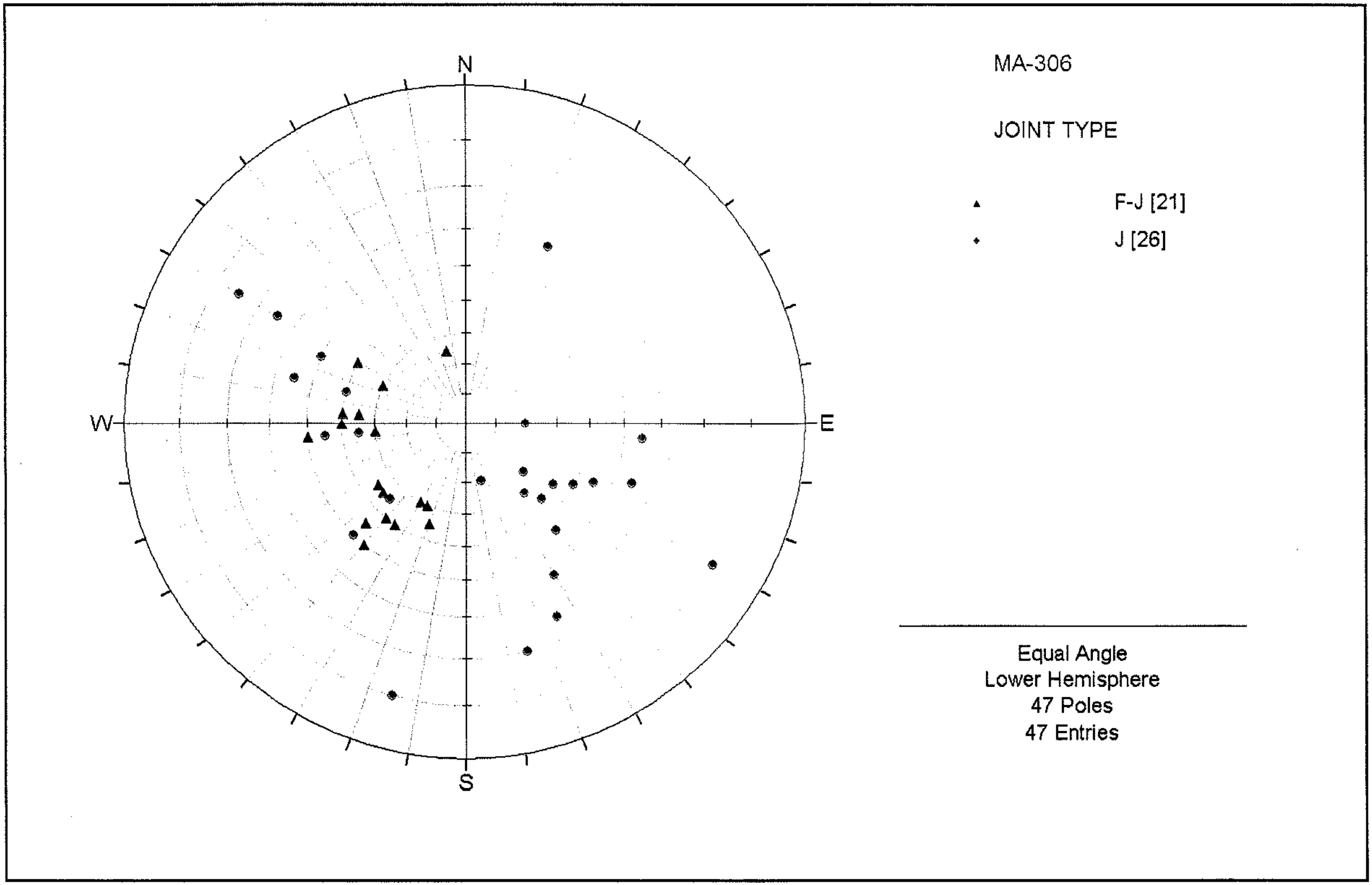
EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC
POLE PLOTS OF DISCONTINUITY DATA

APPENDIX A-3



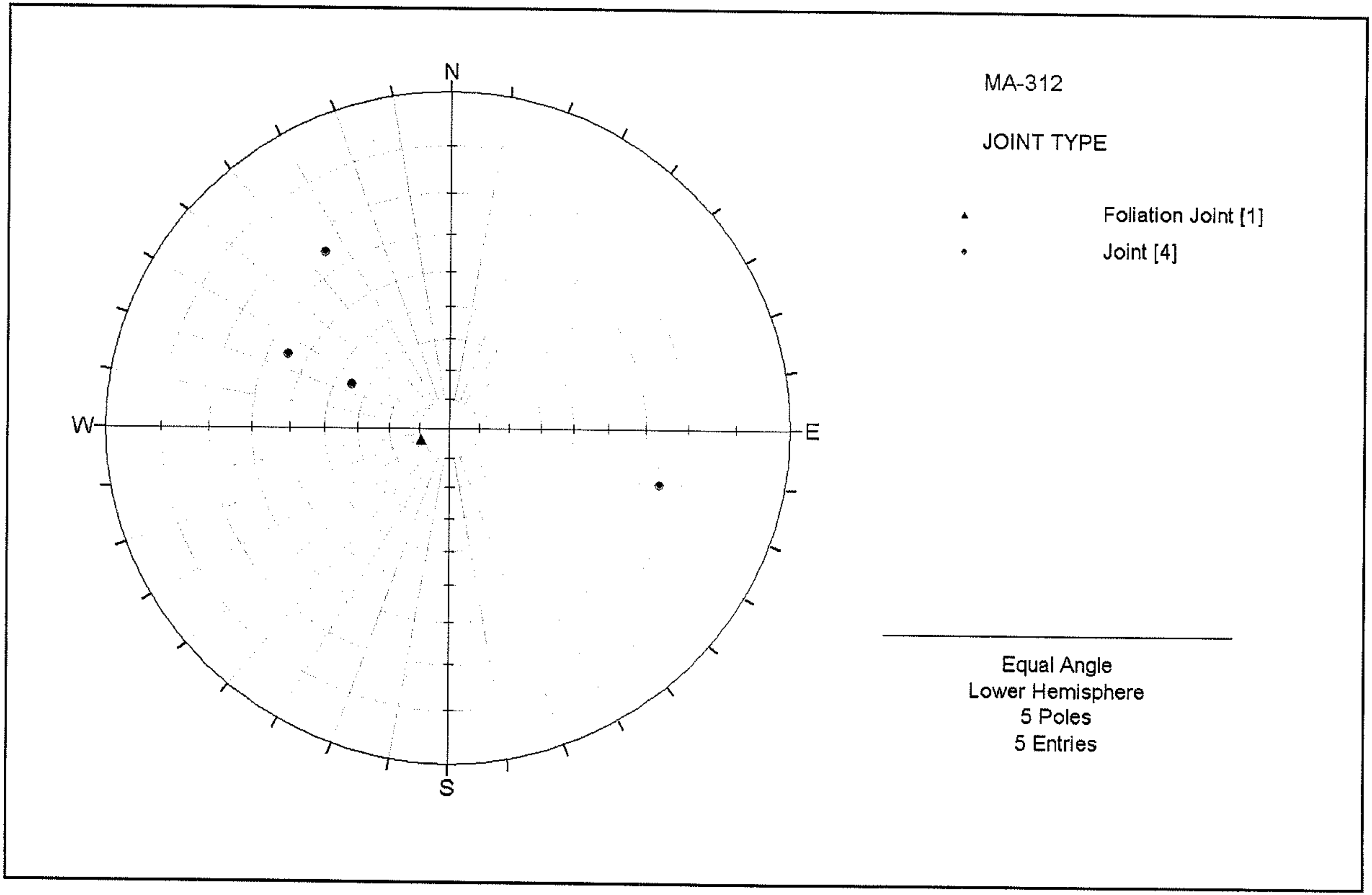
EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC
POLE PLOTS OF DISCONTINUITY DATA

APPENDIX A-3



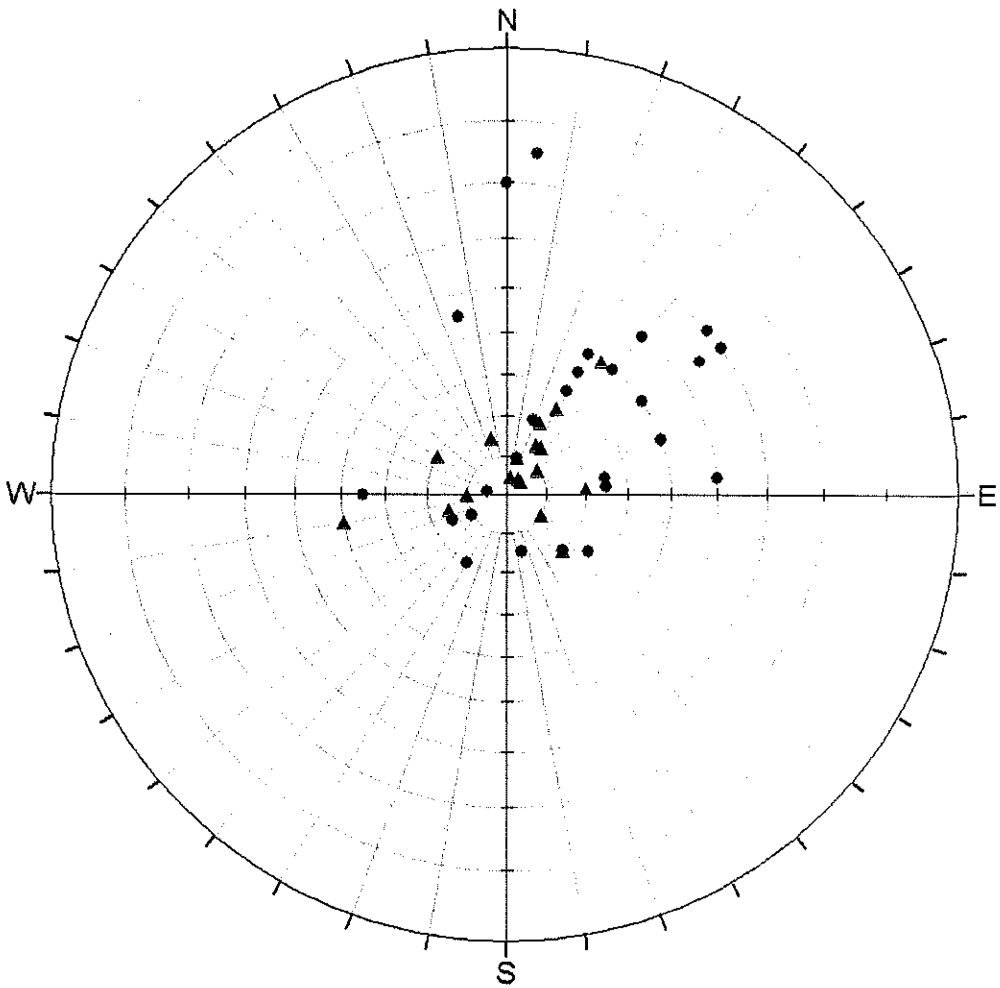
EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC POLE PLOTS OF DISCONTINUITY DATA

APPENDIX A-3



EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC
POLE PLOTS OF DISCONTINUITY DATA

APPENDIX A-3



MA-313

JOINT TYPE

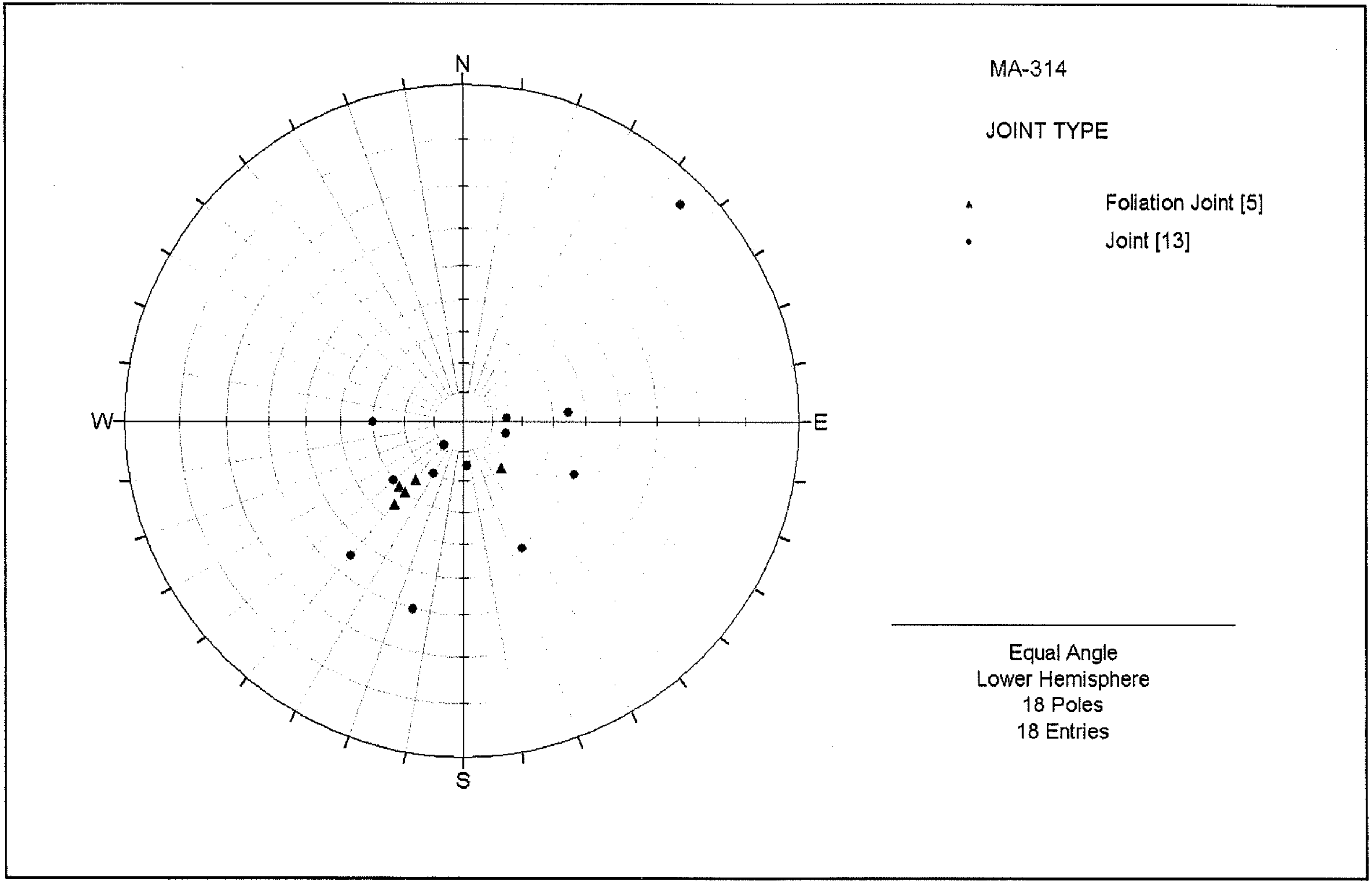
▲ Foliation Joint [18]

• Joint [26]

Equal Angle
Lower Hemisphere
44 Poles
44 Entries

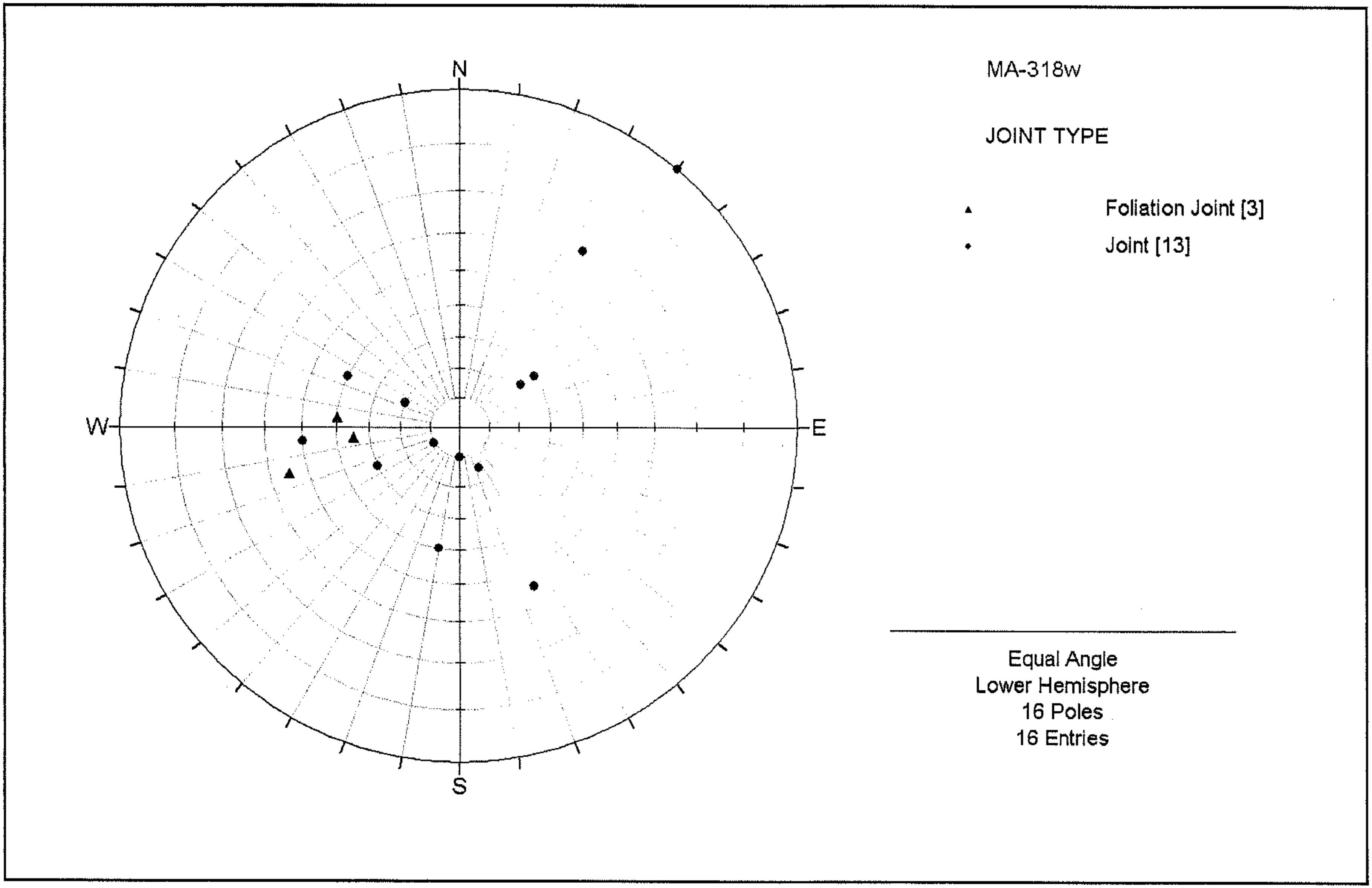
EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC POLE PLOTS OF DISCONTINUITY DATA

APPENDIX A-3



EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC
POLE PLOTS OF DISCONTINUITY DATA

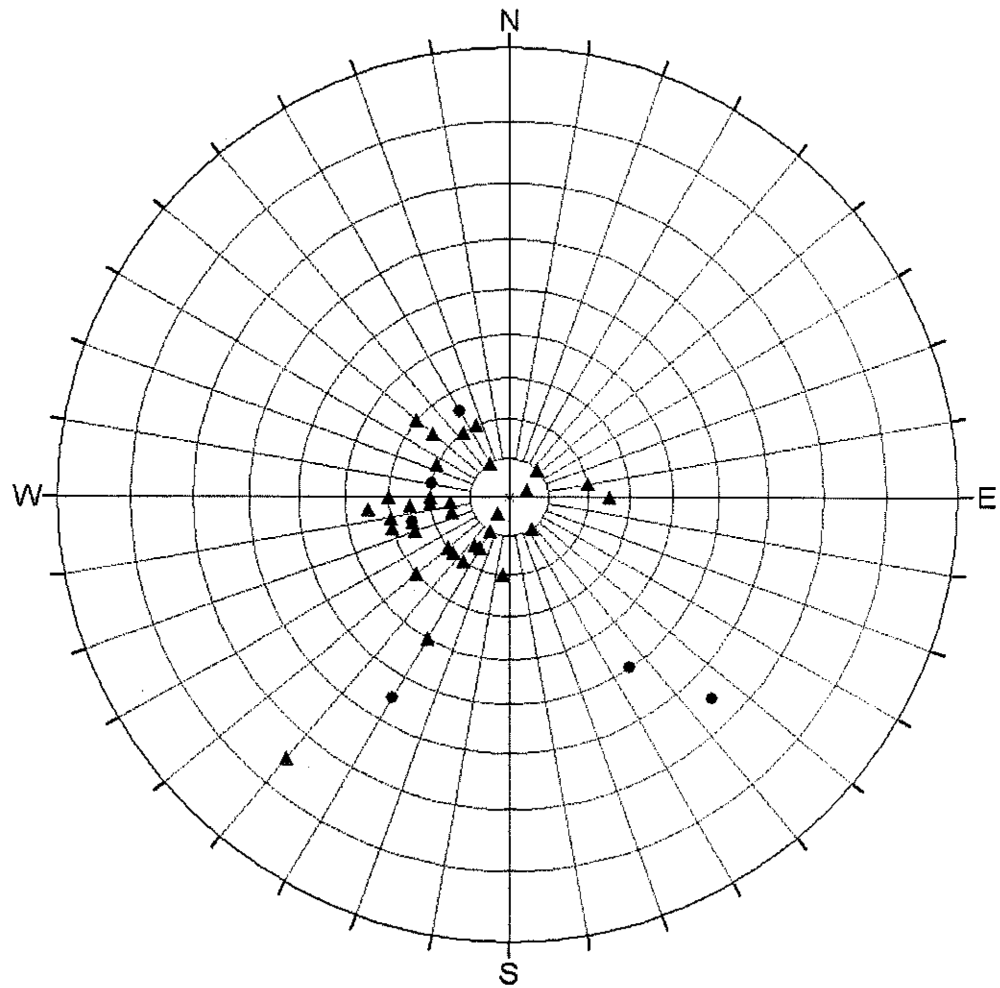
APPENDIX A-3



EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC
POLE PLOTS OF DISCONTINUITY DATA

APPENDIX A-3

SHEET 13



MA-320

JOINT TYPE

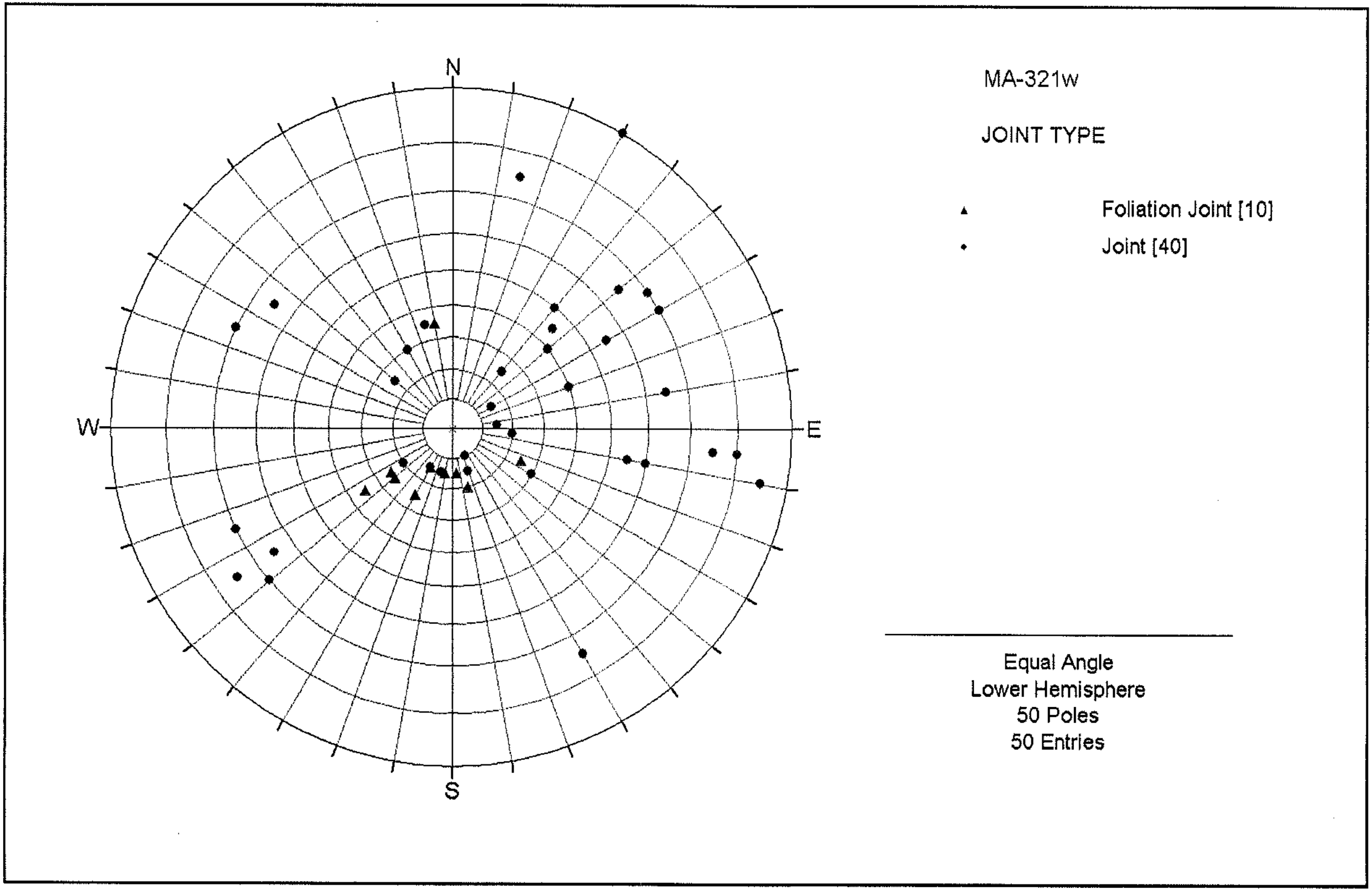
▲ Foliation Joints [34

• Joint [7]

Equal Angle
Lower Hemisphere
41 Poles
41 Entries

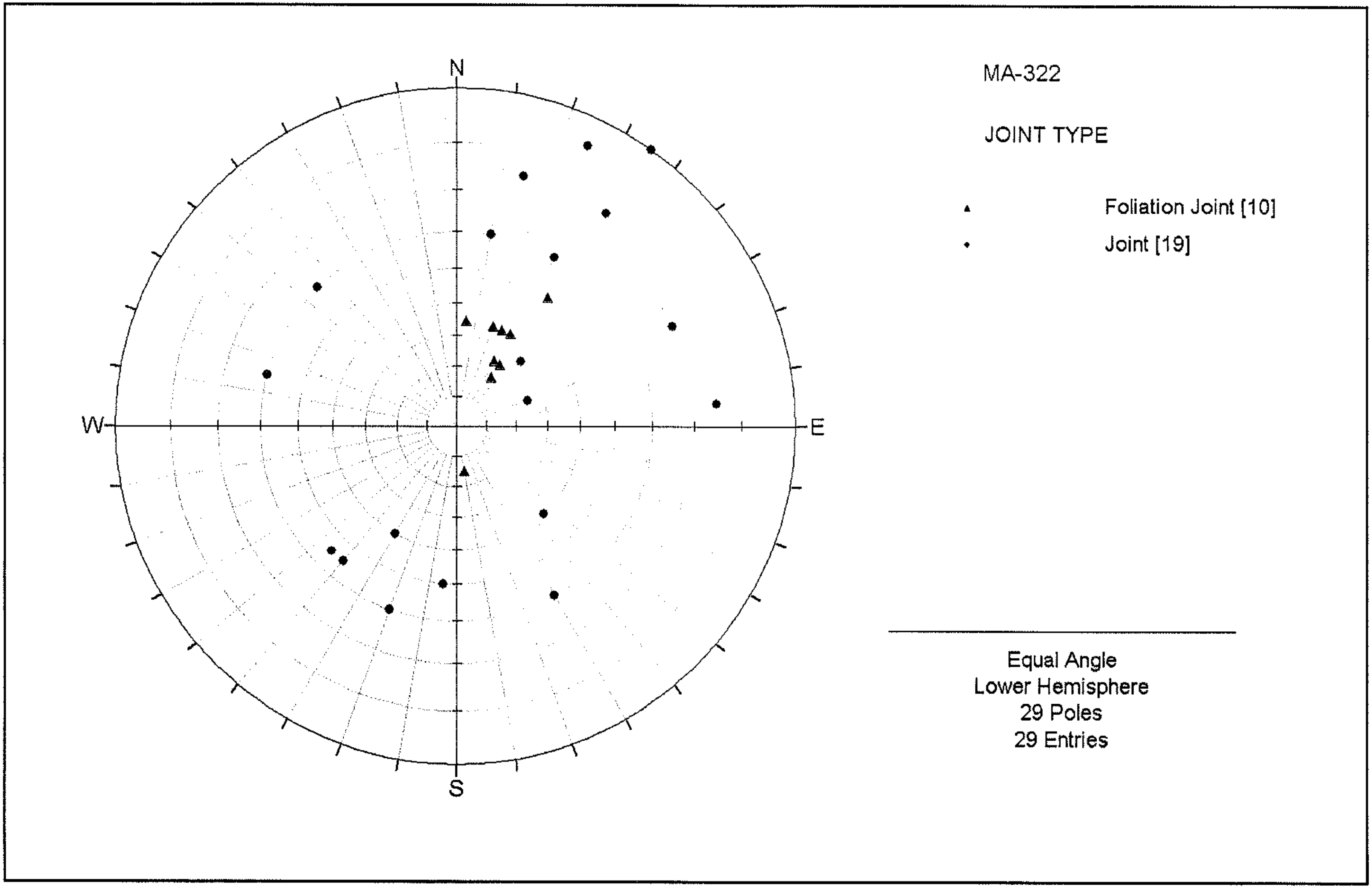
EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC
POLE PLOTS OF DISCONTINUITY DATA

APPENDIX A-3



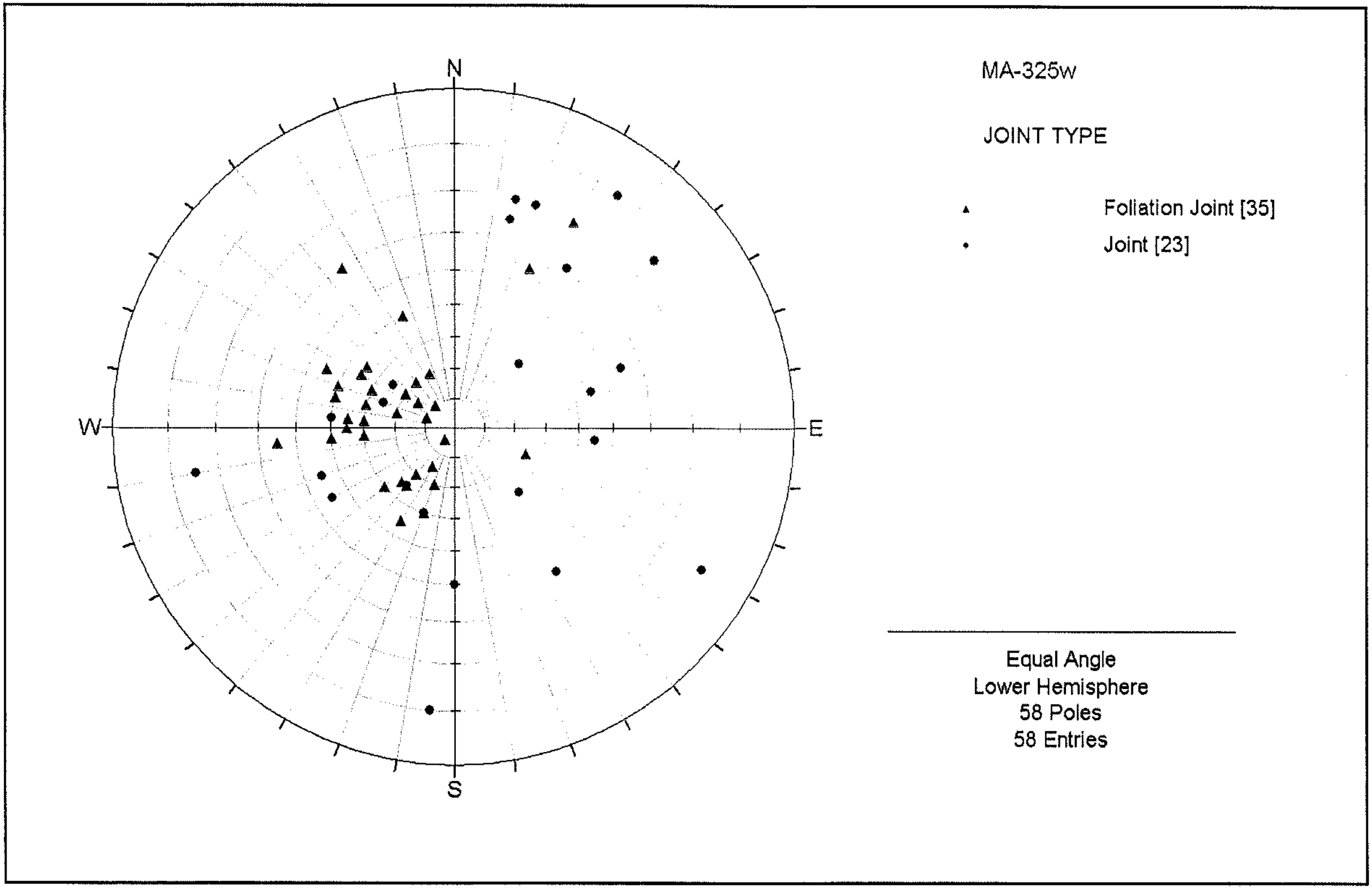
EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC
POLE PLOTS OF DISCONTINUITY DATA

APPENDIX A-3



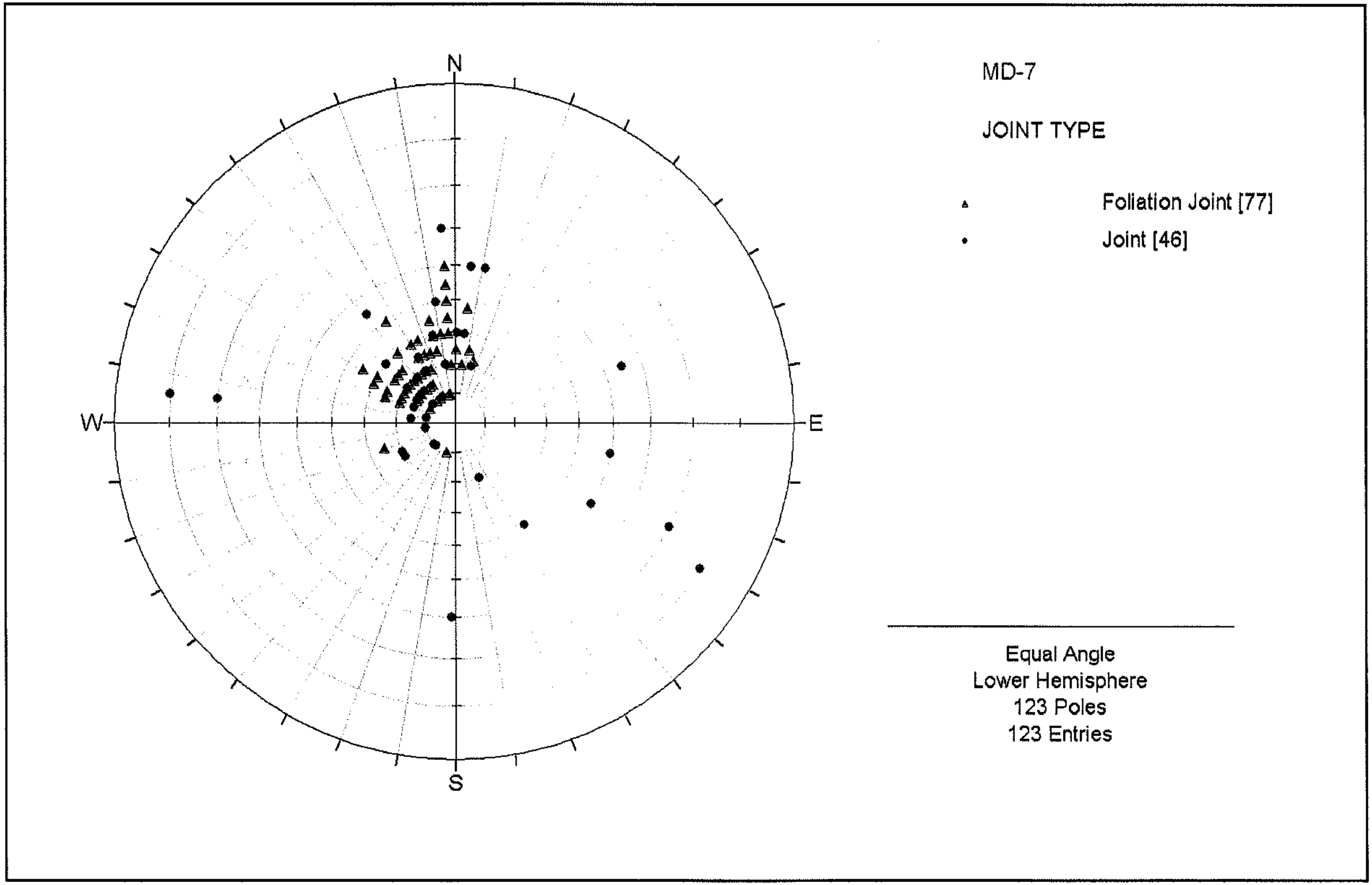
EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC
POLE PLOTS OF DISCONTINUITY DATA

APPENDIX A-3



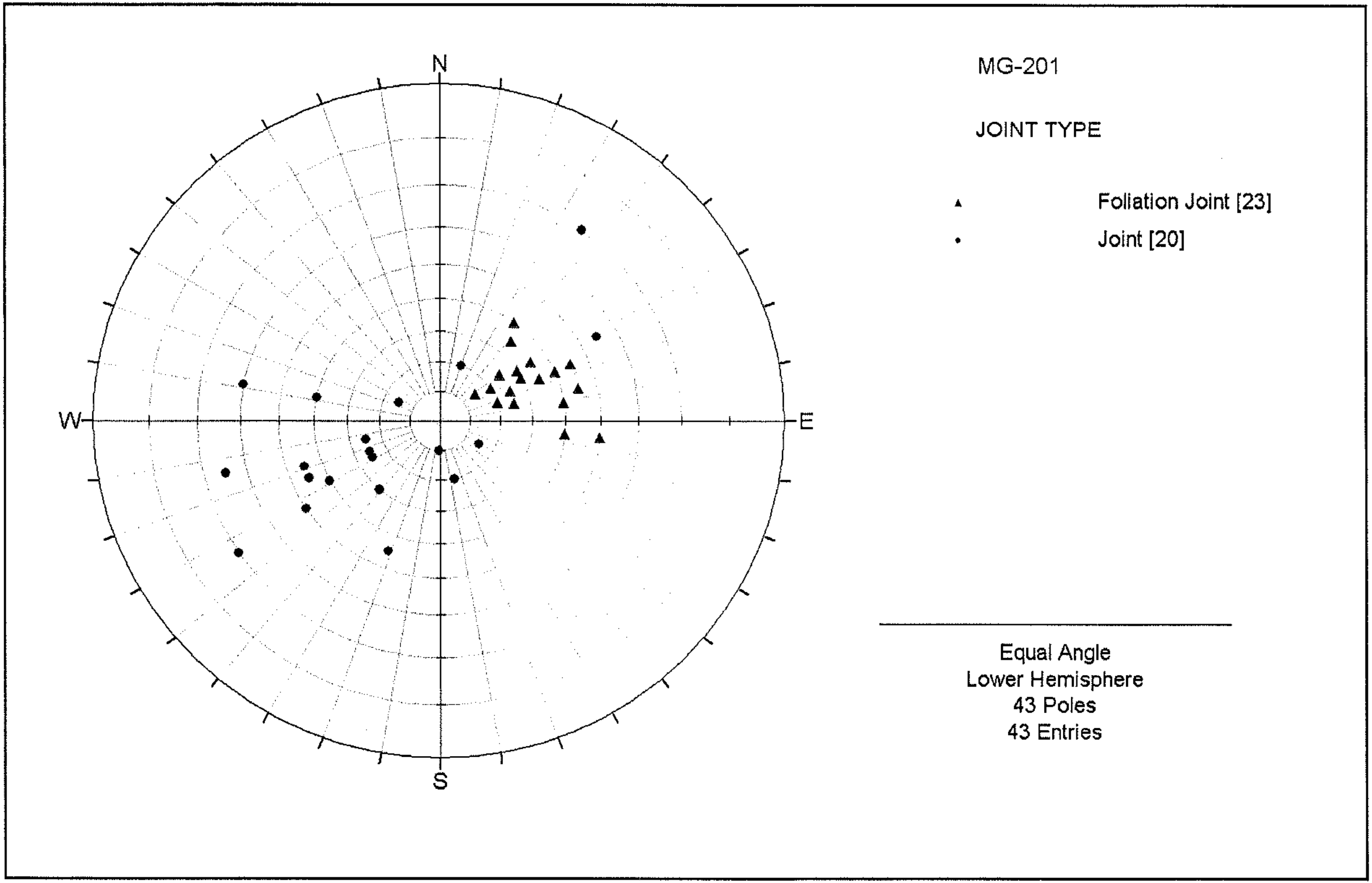
EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC
POLE PLOTS OF DISCONTINUITY DATA

APPENDIX A-3



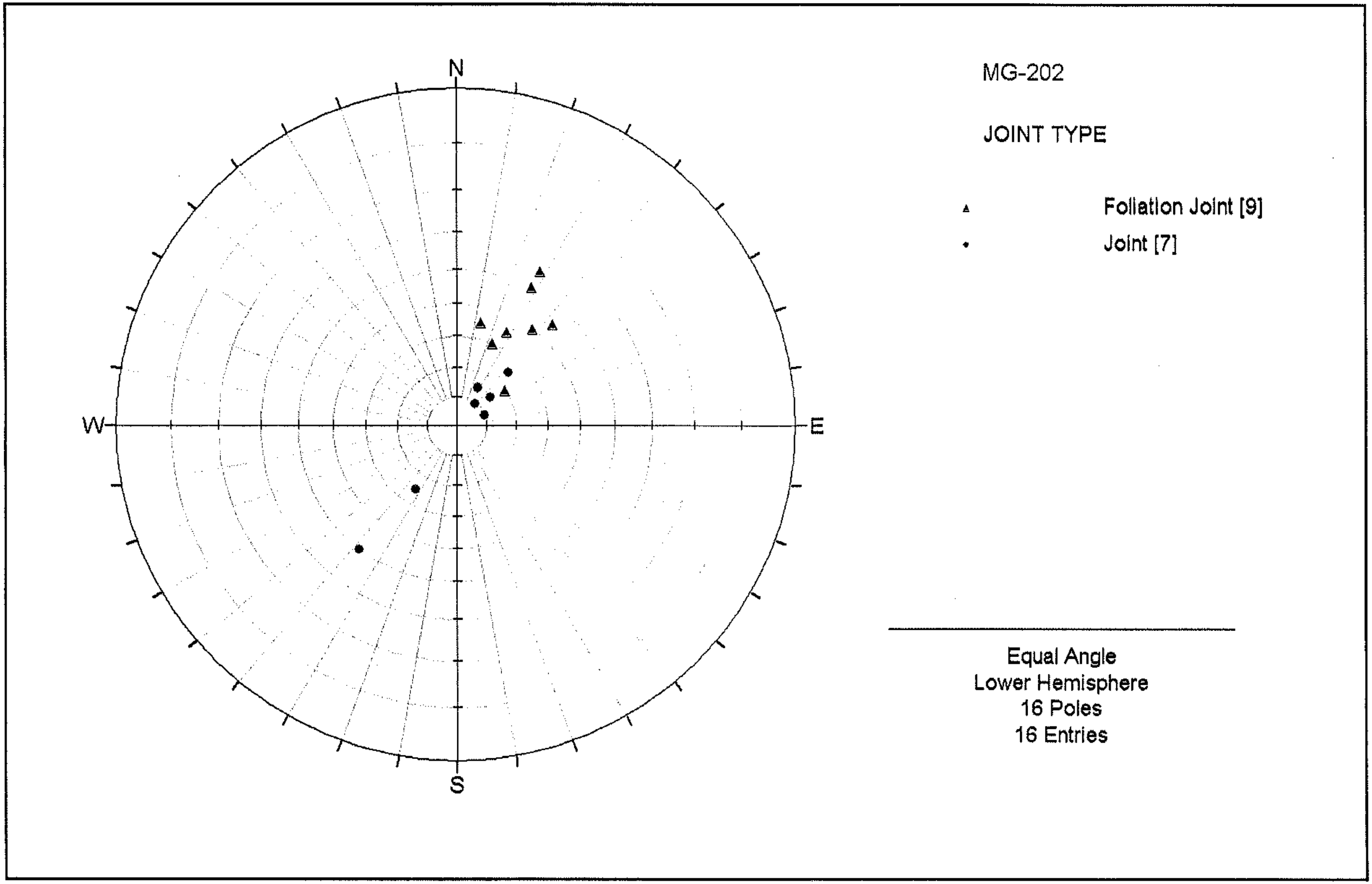
EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC
POLE PLOTS OF DISCONTINUITY DATA

APPENDIX A-3



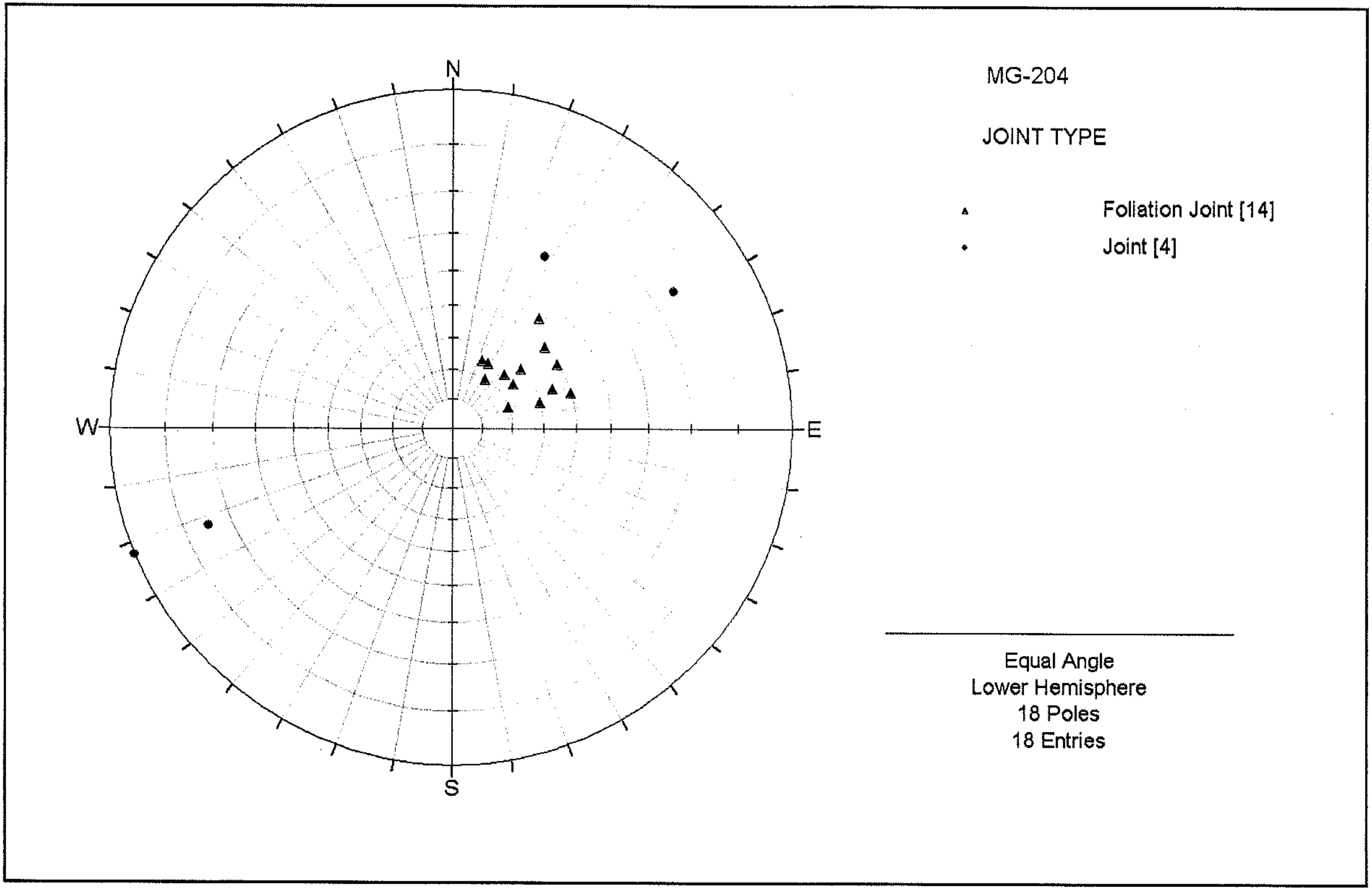
EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC
POLE PLOTS OF DISCONTINUITY DATA

APPENDIX A-3



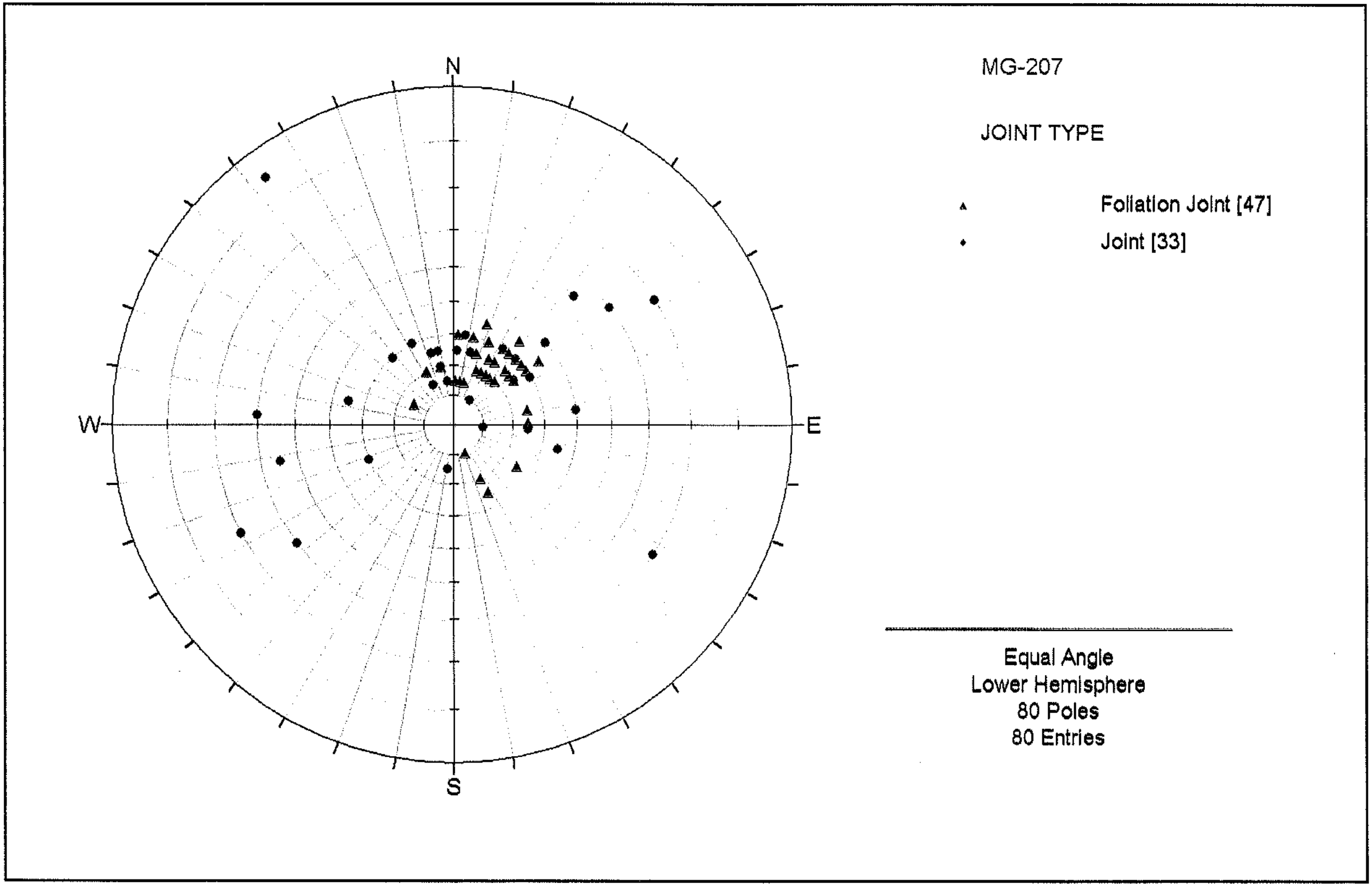
EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC
POLE PLOTS OF DISCONTINUITY DATA

APPENDIX A-3



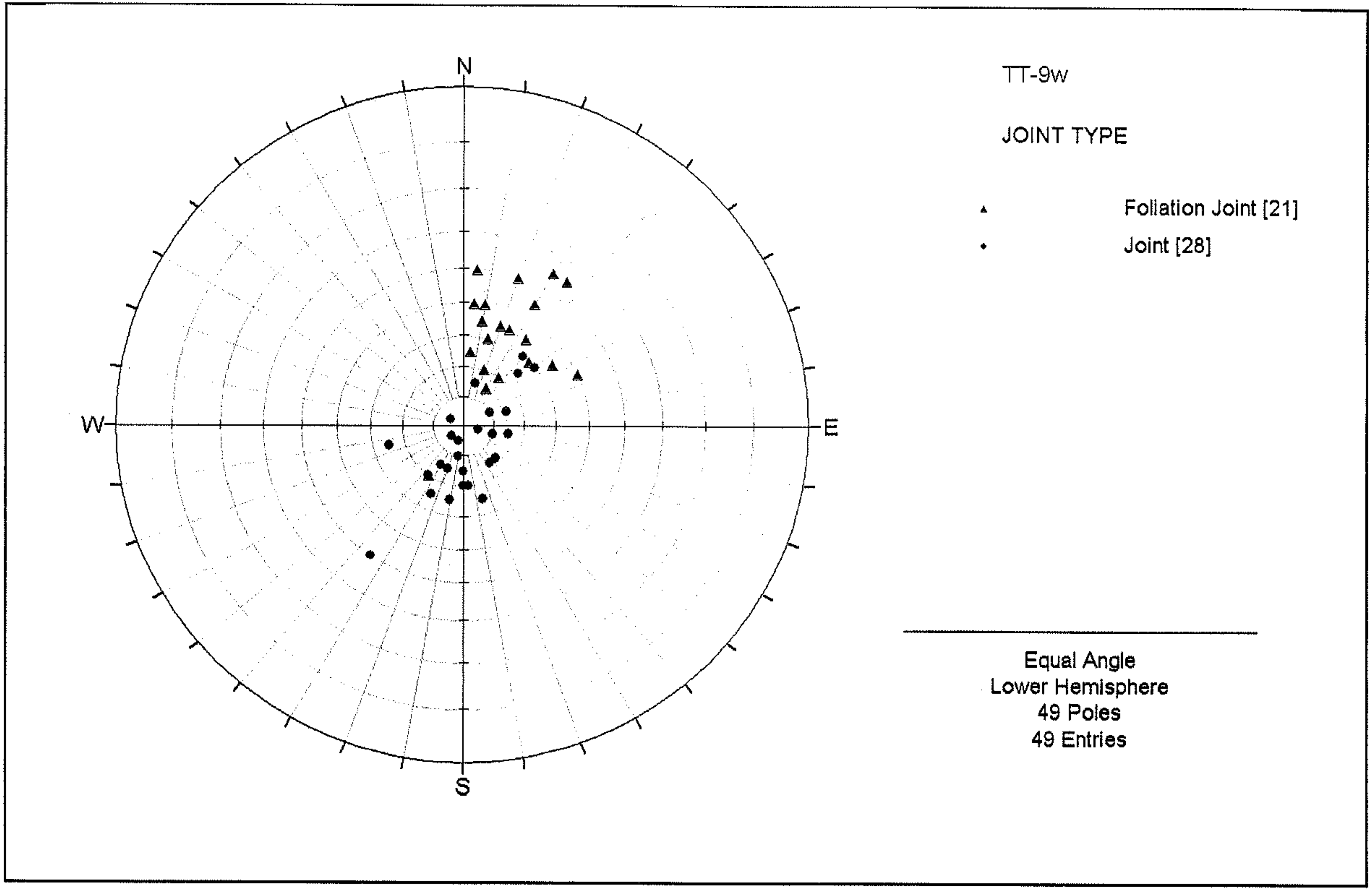
EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC
POLE PLOTS OF DISCONTINUITY DATA

APPENDIX A-3



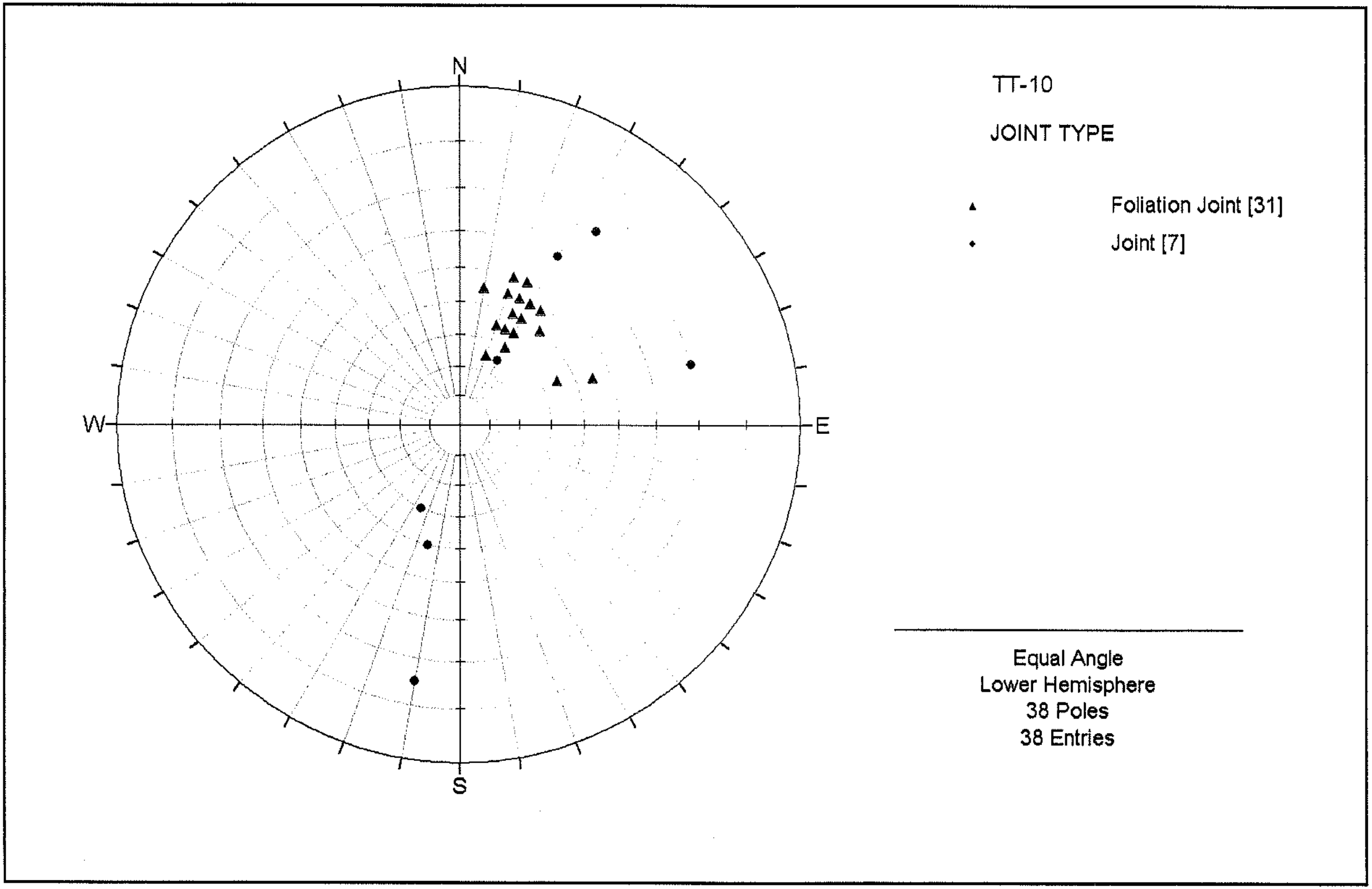
EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC
POLE PLOTS OF DISCONTINUITY DATA

APPENDIX A-3



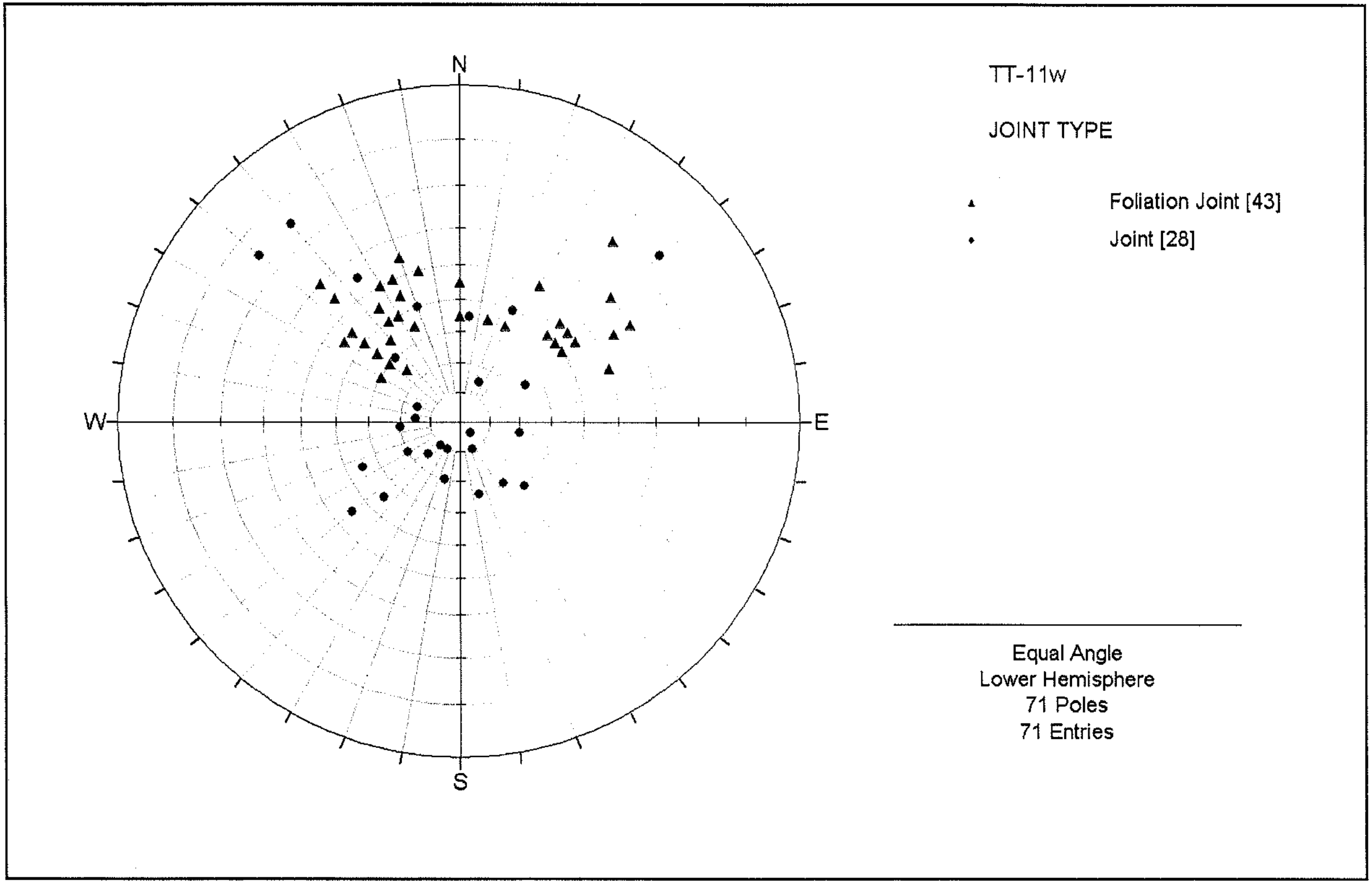
EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC
POLE PLOTS OF DISCONTINUITY DATA

APPENDIX A-3



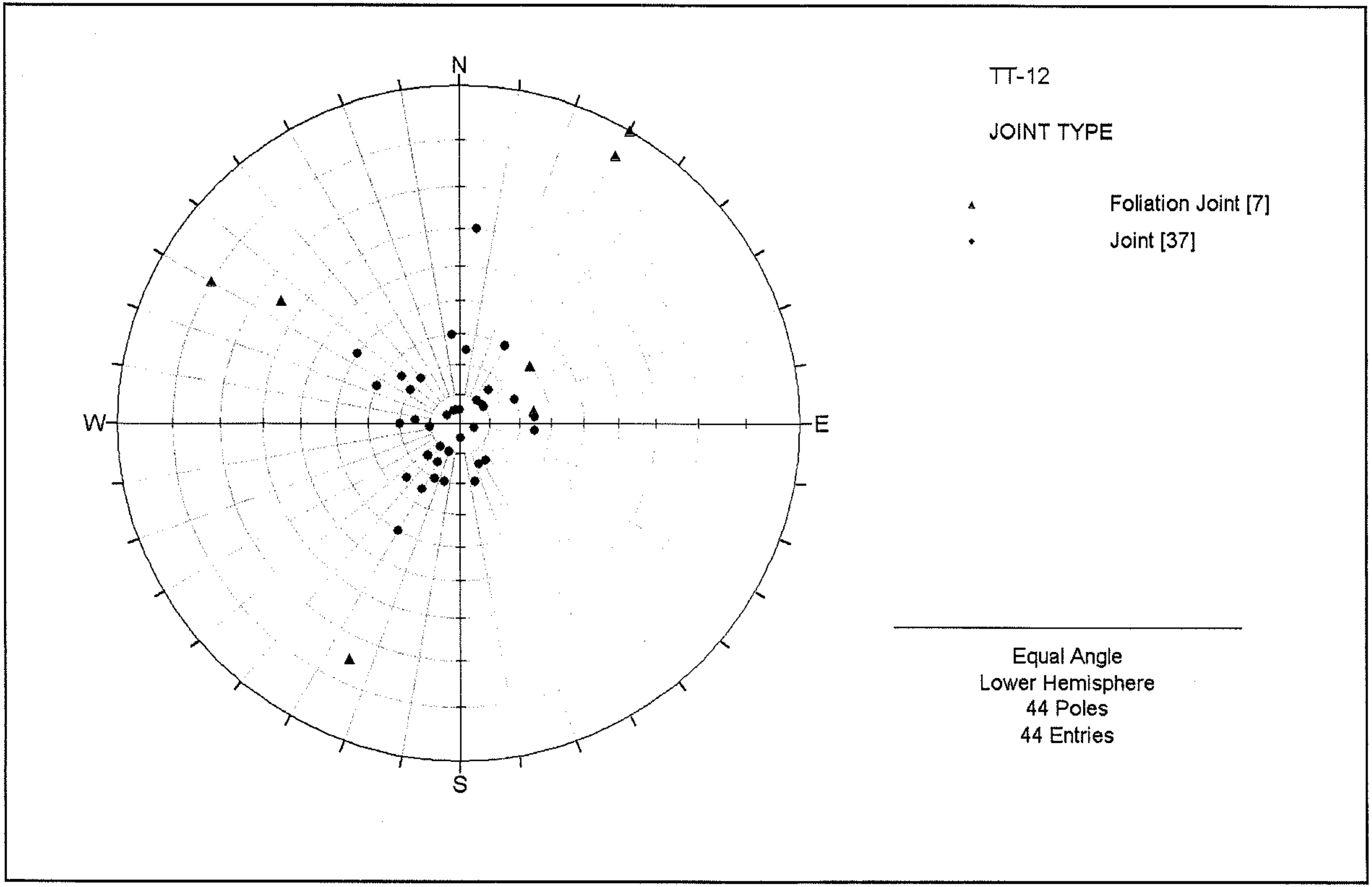
EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC
POLE PLOTS OF DISCONTINUITY DATA

APPENDIX A-3



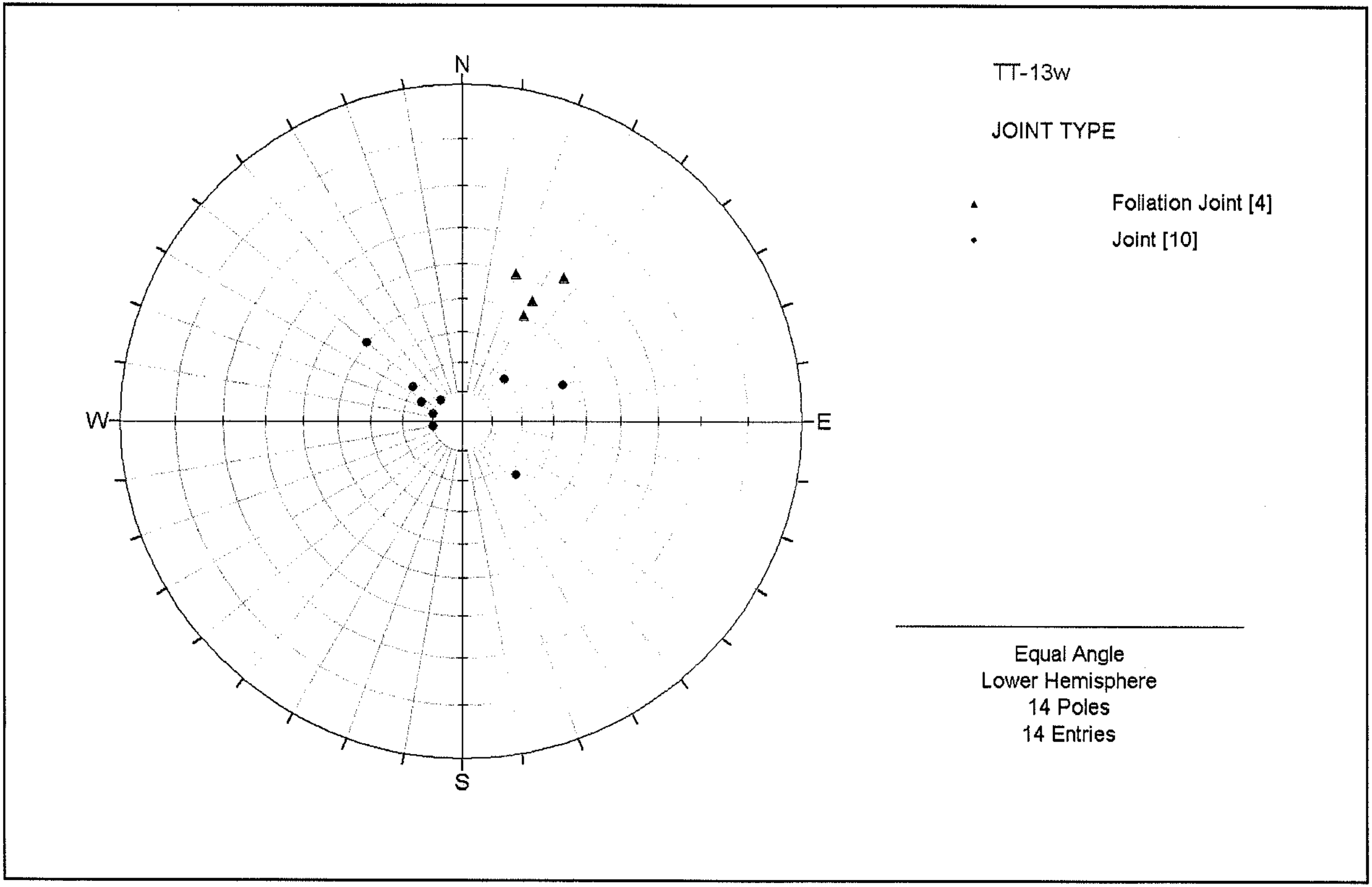
EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC
POLE PLOTS OF DISCONTINUITY DATA

APPENDIX A-3



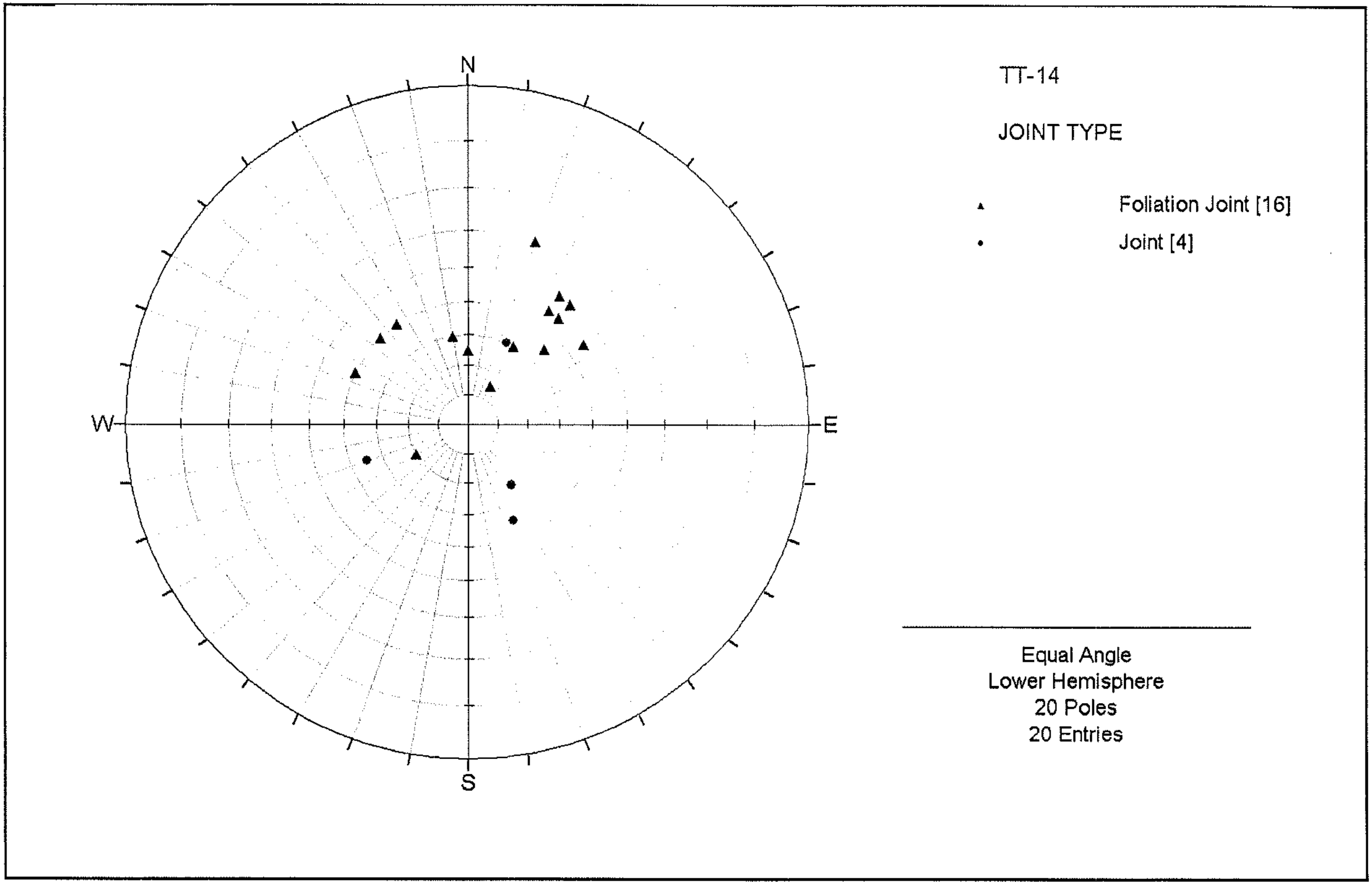
EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC
POLE PLOTS OF DISCONTINUITY DATA

APPENDIX A-3



EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC
POLE PLOTS OF DISCONTINUITY DATA

APPENDIX A-3



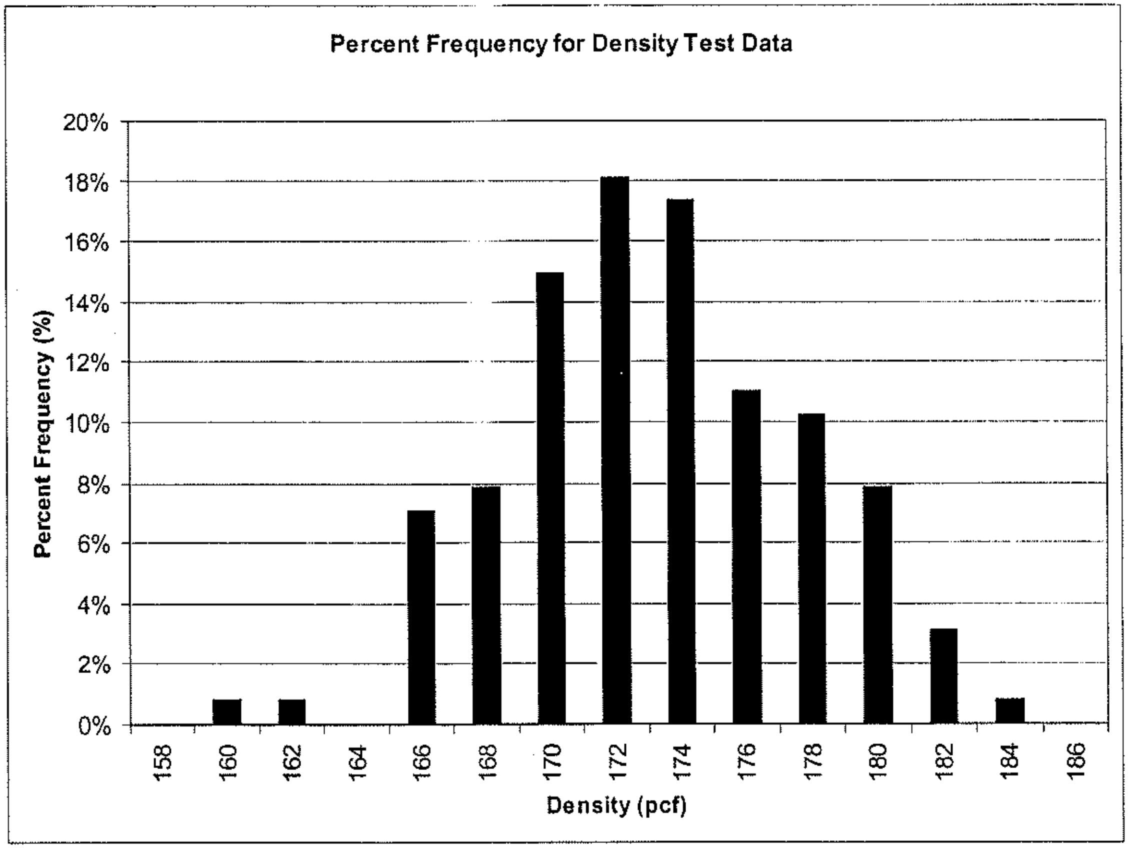
EQUAL ANGLE, LOWER HEMISPHERE STEREOGRAPHIC
POLE PLOTS OF DISCONTINUITY DATA

APPENDIX A-3

APPENDIX B

FREQUENCY HISTOGRAMS OF ROCK CORE LABORATORY TEST DATA

Density Frequency		
Minimum	**158.30**	
Maximum	**184.00**	
Bin	*Frequency*	*Percent*
158.00	0	0%
160.00	1	1%
162.00	1	1%
164.00	0	0%
166.00	9	7%
168.00	10	8%
170.00	19	15%
172.00	23	18%
174.00	22	17%
176.00	14	11%
178.00	13	10%
180.00	10	8%
182.00	4	3%
184.00	1	1%
186.00	0	0%
188.00	0	0%
190.00	0	0%
More	0	0%
Total	**127**	

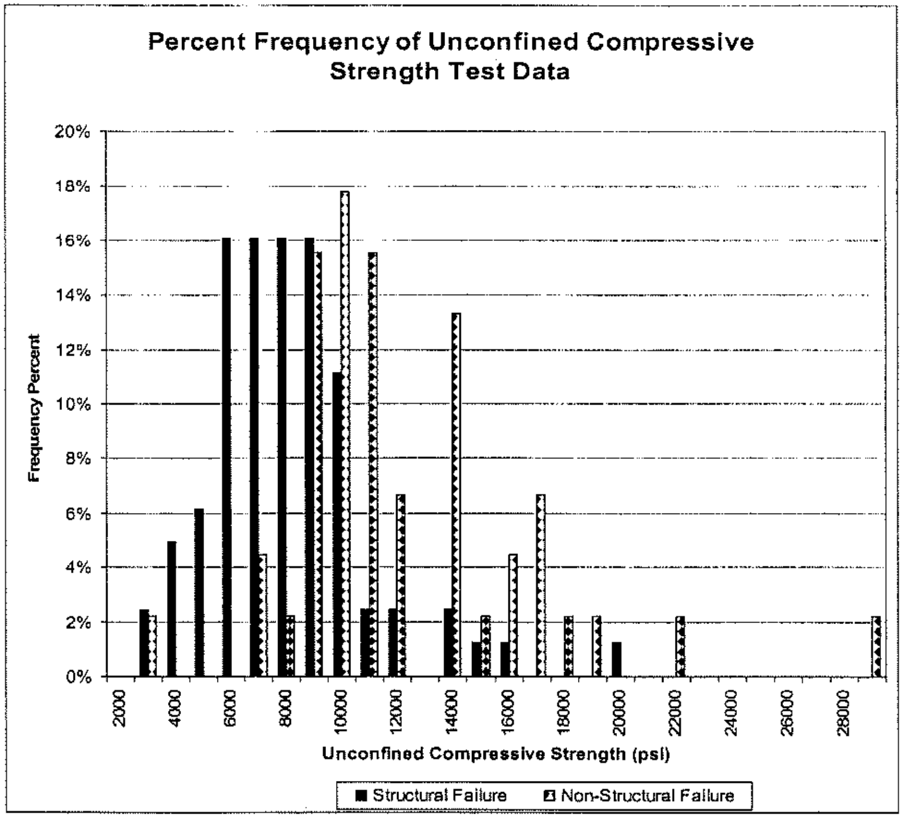


FREQUENCY HISTOGRAMS OF ROCK CORE
LABORATORY TEST DATA

APPENDIX B
SHEET 1

Structural UCS Frequency		
Minimum	2751.0	
Maximum	19686.0	
Bin	*Frequency*	*Percent*
2000	0	0%
3000	2	2%
4000	4	5%
5000	5	6%
6000	13	16%
7000	13	16%
8000	13	16%
9000	13	16%
10000	9	11%
11000	2	2%
12000	2	2%
13000	0	0%
14000	2	2%
15000	1	1%
16000	1	1%
17000	0	0%
18000	0	0%
19000	0	0%
20000	1	1%
21000	0	0%
22000	0	0%
23000	0	0%
24000	0	0%
25000	0	0%
26000	0	0%
27000	0	0%
28000	0	0%
29000	0	0%
More	0	0%
Total	81	

Non-Structural UCS Frequency		
Minimum	2303.0	
Maximum	28177.0	
Bin	*Frequency*	*Percent*
2000	0	0%
3000	1	2%
4000	0	0%
5000	0	0%
6000	0	0%
7000	2	4%
8000	1	2%
9000	7	16%
10000	8	18%
11000	7	16%
12000	3	7%
13000	0	0%
14000	6	13%
15000	1	2%
16000	2	4%
17000	3	7%
18000	1	2%
19000	1	2%
20000	0	0%
21000	0	0%
22000	1	2%
23000	0	0%
24000	0	0%
25000	0	0%
26000	0	0%
27000	0	0%
28000	0	0%
29000	1	2%
More	0	0%
Total	45	



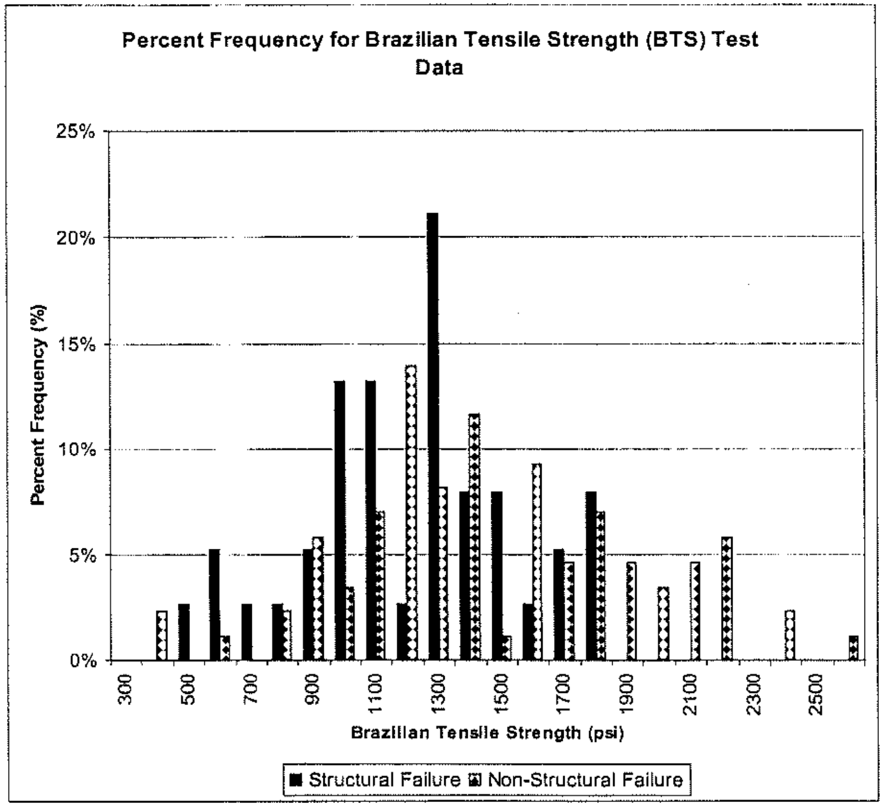
NOTES:
1) The uniaxial compressive strength (UCS) test data are separated to account for the effects of metamorphic fabric on ultimate strength. Test values that have been influenced by metamorphic fabric, mica concentrations, mineral veins or other features are classified as structural failures and do not represent the maximum value for the rock material. Test values that have not been influenced by such features are classified as non-structural failure.

FREQUENCY HISTOGRAMS OF ROCK CORE LABORATORY TEST DATA

APPENDIX B
SHEET 2

Structural BTS Frequency		
Minimum	490.00	
Maximum	1763.61	
Bin	*Frequency*	*Percent*
300	0	0%
400	0	0%
500	1	3%
600	2	5%
700	1	3%
800	1	3%
900	2	5%
1000	5	13%
1100	5	13%
1200	1	3%
1300	8	21%
1400	3	8%
1500	3	8%
1600	1	3%
1700	2	5%
1800	3	8%
1900	0	0%
2000	0	0%
2100	0	0%
2200	0	0%
2300	0	0%
2400	0	0%
2500	0	0%
2600	0	0%
More	0	0%
Total	**38**	

Non-Structural BTS Frequency		
Minimum	357.00	
Maximum	2550.00	
Bin	*Frequency*	*Percent*
300	0	0%
400	2	2%
500	0	0%
600	1	1%
700	0	0%
800	2	2%
900	5	6%
1000	3	3%
1100	6	7%
1200	12	14%
1300	7	8%
1400	10	12%
1500	1	1%
1600	8	9%
1700	4	5%
1800	6	7%
1900	4	5%
2000	3	3%
2100	4	5%
2200	5	6%
2300	0	0%
2400	2	2%
2500	0	0%
2600	1	1%
More	0	0%
Total	**86**	



NOTES:

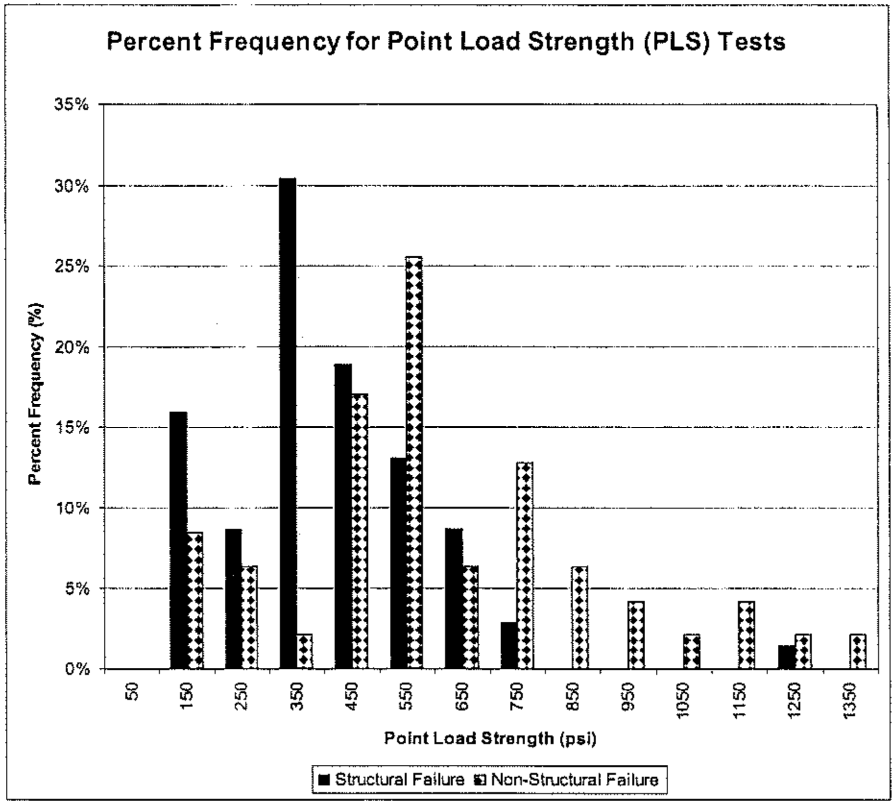
1) The Brazilian Tensile Strength (BTS) test data are separated to account for the effects of metamorphic fabric on ultimate strength. Test values that have been influenced by metamorphic fabric, mica concentrations, mineral veins or other features are classified as structural failures and do not represent the maximum value for the rock material. Test values that have not been influenced by such features are classified as non-structural failure.

FREQUENCY HISTOGRAMS OF ROCK CORE LABORATORY TEST DATA

APPENDIX B
SHEET 3

Structural PLS Frequency		
Minimum	71.00	
Maximum	1242.00	
Bin	*Frequency*	Percent
50	0	0%
150	11	16%
250	6	9%
350	21	30%
450	13	19%
550	9	13%
650	6	9%
750	2	3%
850	0	0%
950	0	0%
1050	0	0%
1150	0	0%
1250	1	1%
1350	0	0%
More	0	0%
Total	**69**	

Non-Structural PLS Frequency		
Minimum	64.00	
Maximum	1281.00	
Bin	*Frequency*	Percent
50	0	0%
150	4	9%
250	3	6%
350	1	2%
450	8	17%
550	12	26%
650	3	6%
750	6	13%
850	3	6%
950	2	4%
1050	1	2%
1150	2	4%
1250	1	2%
1350	1	2%
More	0	0%
Total	**47**	

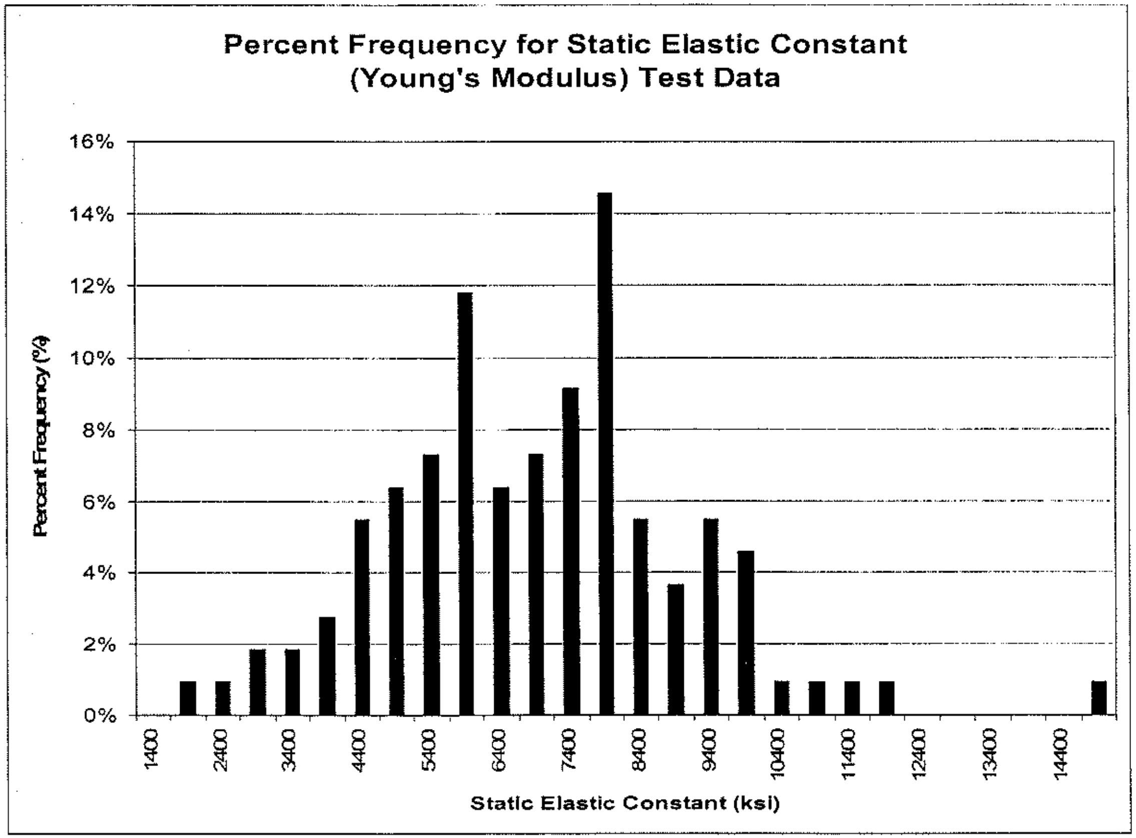


NOTES:
1) The point load strength (PLS) test data are separated to account for the effects of metamorphic fabric on ultimate strength. Test values that have been influenced by metamorphic fabric, mica concentrations, mineral veins or other features are classified as structural failures and do not represent the maximum value for the rock material. Test values that have not been influenced by such features are classified as non-structural failure.

FREQUENCY HISTOGRAMS OF ROCK CORE
LABORATORY TEST DATA

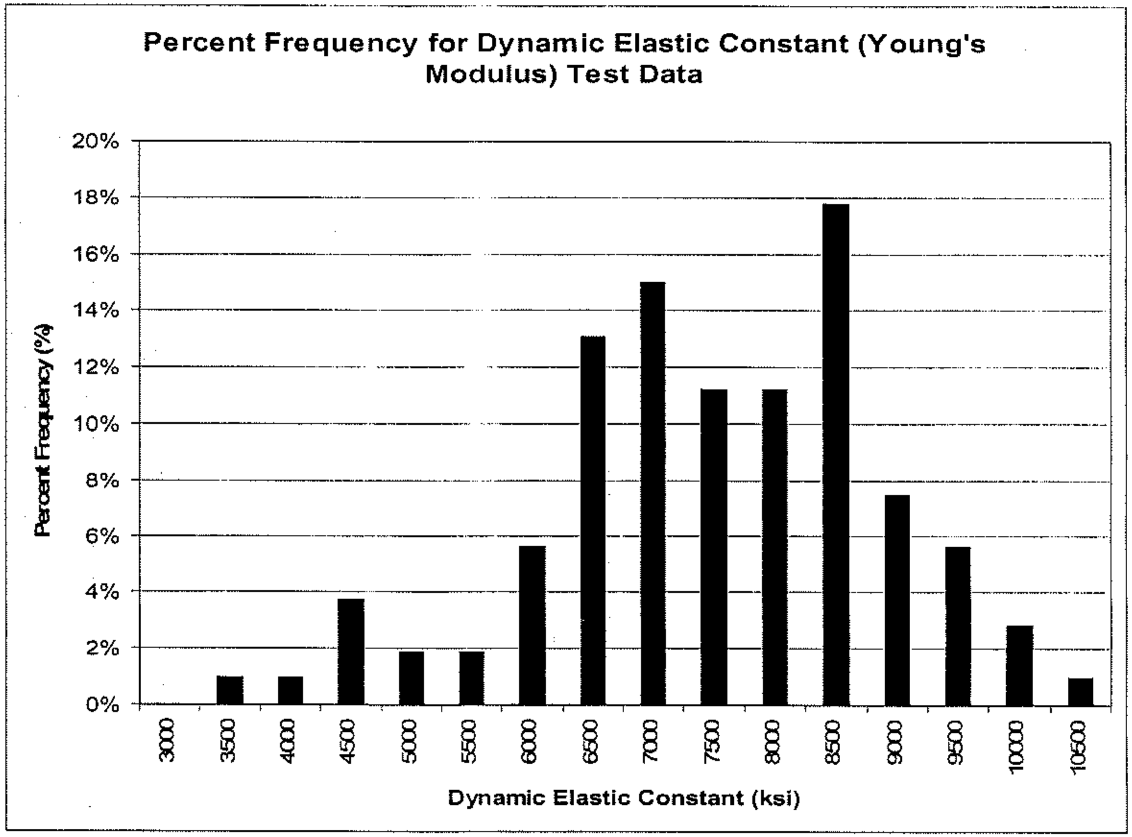
APPENDIX B
SHEET 4

Static Elastic Constant Frequency		
Minimum	**1567.00**	
Maximum	**14626.00**	
Bin	*Frequency*	*Percent*
1400	0	0%
1900	1	1%
2400	1	1%
2900	2	2%
3400	2	2%
3900	3	3%
4400	6	5%
4900	7	6%
5400	8	7%
5900	13	12%
6400	7	6%
6900	8	7%
7400	10	9%
7900	16	15%
8400	6	5%
8900	4	4%
9400	6	5%
9900	5	5%
10400	1	1%
10900	1	1%
11400	1	1%
11900	1	1%
12400	0	0%
12900	0	0%
13400	0	0%
13900	0	0%
14400	0	0%
14900	1	1%
More	0	0%
Total	110	



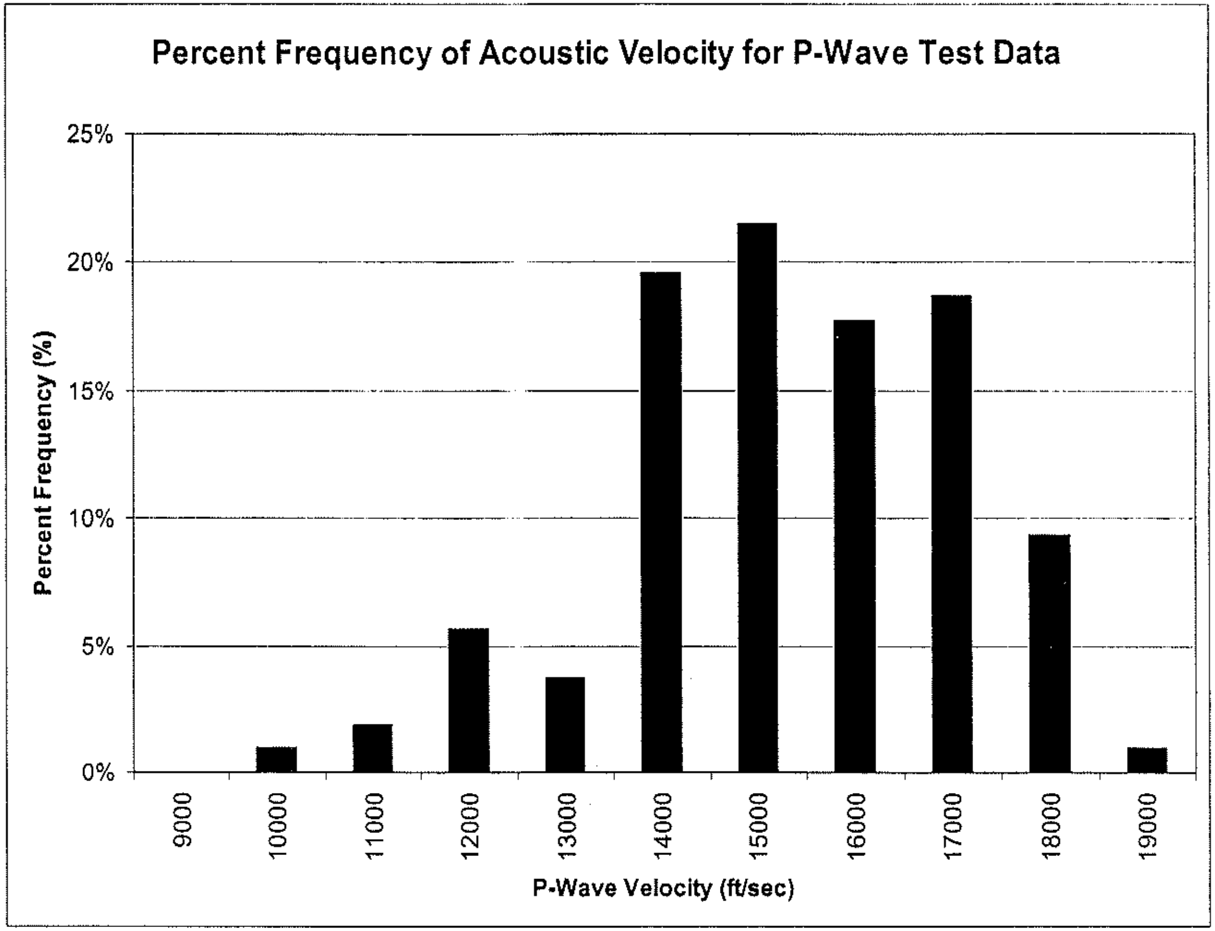
FREQUENCY HISTOGRAMS OF ROCK CORE LABORATORY TEST DATA

Dynamic Elastic Constant Frequency		
Minimum	3037.00	
Maximum	10059.00	
Bin	*Frequency*	*Percent*
3000	0	0%
3500	1	1%
4000	1	1%
4500	4	4%
5000	2	2%
5500	2	2%
6000	6	6%
6500	14	13%
7000	16	15%
7500	12	11%
8000	12	11%
8500	19	18%
9000	8	7%
9500	6	6%
10000	3	3%
10500	1	1%
More	0	0%
Total	**107**	



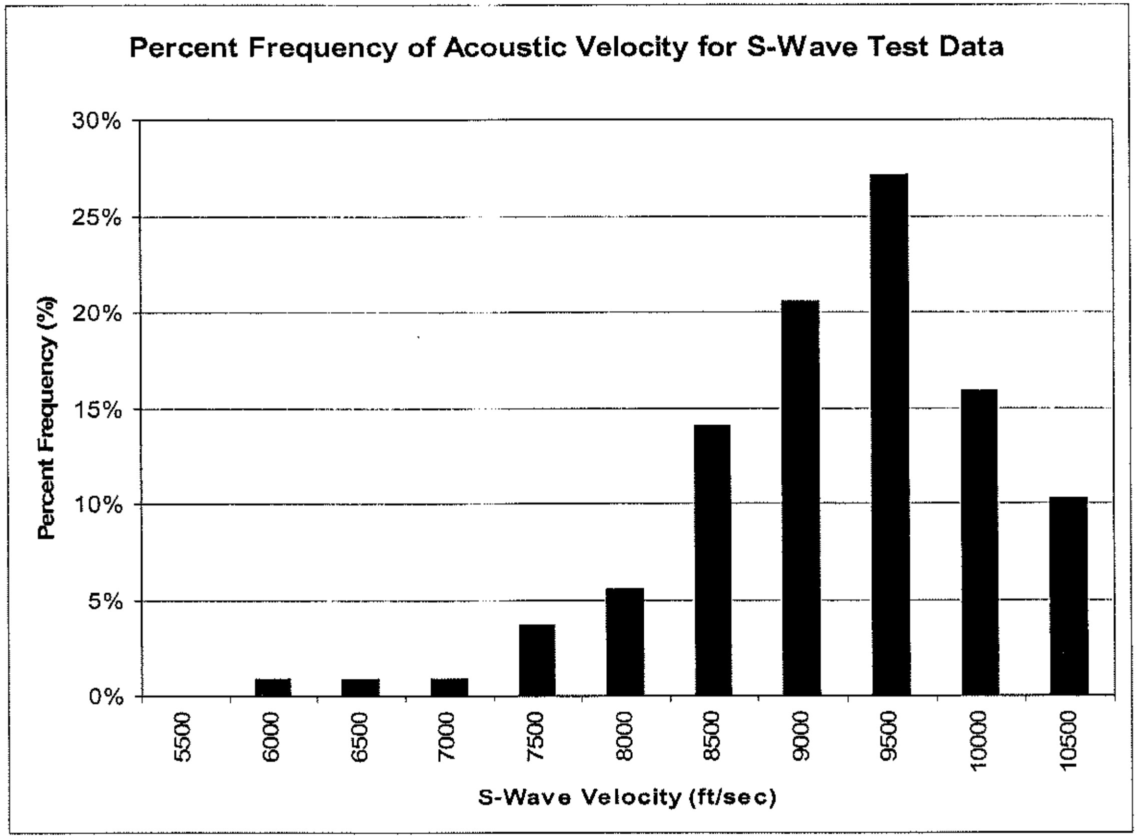
FREQUENCY HISTOGRAMS OF ROCK CORE LABORATORY TEST DATA

P-Wave Velocity Frequency		
Minimum	**9811.00**	
Maximum	**18270.00**	
Bin	*Frequency*	*Percent*
9000	0	0%
10000	1	1%
11000	2	2%
12000	6	6%
13000	4	4%
14000	21	20%
15000	23	21%
16000	19	18%
17000	20	19%
18000	10	9%
19000	1	1%
More	0	0%
Total	**107**	



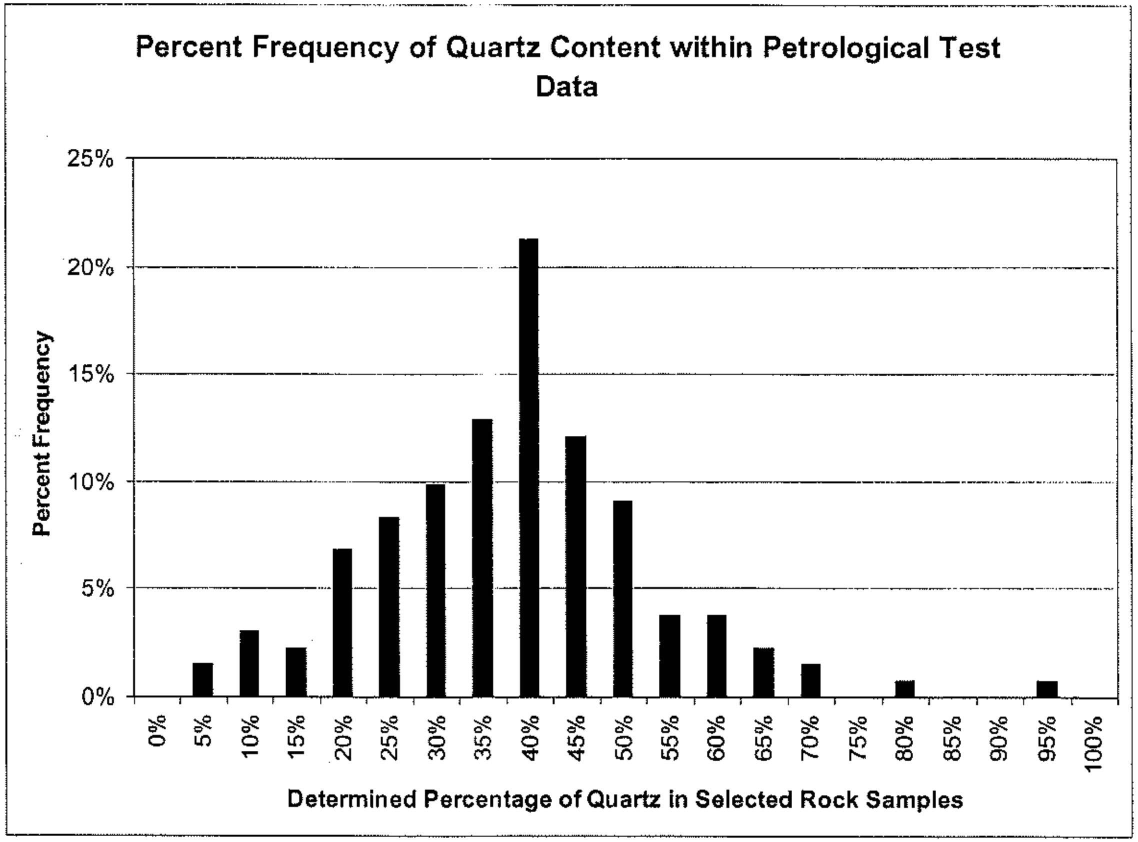
FREQUENCY HISTOGRAMS OF ROCK CORE
LABORATORY TEST DATA

S-Wave Velocity Frequency		
Minimum	5886.00	
Maximum	10400.00	
Bin	*Frequency*	*Percent*
5500	0	0%
6000	1	1%
6500	1	1%
7000	1	1%
7500	4	4%
8000	6	6%
8500	15	14%
9000	22	21%
9500	29	27%
10000	17	16%
10500	11	10%
More	0	0%
Total	107	



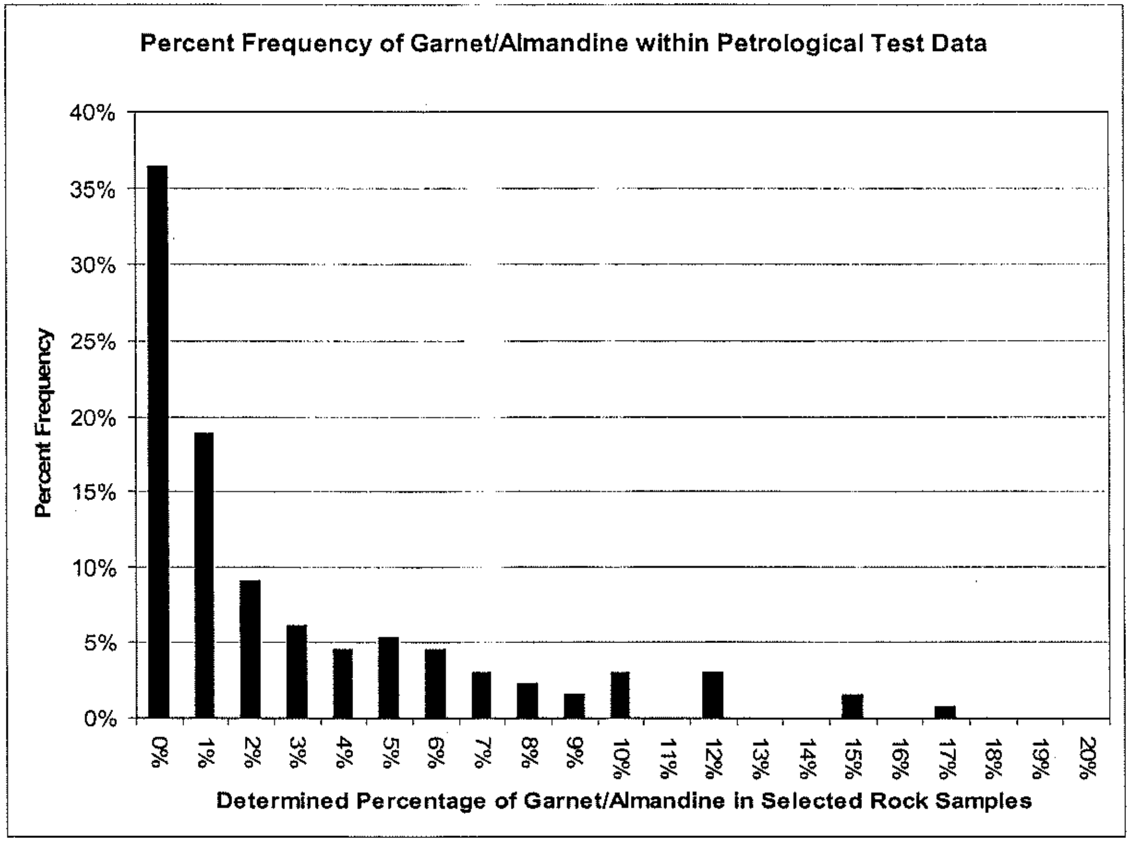
FREQUENCY HISTOGRAMS OF ROCK CORE LABORATORY TEST DATA

Quartz Content Frequency		
Minimum	4	
Maximum	95	
Bin	*Frequency*	Percent
0%	0	0%
5%	2	2%
10%	4	3%
15%	3	2%
20%	9	7%
25%	11	8%
30%	13	10%
35%	17	13%
40%	28	21%
45%	16	12%
50%	12	9%
55%	5	4%
60%	5	4%
65%	3	2%
70%	2	2%
75%	0	0%
80%	1	1%
85%	0	0%
90%	0	0%
95%	1	1%
100%	0	0%
More	0	
Total	**132**	



FREQUENCY HISTOGRAMS OF ROCK CORE LABORATORY TEST DATA

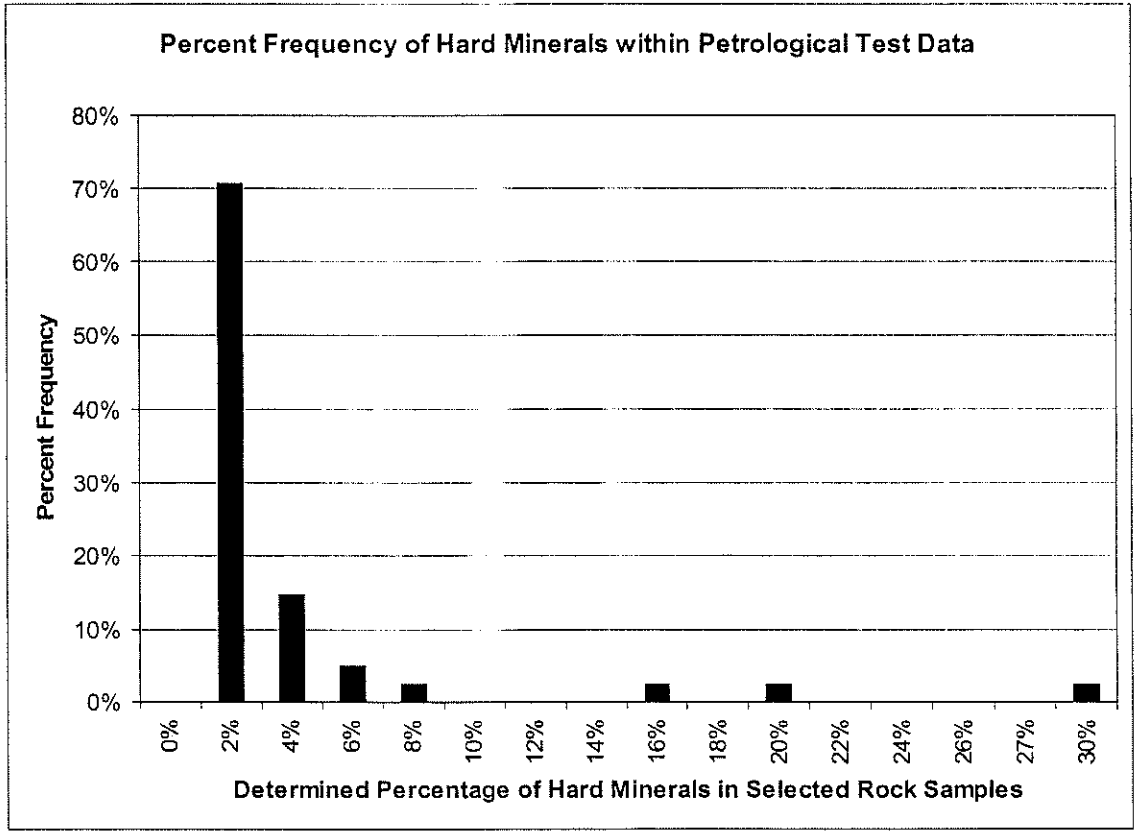
Percent Frequency of Garnet/Almandine		
Minimum	**0**	
Maximum	**17**	
Bin	*Frequency*	*Percent*
0%	48	36%
1%	25	19%
2%	12	9%
3%	8	6%
4%	6	5%
5%	7	5%
6%	6	5%
7%	4	3%
8%	3	2%
9%	2	2%
10%	4	3%
11%	0	0%
12%	4	3%
13%	0	0%
14%	0	0%
15%	2	2%
16%	0	0%
17%	1	1%
18%	0	0%
19%	0	0%
20%	0	0%
More	0	
Total	**132**	



FREQUENCY HISTOGRAMS OF ROCK CORE LABORATORY TEST DATA

APPENDIX B
SHEET 10

Hard Mineral Content Frequency[1]		
Minumum	1	
Maximum	30	
Bin	*Frequency*	*Percent*
0%	0	0%
2%	29	71%
4%	6	15%
6%	2	5%
8%	1	2%
10%	0	0%
12%	0	0%
14%	0	0%
16%	1	2%
18%	0	0%
20%	1	2%
22%	0	0%
24%	0	0%
26%	0	0%
27%	0	0%
30%	1	2%
More	0	0%
Total	41	

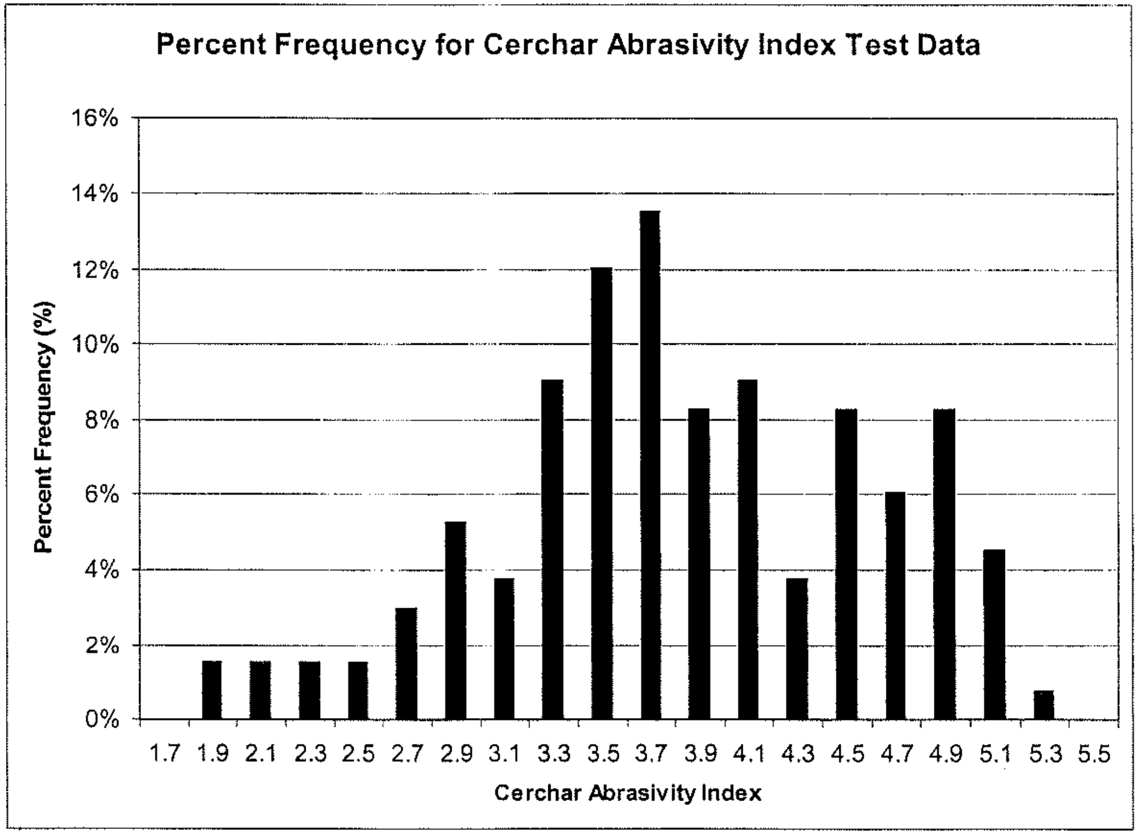


NOTES:
1) Andalusite, Sillimanite, Staurolite, Tourmaline and Kyanite all have a Moh's Hardness of 7 or greater and were used to complete this Hard Mineral frequency histogram. Quartz and Garnet/Almandine percentage determinations are presented in separate histograms.

FREQUENCY HISTOGRAMS OF ROCK CORE LABORATORY TEST DATA

APPENDIX B
SHEET 11

Cerchar Abrasivity Frequency		
Minimum	**1.7**	
Maximum	**5.2**	
Bin	*Frequency*	*Percent*
1.5	0	0%
1.7	0	0%
1.9	2	2%
2.1	2	2%
2.3	2	2%
2.5	2	2%
2.7	4	3%
2.9	7	5%
3.1	5	4%
3.3	12	9%
3.5	16	12%
3.7	18	14%
3.9	11	8%
4.1	12	9%
4.3	5	4%
4.5	11	8%
4.7	8	6%
4.9	11	8%
5.1	6	5%
5.3	1	1%
5.5	0	0%
More	0	0%
Total	**135**	



FREQUENCY HISTOGRAMS OF ROCK CORE LABORATORY TEST DATA

APPENDIX C

ROCK MASS CLASSIFICATION BY THE Q AND RMR SYSTEMS

Boring Number	Core Run No.	From (ft)	To (ft)	RQD					Jn					Jr					Ja					Jw					SRF					Q					RMR `15 log Q + 50 (1)	NOTES
				Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean		
TT-1		12.0	53.0	45	95	65	95	77	3.0	9.0	4.0	9.0	6.8	0.5	1.5	1.5	1.5	1.3	1.0	5.0	5.0	5.0	1.8	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	0.3	31.4	1.4	4.7	5.4	61.0	
		53.0	end	95	95	95	95	95	2.0	4.0	3.0	4.0	3.3	1.5	1.5	1.5	1.5	1.5	1.0	2.0	2.0	2.0	1.7	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	11.8	47.0	11.8	15.7	16.8	68.4	
TT2		12.0	32.0	75	85	75	85	80	4.0	9.0	4.0	9.0	6.5	1.5	1.5	1.5	1.5	1.5	2.0	4.0	2.0	4.0	3.0	0.66	0.66	0.66	0.66	0.66	2.5	2.5	2.5	2.5	2.5	0.8	4.2	0.8	4.2	1.6	53.2	
		32.0	end	85	95	85	95	93	2.0	6.0	3.0	6.0	3.9	1.5	1.5	1.5	1.5	1.5	1.0	2.0	1.0	2.0	1.4	0.66	1.00	0.66	1.00	0.70	1.0	1.0	1.0	1.0	1.0	7.0	71.3	7.0	47.5	17.9	68.8	
TT-3				65	95	85	95	88	1.0	9.0	4.0	9.0	5.0	1.5	1.5	1.5	1.5	1.5	1.0	3.0	1.0	2.0	1.9	0.66	1.00	0.66	1.00	0.70	1.0	1.0	1.0	1.0	1.0	2.4	142.5	4.7	35.6	9.7	64.8	
TT-4		22.0	end	95	95	95	95	95	1.0	4.0	4.0	4.0	3.3	1.0	1.5	1.5	1.5	1.4	1.0	6.0	1.0	3.0	2.8	0.66	1.00	1.00	1.00	0.90	1.0	1.0	1.0	1.0	1.0	2.6	142.5	11.9	35.6	13.0	66.7	
TT-5		66.0	92.0	45	75	65	75	62	1.0	9.0	9.0	9.0	7.3	1.0	1.0	1.0	1.0	1.0	1.0	3.0	1.0	3.0	2.0	0.66	1.00	0.66	0.66	0.70	1.0	1.0	1.0	1.0	1.0	1.1	75.0	1.6	5.5	3.0	57.1	
	omits 66 to 92'	32.0	end	45	95	85	95	86	2.0	6.0	3.0	6.0	3.9	0.5	3.0	0.5	3.0	1.4	1.0	2.0	1.0	1.0	1.3	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	1.9	142.5	7.1	95.0	23.7	70.6	
TT-6		20.0	56.0	95	95	95	95	95	4.0	9.0	4.0	4.0	5.3	1.0	1.5	1.5	1.5	1.4	2.0	4.0	2.0	4.0	2.8	0.66	1.00	1.00	1.00	0.90	1.0	1.0	1.0	1.0	1.0	1.7	17.8	8.9	17.8	8.1	63.6	
		56.0	end	95	95	95	95	95	1.0	3.0	1.0	3.0	1.8	1.0	1.5	1.0	1.5	1.3	0.8	2.0	1.0	2.0	1.4	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	15.8	190.0	15.8	142.5	49.0	75.4	
TT-7		15.5	51.0	85	95	85	85	88	3.0	9.0	9.0	9.0	7.5	1.5	1.5	1.5	1.5	1.5	2.0	6.0	2.0	2.0	3.0	0.66	1.00	0.66	0.66	0.70	1.0	1.0	1.0	1.0	1.0	1.6	23.8	4.7	4.7	4.1	59.2	
		51.0	end	85	95	95	95	94	0.5	4.0	0.5	4.0	1.7	0.5	4.0	0.5	4.0	1.6	0.8	3.0	0.8	2.0	1.6	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	3.5	1013.3	5.9	1013.3	55.3	76.1	
TT-8				95	95	95	95	95	1.0	4.0	1.0	4.0	2.6	1.0	3.0	1.5	3.0	1.9	0.8	2.0	0.8	2.0	1.5	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	11.9	380.0	17.8	380.0	46.3	75.0	
TT-9W		45.3	end	85	95	95	95	94	0.5	4.0	2.0	4.0	3.2	1.5	4.0	1.5	3.0	1.9	0.8	2.0	1.0	2.0	1.4	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	15.9	1013.3	17.8	142.5	39.9	74.0	
TT-10	omits 120' to 130'	35.5	198.5	5	95	85	95	92	1.0	6.0	1.0	4.0	2.6	0.5	3.0	1.0	1.5	1.4	1.0	3.0	1.0	2.0	1.5	0.66	1.00	0.66	1.00	1.00	1.0	1.0	1.0	1.0	1.0	0.1	285.0	7.0	142.5	33.0	72.8	
		120.0	130.0	25	45	25	45	35	3.0	4.0	3.0	4.0	3.5	1.5	1.5	1.5	1.5	1.5	1.0	4.0	1.0	4.0	2.5	0.66	1.00	0.66	1.00	0.80	5.0	5.0	5.0	5.0	5.0	0.3	4.5	0.3	4.5	1.0	49.7	
TT-11W		61.6	end	85	95	95	95	94	0.5	9.0	4.0	9.0	4.3	0.5	4.0	1.0	3.0	1.7	0.8	4.0	1.0	2.0	1.7	0.66	1.00	0.66	1.00	0.80	1.0	1.0	1.0	1.0	1.0	0.8	1013.3	3.5	71.3	17.5	68.6	
TT-12				55	95	85	95	94	1.0	4.0	1.0	3.0	2.1	1.0	1.5	1.0	1.5	1.4	1.0	4.0	1.0	2.0	1.7	0.66	1.00	0.66	1.00	1.00	1.0	1.0	1.0	1.0	1.0	2.3	142.5	9.4	142.5	36.9	73.5	
TT-13W		25.0	end	95	95	95	95	95	0.5	4.0	0.5	4.0	2.4	1.0	4.0	1.5	1.5	1.8	0.8	2.0	1.0	2.0	1.2	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	11.9	1013.3	17.8	285.0	59.4	76.6	
TT-14				15	95	85	95	83	0.5	6.0	1.0	4.0	2.9	1.0	4.0	1.0	1.5	1.4	0.8	4.0	1.0	3.0	2.0	0.66	1.00	0.66	1.00	1.00	1.0	1.0	1.0	1.0	1.0	0.4	1013.3	4.7	142.5	20.0	69.5	
TT-15		19.0	end	85	95	95	95	93	1.0	6.0	1.0	4.0	3.2	0.5	3.0	1.5	1.5	1.5	1.0	3.0	1.0	2.0	1.9	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	2.4	285.0	17.8	142.5	22.9	70.4	
TT-17		22.0	end	75	95	95	95	92	0.5	9	1.0	3.0	2.4	1.0	4.0	1.0	1.5	2.1	0.8	6.0	0.8	2.0	2.2	0.66	1.00	1.00	1.00	0.93	1.0	1.0	1.0	1.0	1.0	0.9	1013.3	15.8	190.0	34.0	73.0	
MD-8A		0.0	36.5	65	95	70	90	77	4.0	9	4.0	9.0	6.0	1.0	1.5	1.0	1.0	1.1	1.0	1.0	1.0	1.0	1.0	0.66	1.00	0.66	1.00	0.80	1.0	1.0	1.0	1.0	1.0	4.8	35.6	5.1	22.5	11.3	65.8	
		36.5	end	95	95	95	95	95	2.0	4	2.0	4.0	3.4	1.0	1.5	1.0	1.0	1.1	1.0	1.0	1.0	1.0	1.0	0.66	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	15.7	71.3	23.8	47.5	30.7	72.3	
MD-18		11.0	21.0	75	75	75	75	75	9.0	9	9.0	9.0	9.0	1.5	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	4.1	4.1	4.1	4.1	4.1	59.2	
		21.0	end	85	95	95	95	94	0.5	9	0.5	4.0	2.8	0.5	1.5	0.5	1.5	1.2	0.8	4.0	2.0	4.0	2.6	0.66	1.00	1.00	1.00	0.90	1.0	1.0	1.0	1.0	1.0	0.8	380.0	3.0	142.5	13.9	67.2	
MG-24A	Omit C3 & C4	40.0	end	95	95	95	95	95	3.0	4.0	3.0	4.0	3.8	1.5	1.5	1.5	1.5	1.5	1.00	4.0	1.0	4.0	2.6	0.66	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	5.9	47.5	8.9	47.5	14.4	67.4	Omit runs C3 and C4 due to drilling damage. Two joint sets common clay fill
MG-127				95	95	95	95	96	1.0	4.0	1.0	4.0	2.8	1.0	3.0	1.5	3.0	1.9	1.00	4.0	1.0	4.0	2.6	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	5.9	285.0	8.9	285.0	24.8	70.9	
MG-129		0.0	105.0	75	95	85	95	88	2.0	9.0	2.0	4.0	4.1	1.0	3.0	1.5	3.0	1.9	2.00	8.0	2.0	4.0	3.5	0.66	1.00	0.66	0.66	0.70	1.0	1.0	1.0	1.0	1.0	0.7	71.3	5.3	47.0	8.2	63.7	
		105.0	190.0	95	95	95	95	95	1.0	3.0	2.0	2.0	2.0	0.5	3.0	3.0	3.0	2.1	2.00	4.0	2.0	2.0	2.4	0.86	1.00	0.66	1.00	0.80	1.0	1.0	1.0	1.0	1.0	2.6	142.5	47.0	71.3	33.3	72.8	
MG-130	C4	37.0	47.0	78	78	78	78	78	6.0	6.0	6.0	6.0	6.0	1.0	1.0	1.0	1.0	1.0	1.00	1.0	1.0	1.0	1.0	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	8.6	8.6	8.6	8.6	8.6	64.0	
	Omit C4			95	95	95	95	95	2.0	4.0	2.0	4.0	3.4	1.0	1.5	1.0	1.0	1.0	1.00	2.0	1.0	1.0	1.1	0.66	1.00	1.00	1.00	0.90	1.0	1.0	1.0	1.0	1.0	7.8	71.3	23.8	47.5	22.9	70.4	
MG-131	Omit C2 & C12			95	95	95	95	95	1.0	4.0	2.0	4.0	3.2	0.5	1.5	1.5	1.5	1.4	1.00	6.0	1.0	2.0	2.2	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	2.0	142.5	17.8	71.3	18.9	69.1	
MG-133				75	95	95	95	93	1.0	6.0	1.0	4.0	2.2	1.5	3.0	1.5	1.5	1.7	1.00	4.0	1	2	2.1	0.66	1.00	1.00	1.00	0.90	1.0	1.0	1.0	1.0	1.0	3.1	285.0	17.8	142.5	30.8	72.3	
MG-135		14.0	end	95	95	95	95	95	1.0	4.0	2.0	4.0	3.0	1.0	3.0	1	1	1.3	1.00	2.0	1	1	1.2	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	11.9	285.0	23.8	47.5	34.3	73.0	
MG-201		12.0	38.0	85	95	85	95	90	2.0	9.0	4.0	4.0	4.8	1.0	1.0	1	1	1	0.75	4.0	0.75	4	1.9	0.66	1.00	1.00	1.00	0.90	1.0	1.0	1.0	1.0	1.0	1.6	63.3	5.3	31.7	8.9	64.2	
		38.0	end	85	95	95	95	94	0.5	4.0	0.5	2.0	1.7	1.0	4.0	1.5	4	2.1	0.75	4.0	0.75	4	1.9	0.66	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	3.5	1013.3	17.8	1013.3	61.1	76.8	

Note:
1) N. Barton, The influence of joint properties in modeling jointed Keynote Lecture, 8th Congress of ISRM, Tokyo, vol.3, Rotterdam: Balkema, 1995.

BORINGS
TT 1 to 15, 17
MD 8A, 18
MG 24A, 127, 129, 130, 131, 133, 135, 201

ROCK MASS CLASSIFICATION
Q-SYSTEM

Table Q1
Station 1+00 to 18+50

Boring Number	Core Run No.	From (ft)	To (ft)	RQD					Jn					Jr					Ja					Jw					SRF					Q					RMR 15 log Q + 50 (1)	NOTES
				Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean		
MG-10				95	95	95	95	95	3.0	4.0	3.0	4.0	3.7	1.0	1.5	1.0	1.5	1.1	2.00	4.0	3.00	4.0	3.4	0.66	2.00	0.66	0.66	0.80	1.0	1.0	1.0	1.0	1.0	3.9	47.5	3.9	10.5	6.6	62.3	
MG-54				95	95	95	95	95	0.5	3.0	0.5	3.0	1.8	1.0	4.0	1.5	4.0	2.0	0.75	2.0	0.75	2.0	1.7	0.66	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	10.5	1013	23.8	1013	62.1	76.9	Omit C1, C2, C18 and C19
MG-67		0.0	40.0	85	95	85	95	90	2.0	9.0	4.0	4.0	4.8	0.5	1.5	1.0	1.0	1.0	2.00	6.0	2.00	2.0	4.3	0.66	1.00	0.66	1.00	0.80	1.0	1.0	1.0	1.0	1.0	0.5	35.6	7.0	11.9	3.5	58.1	Applies to Pegmatite at 40.1
		40.0	end	95	95	95	95	95	1.0	4.0	4.0	4.0	2.8	1.5	3.0	1.5	1.5	1.9	2.00	3.0	2.00	2.0	2.3	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	11.9	142.5	17.8	17.8	28.0	71.7	
		All		85	95	95	95	93	1.0	9.0	2.0	4.0	3.8	0.5	3.0	1.0	1.5	1.4	2.00	6.0	2.00	3.0	3.1	0.66	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	0.5	142.5	7.9	35.6	11.1	65.7	
MG-69	C-1	1.0	5.0	35	35	35	35	35	6.0	6.0	6.0	6.0	6.0	1.0	1.0	1.0	1.0	1.0	12.0	12.0	12.0	12.0	12.0	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	0.5	0.5	0.5	0.5	0.5	45.3	
	C-2 to C-4	5.0	19.5 end	95	95	95	95	95	0.5	1.0	0.5	1.0	0.6	1.0	4.0	1.0	4.0	3.0	0.00	1.0	0.00	1.0	0.3	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	95.0	760	95.0	760	1563	98.0	Short boring. No joints observed below 5.45 ft depth.
MG-74				85	95	95	95	94	0.5	4.0	2.0	4.0	2.6	0.5	4.0	0.5	1.5	1.4	0.75	3.0	2.00	2.0	1.8	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	3.5	1013	5.9	35.6	28.1	71.7	
MG-79	C1	0.9	4.5	15	15	15	15	15	2.0	2.0	2.0	2.0	2.0	1.0	1.0	1.0	1.0	1.0	2.00	8.0	8.00	8.0	8.0	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	0.6	2.5	0.6	0.6	0.6	46.9	
	C2 to C4	4.5	19.5	95	95	95	95	95	1.0	2.0	1.0	2.0	1.3	1.0	1.5	1.0	1.5	1.2	2.00	4.0	2.00	4.0	3.3	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	11.9	71.3	11.9	71.3	26.6	71.4	
MG-108				75	95	85	95	87	2.0	6.0	2.0	6.0	4.6	0.5	3.0	0.5	1.5	1.2	2.00	6.0	3.00	6.0	4.0	0.66	1.00	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	0.7	71.3	0.8	15.7	3.7	58.6	
MG-109				95	95	95	95	95	0.5	3.0	1.0	3.0	1.8	1.5	4.0	1.5	1.5	1.9	0.75	3.0	1.00	3.0	1.8	0.66	1.00	1.00	1.00	0.90	1.0	1.0	1.0	1.0	1.0	10.5	1013	15.8	142.5	50.1	75.5	
MG-110	C4	17.0	27.0	80	80	80	80	80	6.0	6.0	6.0	6.0	6.0	1.5	1.5	1.5	1.5	1.5	4.00	4.0	4.00	4.0	4.0	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	3.3	3.3	3.3	3.3	3.3	57.8	Applies 24.9 to 25.6'
		27.0	end	95	95	95	95	95	2.0	4.0	2.0	4.0	3.5	1.5	1.5	1.5	1.5	1.5	0.75	2.0	1.00	2.0	1.4	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	17.8	95.0	17.8	71.3	29.1	72.0	
MG-112	C3	10.0	20.0	85	85	85	85	85	9.0	9.0	9.0	9.0	9.0	1.5	1.5	1.5	1.5	1.5	2.00	2.0	2.00	2.0	2.0	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	4.7	4.7	4.7	4.7	4.7	60.0	
		20.0	end	95	95	95	95	95	2.0	4.0	2.0	2.0	2.4	1.5	1.5	1.5	1.5	1.5	1.00	2.0	1.00	1.0	1.2	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	17.8	71.3	71.3	71.3	49.5	75.4	
MG-114W	C12			28	28	28	28	28	4.0	4.0	4.0	4.0	4.0	1.5	1.5	1.5	1.5	1.5	1.00	1.0	1.00	1.0	1.0	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	6.9	6.9	6.9	6.9	6.9	62.6	
	omit C12			95	95	95	95	95	0.5	3.0	0.5	2.0	1.3	1.5	4.0	1.5	4.0	2.6	0.75	3.0	0.75	1.0	1.1	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	15.8	1013	71.3	1013	172.7	83.6	
MG-115	C1 to C4	2.0	22.0	55	95	55	95	78	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.5	1.5	2.00	3.0	2.00	3.0	2.5	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	13.8	35.6	13.8	35.6	23.4	70.5	
MG-117				65	95	85	95	89	0.5	4.0	0.5	3.0	1.7	1.0	4.0	1.0	4.0	2.1	0.75	2.0	0.75	2.0	1.2	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	8.1	1013	14.2	1013	91.6	79.4	
MG-120				95	95	95	95	95	0.5	4.0	1.0	4.0	2.0	1.0	4.0	1.0	1.5	1.8	0.75	3.0	1.00	3.0	1.7	0.66	1.00	1.00	1.00	0.90	1.0	1.0	1.0	1.0	1.0	5.2	1013	7.9	142.5	45.3	74.8	
MG-121	C6 to C8	50.0	60.0	85	85	85	85	85	6.0	9.0	9.0	9.0	8.0	1.0	1.0	1.0	1.0	1.0	1.00	2.0	2.00	2.0	1.7	0.67	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	3.1	9.4	3.1	3.1	4.1	59.2	Cluster of joints
	Omit C6-C8			95	95	95	95	95	1.0	6.0	2.0	4.0	3.3	1.0	2.0	1.0	1.0	1.2	1.00	2.0	1.00	1.0	1.3	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	7.9	190.0	23.8	47.5	26.6	71.4	
MG-124	C1 to C3	5.0	20.0 end	85	95	85	95	92	0.5	3.0	0.5	3.0	2.2	1.5	4.0	1.5	4.0	2.3	0.75	4.0	2.00	4.0	2.0	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	10.6	1013	10.6	380.0	48.1	75.2	
MG-126	C9			77	77	77	77	77	9.0	9.0	9.0	9.0	9.0	1.5	1.5	1.5	1.5	1.5	3.00	3.0	3.00	3.0	3.0	1.00	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	4.3	2.8	2.8	2.8	2.8	56.8	
	Omit C9			95	95	95	95	95	0.5	9.0	0.5	4.0	2.3	1.0	4.0	1.0	4.0	2.2	0.75	3.0	0.75	2.0	1.2	0.66	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	2.3	1013	11.9	1013	75.7	78.2	
MG-202	Omit 0-8'			95	95	95	95	95	0.5	6.0	0.5	4.0	2.4	1.0	4.0	1.5	4	2.4	0.75	2.0	0.75	2	1.3	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	7.9	1013	17.8	1013	73.1	78.0	
MG-203				85	95	95	95	94	0.5	3.0	0.5	2.0	1.3	1.0	4.0	1.5	4	2.6	0.75	4.0	0.75	2	1.5	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	7.1	1013	35.6	1013	125.3	81.5	
MG-204		2.0	7.0	65	65	65	65	65	9.0	9.0	9.0	9.0	9.0	0.5	0.5	0.5	0.5	0.5	4.00	4.0	4.00	4	4	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	0.6	0.6	0.6	0.6	0.6	46.6	
	Omit 2-7'			85	95	85	95	92	0.5	4.0	0.5	3.0	1.9	0.5	4.0	1.5	4	2.1	0.75	4.0	0.75	3	2.2	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	2.7	1013	14.2	1013	46.2	75.0	
MG-205				65	95	85	95	89	2.0	9.0	3.0	4.0	4.2	1.5	3.0	1.5	1.5	1.6	1.00	4.0	1	3	2.3	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	2.7	142.5	10.6	47.5	14.7	67.5	
MG-302	C2 to C13	6.0	120.0 end	65	95	85	95	92	2.0	6.0	2.0	6.0	3.5	0.5	1.5	0.5	1.5	1.3	1.00	4.0	1	2	1.8	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	1.4	71.3	3.5	71.3	19.0	69.2	Omit run C1
MG-306		0.0	10.0	65	65	65	65	65	9.0	9.0	9.0	9.0	9.0	1.5	1.5	1.5	1.5	1.5	2.00	2.0	2	2	2	0.66	0.66	0.66	0.66	0.66	2.5	2.5	2.5	2.5	2.5	1.4	1.4	1.4	1.4	1.4	52.3	
		10.0	end	75	95	95	95	90	2.0	4.0	2.0	4.0	3.3	1.5	1.5	1.5	1.5	1.5	1.00	1.0	1	1	1	1.00	1.00	1.00	1.00	1.00	2.5	2.5	2.5	2.5	2.5	11.3	28.5	14.3	28.50	16.4	68.2	
MG-307				85	95	95	95	94	0.5	4.0	0.5	4.0	2.8	1.5	4.0	1.5	4	2.1	0.75	1.0	0.75	0.75	0.9	1.00	1.00	1.00	1.00	1.00	2.5	2.5	2.5	2.5	2.5	12.8	405.3	19.0	405.3	31.3	72.4	
MG-308		5.3	10.3	25	25	25	25	25	12.0	12.0	12.0	12.0	12.0	1.5	1.5	1.5	1.5	1.5	1.00	1.0	1	1	1	0.50	0.50	0.50	0.50	0.50	2.5	2.5	2.5	2.5	2.5	0.6	0.6	0.6	0.6	0.6	46.9	
		10.3	end	95	95	95	95	95	3.0	9.0	3.0	4.0	5.0	1.5	1.5	1.5	1.5	1.5	1.00	1.0	1	1	1	0.66	0.66	0.66	0.66	0.66	2.5	2.5	2.5	2.5	2.5	4.2	12.5	9.4	12.5	7.5	63.1	
MG-309	C2 to C10	7.0	59.0	45	65	45	65	55.9	2.0	9.0	9.0	9.0	6.9	0.5	1.5	1	1.5	1.1	3.00	4.0	4	4	4	0.66	1.00	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	0.4	16.3	0.8	1.8	1.5	52.5	Omit run C1
	C11 to C12	59.0	79.0 end	95	95	95	96	95	3.0	3.0	3.0	3.0	3.0	0.5	0.5	0.5	0.5	0.5	3.00	4.0	3	4	3.5	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	4.0	5.3	4.0	5.3	4.5	59.8	
MG-312		24.0		85	95	95	95	95	0.5	4.0	0.5	4.0	2.0	1.5	4.0	1.5	4	2.2	0.75	3.0	0.75	2	1.3	0.66	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	7.0	1013	17.8	380.0	80.4	78.6	
MG-313		3.0	13.0	35	35	35	35	35	4.0	4.0	4.0	4.0	4.0	1.5	1.5	1.5	1.5	1.5	3.00	3.0	3	3	3	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	2.9	2.9	2.9	2.9	2.9	56.9	
		13.0	38.0	65	95	85	95	82	3.0	9.0	6.0	9.0	6.0	1.5	1.5	1.5	1.5	1.5	1.00	2.0	1	2	1.7	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	3.6	31.4	4.7	14.0	8.0	63.5	
		38.0	end	95	95	95	95	95	0.5	4.0	1.0	4.0	2.2	1.0	4.0	1	1.5	1.7	0.75	3.0	1	2	1.5	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	7.9	1013	11.9	95.0	48.9	75.3	
MD-1				85	95	95	95	94	0.5	9	2.0	9.0	3.9	0.5	4.0	1.5	1.5	1.5	0.8	4.0	1.00	4.0	1.9	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	1.2	1013	4.0	71.3	19.0	69.2	
MD-5				95	95	95	95	95	0.5	4	0.5	4.0	1.8	1.0	4.0	1.0	4.0	1.9	0.8	3.0	0.75	3.0	1.7	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	7.9	1013	7.9	1013	59.0	76.6	
MD-7				65	95	95	95	95	0.5	9	4.0	9.0	5.0	1.0	4.0	1.0	1.5	1.5	0.8	3.0	1.00	2.0	1.3	0.66	1.00	0.66	1.00	0.90	1.0	1.0	1.0	1.0	1.0	1.6	1013	3.5	35.6	19.7	69.4	
MD-9				95	95	95	95	95	0.5	4	0.5	4.0	2.0	1.5	4.0	1.5	4.0	2.3	0.8	2.0	0.75	2.0	1.2	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	17.8	1013	17.8	1013	91.0	79.4	
MD-10				95	95	95	95	95	0.5	4	0.5	4.0	2.0	1.5	4.0	1.5	4.0	2.0	0.8	2.0	0.75	2.0	1.3	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	17.8	1013	17.8	1013	73.1	78.0	
MD-11				85	95	95	95	93	1.0	4	4.0	4.0	3.5	1.0	1.5	1.5	1.5	1.8	1.0	3.0	1.00	3.0	1.9	0.66	1.00	0.66	1.00	0.90	1.0	1.0	1.0	1.0	1.0	4.7	142.5	7.8	35.6	22.7	70.3	
MD-12				85	95	95	95	94	1.0	9	1.0	4.0	3.0	1.5	1.5	1.5	1.5	1.5	1.0	2.0	1.00	2.0	1.3	0.66	1.00	1.00	1.00	0.90	1.0	1.0	1.0	1.0	1.0	4.7	142.5	17.8	142.5	32.5	72.7	
MD-13		21.0	end	95	95	95	95	95	0.5	9	3.0	6.0	3.8	1.5	4.0	1.5	1.5	1.7	0.8	3.0	1.00	2.0	1.7	0.66	1.00	1.00	1.00	0.90	1.0	1.0	1.0	1.0	1.0	3.5	1013	11.9	47.5	22.5	70.3	Rockhead to 21' lower quality. Excluded from classification
		0.0	end	75	95	95	95	93	0.5	9	3.0	9.0	4.6	1.5	4.0	1.5	1.5	1.7	0.8	6.0	1.00	2.0	2.1	0.66	1.00	0.66	1.00	0.90	1.0	1.0	1.0	1.0	1.0	1.4	1013	5.2	47.5	14.7	67.5	Rockhead to 21' included in classification
MD-15		16.0	end	85	95	95	95	94	1.0	9	1.0	4.0	3.3	1.0	4.0	1.5	1.5	1.7	2.0	4.0	2.00	4.0	2.3	0.66	1.00	1.00	1.00	0.90	1.0	1.0	1.0	1.0	1.0	1.6	190.0	8.9	71.3	18.9	69.2	
MD-16W		8.0	42.0	65	75	65	65	68	9.0	9	9.0	9.0	9.0	1.5	4.0	1.5	4.0	2.0	2.0	4.0	2.00	4.0	3.3	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	1.8	11.0	1.8	9.5	3.0	57.2	
		42.0	end	95	95	95	95	95	2.0	9	4.0	9.0	5.4	1.5	1.5	1.5	1.5	1.5	1.0	4.0	1.00	1.0	1.6	0.66	1.00	0.66	1.00	0.90	1.0	1.0	1.0	1.0	1.0	2.6	71.3	10.5	35.6	14.8	67.6	
		8.0	42.0	65	95	65	95	85	2.0	9	4.0	9.0	6.7	1.5	1.5	1.5	1.5	1.5	1.0	4.0	1.00	4.0	2.2	0.66	1.00	0.66	1.00	0.80	1.0	1.0	1.0	1.0	1.0	1.8	71.3	1.8	35.6	6.9	62.6	
MD-17		16.0	end	95	95	95	95	95	2.0	6	2.0	6.0	3.6	1.5	1.5	1.5	1.5	1.6	1.0	2.0	1.00	1.0	1.2	0.66	1.00	1.00	1.00	0.90	1.0	1.0	1.0	1.0	1.0	7.8	71.3	23.8	71.3	29.7	72.1	
MD-19W				95	95	95	95	95	0.5	4	0.5	3.0	1.4	1.0	4.0	1.0	4.0	2.7	0.8	4.0	0.75	2.0	1.4	0.66	1.00	1.00	1.00	0.90	1.0	1.0	1.0	1.0	1.0	3.9	1013	15.8	1013	117.8	81.1	
MD-20A		16.0	end	95	95	95	95	95	0.5	4	1.0	4.0	2.8	1.5	4.0	1.5	1.5	2.0	0.8	2.0	0.75	2.0	1.7	0.66	1.00	1.00	1.00	0.90	1.0	1.0	1.0	1.0	1.0	11.8	1013	17.8	190.0	35.9	73.3	
MD-23				95	95	95	95	95	0.5	4	0.5	4.0	2.7	0.5	4.0	1.0	1.5	1.6	0.8	3.0	0.75	3.0	1.5	0.66	1.00	1.00	1.00	0.90	1.0	1.0	1.0	1.0	1.0	2.6	1013	7.9	380.0	33.8	72.9	

Note:

1) N. Barton, The influence of joint properties in modeling jointed rock masses, Keynote Lecture, 8th Congress of ISRM, Tokyo, vol.3, Rotterdam: Balkema, 1995.

BORINGS
MG 10, 54, 67, 74
108-112, 114W, 117, 120, 121, 126, 136,
202-205, 306-308, 312, 313
MD 1, 5, 7, 9-13, 15-17, 19W, 20A, 23

ROCK MASS CLASSIFICATION
Q-SYSTEM

Table Q2
Station 18+50 to 31+00

Boring Number	Core Run No.	From (ft)	To (ft)	RQD					Jn					Jr					Ja					Jw					SRF					Q					RMR 15 log Q + 50 [1]	NOTES
East				Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean		
MA-144		38.0	end	95	95	95	95	95	1.0	4.0	4.0	4.0	3.4	1.5	1.5	1.5	1.5	1.5	1.00	6.0	1	2	2.7	0.66	1.00	0.66	1.00	0.90	1.0	1.0	1.0	1.0	1.0	3.9	142.5	11.8	35.6	14.0	67.2	
MA-146				95	95	95	95	95	0.5	6.0	1.0	4.0	3.0	1.0	1.5	1	1	1.1	1.00	4.0	1	1	1.5	0.66	1.00	0.66	1.00	0.90	1.0	2.5	1.0	1.0	1.2	1.0	285.0	15.7	95.0	17.4	68.6	
MA-148				85	95	85	95	89	3.0	9.0	3.0	9.0	6.9	1.0	1.5	1	1	1.1	1.00	4.0	3	4	3.5	0.50	0.66	0.50	0.66	0.60	2.5	2.5	2.5	2.5	2.5	0.5	12.5	0.5	2.8	1.0	49.8	Fault?
MA-149				85	95	95	95	93	2.0	6.0	3.0	6.0	4.9	1.0	1.5	1.5	1.5	1.5	1.00	4.0	1	2	2	0.66	1.00	0.66	1.00	0.80	1.0	1.0	1.0	1.0	1.0	2.3	71.3	7.8	47.5	11.4	65.8	
MA-150				55	95	95	95	93	1.0	9.0	1.0	6.0	3.5	1.5	1.5	1.5	1.5	1.5	1.00	6.0	1	4	2.5	0.66	1.00	0.66	0.66	0.70	1.0	1.0	1.0	1.0	1.0	1.0	142.5	3.9	94.1	11.2	65.7	
MA-151W				75	95	85	95	92	0.5	6.0	0.5	6.0	3.2	1.5	1.5	1.5	1.5	1.5	1.00	6.0	1	2	1.5	0.66	1.00	0.66	1.00	0.80	1.0	1.0	1.0	1.0	1.0	2.1	285.0	7.0	285.0	23.0	70.4	
MA-153				95	95	95	95	95	1.0	4.0	4.0	4.0	3.3	0.5	3.0	0.5	3	1.5	1.00	4.0	2	2	2	0.66	1.00	0.66	1.00	0.80	1.0	1.0	1.0	1.0	1.0	2.0	285.0	3.9	35.6	17.3	68.6	23-45 slickernsides
MA-311		34.0	end	55	95	95	95	89	2.0	9.0	4.0	9.0	6.0	1.5	1.5	1.5	1.5	1.5	1.00	4.0	2	2	2.2	0.66	1.00	0.66	0.66	0.80	1.0	1.0	1.0	1.0	1.0	1.5	71.3	5.2	11.8	8.1	63.6	Inclined boring toward 300 deg. Azimuth
MG-7	C2-C5	24.0	55.0	65	95	65	95	78	9.0	9.0	9.0	9.0	9.0	1.5	3.0	1.5	3.0	2.5	2.00	4.0	2.0	2.0	2.7	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	1.8	10.5	3.6	10.5	5.3	60.9	Possible drilling damage
		55.0	end	95	95	95	95	95	0.5	4.0	2.0	4.0	2.0	1.5	4.0	1.5	4.0	2.7	0.75	2.0	0.8	2.0	1.5	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	17.8	1013.3	17.8	253.3	85.5	79.0	
		24.0	end	65	95	95	95	91	0.5	9.0	2.0	9.0	3.6	1.5	4.0	1.5	4.0	2.7	0.75	4.0	0.8	2.0	1.5	0.66	1.00	0.66	1.00	0.90	1.0	1.0	1.0	1.0	1.0	1.8	1013.3	5.2	253.3	41.0	74.2	
MG-9	C2	16.5	26.5	55	55	55	55	55	12.0	12.0	12.0	12.0	12.0	1.0	1.0	1.0	1.0	1.0	2.00	2.0	2.0	2.0	2.0	0.66	0.66	0.66	0.66	0.66	2.5	2.5	2.5	2.5	2.5	0.6	0.6	0.6	0.6	0.6	46.7	Extremely fractured 25.5-26.5. Slickensides at 20.5'
		26.5	end	95	95	95	95	95	1.0	4.0	1.0	4.0	2.9	1.0	1.5	1.0	1.5	1.3	1.00	3.0	1.0	3.0	2.4	0.66	1.00	1.00	1.00	0.90	1.0	1.0	1.0	1.0	1.0	5.2	142.5	7.9	142.5	16.0	68.0	Discount 86 to 96 because of vertical fracture
MG-101		15.0	end	95	95	95	95	95	0.5	4.0	2.0	4.0	2.9	1.0	1.5	1.0	1.5	1.2	0.75	6.0	1.0	6.0	2.0	0.66	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	2.6	380.0	4.0	71.3	19.7	69.4	
MG-103				65	95	95	95	90	0.5	4.0	2.0	4.0	2.8	1.0	4.0	1.5	1.5	1.8	0.75	4.0	1.0	1.0	1.5	0.66	1.00	0.66	1.00	0.90	1.0	1.0	1.0	1.0	1.0	2.7	1013.3	23.5	71.3	34.7	73.1	Healed breccia and mineralization from 40' to 50'
MG-104		20.0	end	85	95	95	95	94	2.0	9.0	3.0	6.0	4.4	1.5	1.5	1.5	1.5	1.5	1.00	4.0	1.0	2.0	1.7	0.66	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	2.3	71.3	11.9	47.5	18.9	69.1	1 to 20' omitted because barrel blocked. Iron staining on joints
MG-105				95	95	95	95	95	0.5	4.0	0.5	4.0	2.8	0.5	4.0	1.5	4.0	1.9	0.75	4.0	0.8	1.0	1.4	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	3.0	1013.3	35.6	1013.3	46.0	74.9	
MG-107				85	95	95	95	94	0.5	6.0	0.5	4.0	2.6	1.0	4.0	1.0	4.0	2.0	0.75	4.0	0.8	2.0	1.4	0.66	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	2.3	1013.3	11.9	1013.3	51.6	75.7	
MG-136				95	95	95	95	95	0.5	4.0	0.5	2.0	1.5	0.5	4.0	1	4	2.3	0.75	4.0	0.75	2	1.7	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	3.0	1013.3	23.8	1013.3	85.7	79.0	
MG-314	omit 35' to 45	15.0	end	85	95	95	95	94	0.5	9.0	1.0	6.0	3.1	0.5	4.0	0.5	1.5	1.4	0.75	4.0	1	4	2.4	0.66	1.00	0.66	1.00	1.00	1.0	1.0	1.0	1.0	1.0	0.8	1013.3	1.3	142.5	17.7	68.7	Inclined boring toward 210 deg. Azimuth
		35.0	45.0	5	95	5	95	65	2.0	2.0	2.0	2.0	2.0	0.5	0.5	0.5	0.5	0.5	2.00	2.0	2	2	2	0.66	0.66	0.66	0.66	0.66	5.0	5.0	5.0	5.0	5.0	0.1	1.6	0.1	1.6	1.1	50.5	Healed, granitic breccia veins and mineralization from 35' to 45'

Boring Number	Core Run No.	From (ft)	To (ft)	RQD					Jn					Jr					Ja					Jw					SRF					Q					RMR 15 log Q + 50 [1]	NOTES
West				Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean		
MA-1		26.0	34.0	15	15	15	15	15	9.0	9.0	9.0	9.0	9.0	1.5	1.5	1.5	1.5	1.5	1.00	1.0	1.0	1.0	1.0	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	1.7	1.7	1.7	1.7	1.7	53.3	Possible drilling damage
	Omit zone			65	95	85	95	84	2.0	9.0	4.0	9.0	6.0	1.0	1.5	1.5	1.5	1.5	1.00	2.0	1.0	1.0	1.1	0.66	1.00	0.66	1.00	0.80	1.0	1.0	1.0	1.0	1.0	2.4	71.3	9.4	35.6	15.3	67.8	
MA-145A		29.0	end	75	95	85	95	88	2.0	9.0	4.0	9.0	5.7	1.0	1.5	1.5	1.5	1.4	1.00	3.0	1	2	1.8	0.66	1.00	0.66	1.00	0.80	1.0	1.0	1.0	1.0	1.0	1.8	71.3	4.7	35.6	9.6	64.7	
MA-147		47.2	52.0	25	25	25	25	25	9.0	9.0	9.0	9.0	9.0	1.5	1.5	1.5	1.5	1.5	10.0	10.0	10	10	10	0.33	0.33	0.33	0.33	0.33	1.0	1.0	1.0	1.0	1.0	0.1	0.1	0.1	0.1	0.1	37.1	Water inflow
	Omit 47-52			45	95	65	85	74	0.5	9.0	9.0	9.0	7.8	1.0	1.5	1	1	1.1	0.75	4.0	4	4	3.8	0.50	1.00	0.50	0.66	0.60	1.0	1.0	1.0	1.0	1.0	0.6	380.0	0.9	1.6	1.6	53.3	
MA-152		36.0	50.0	65	65	65	65	65	6.0	6.0	6.0	6.0	6.0	1.5	1.5	1.5	1.5	1.5	3.00	3.0	3	3	3	0.50	0.50	0.50	0.50	0.50	1.0	1.0	1.0	1.0	1.0	2.7	2.7	2.7	2.7	2.7	56.5	
		87.0	108.0	65	65	65	65	65	6.0	6.0	6.0	6.0	6.0	1.5	1.5	1.5	1.5	1.5	3.00	3.0	3	3	3	0.50	0.50	0.50	0.50	0.50	1.0	1.0	1.0	1.0	1.0	2.7	2.7	2.7	2.7	2.7	56.5	
	Other			85	95	85	95	90	2.0	6.0	2.0	4.0	3.7	1.5	1.5	1.5	1.5	1.5	1.00	2.0	1	1	1.3	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	7.0	47.0	21.0	47.0	18.5	69.0	
MA-311		109.0	147.0	25	75	55	75	55	9.0	20.0	2.0	9.0	13.7	0.5	1.5	1	1.5	1.2	1.00	8.0	4	8	7.3	0.50	0.66	0.50	0.50	0.50	7.5	7.5	7.5	7.5	7.5	0.0	1.1	0.1	0.9	0.0	29.7	Inclined boring toward 300 deg. Azimuth
MG-8		36.0	68.5	10	15	10	10	11	15.0	20.0	20.0	20.0	18.8	1.0	1.0	1.0	1.0	1.0	4.00	10.0	10.0	10.0	8.5	0.66	1.00	0.66	0.66	0.66	2.5	2.5	2.5	2.5	2.5	0.0	0.1	0.0	0.0	0.02	23.9	
	No breccia			45	75	45	45	58	4.0	9.0	9.0	9.0	7.8	0.5	1.0	0.5	1.0	0.8	2.00	4.0	4.0	4.0	3.5	0.66	1.00	0.66	0.66	0.70	2.5	2.5	2.5	2.5	2.5	0.2	3.8	0.2	0.3	0.5	45.2	
		All		10	75	10	45	34	4.0	20.0	9.0	20.0	13.3	0.5	1.0	0.5	1.0	0.9	2.00	10.0	4.0	10.0	6.0	0.66	1.00	0.66	0.66	0.70	2.5	2.5	2.5	2.5	2.5	0.0	3.8	0.0	0.3	0.1	35.5	
MG-8A				10	45	25	45	30	15.0	20.0	15.0	15.0	16.4	0.5	1.0	0.5	1.0	0.9	4.00	6.0	4.0	6.0	5.0	0.66	1.00	0.66	0.66	0.70	2.5	2.5	2.5	2.5	2.5	0.0	0.3	0.0	0.2	0.1	34.5	
MG-10				95	95	95	95	95	3.0	4.0	3.0	4.0	3.7	1.0	1.5	1.0	1.0	1.1	1.00	4.0	3.0	4.0	3.4	0.66	1.00	0.66	0.66	0.80	1.0	1.0	1.0	1.0	1.0	3.9	47.5	3.9	7.0	6.6	62.3	
MG-102				85	95	45	95	91	2.0	9.0	4.0	9.0	5.4	1.5	1.5	1.5	1.5	1.5	1.00	6.0	1.0	6.0	2.7	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	1.6	47.0	0.8	23.5	6.2	61.9	
MG-106				55	85	75	85	77	4.0	9.0	4.0	9.0	5.9	0.5	1.0	0.5	0.5	0.6	4.00	6.0	6.0	6.0	5.6	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	0.3	3.5	0.5	1.2	0.9	49.5	
MG-207	Omit C1-C3			65	95	85	95	88	2.0	9.0	2.0	6.0	4.7	1.0	3.0	1	1.5	1.5	2.00	4.0	2	4	3.7	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	1.2	47.0	2.3	23.5	5.0	60.5	
MG-304	C15			19	19	19	19	19	9.0	9.0	9.0	9.0	9.0	1.5	1.5	1.5	1.5	1.5	6.00	6.0	6	6	6	0.66	0.66	0.66	0.66	0.66	2.5	2.5	2.5	2.5	2.5	0.1	0.1	0.1	0.1	0.1	37.2	Inclined boring toward 225 deg. Azimuth. 50% total recovery
	Omit C15			75	95	85	95	90	2.0	9.0	3.0	9.0	4.5	0.5	1.5	1.5	1.5	1.2	1.00	6.0	2	4	2.8	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	0.5	47.0	2.3	15.7	5.7	61.3	
MG-305				65	95	85	95	89	2.0	9.0	2.0	4.0	4.2	0.5	1.5	0.5	1.5	1.2	1.00	4.0	2	3	2.3	0.66	1.00	0.66	0.66	0.70	1.0	1.0	1.0	1.0	1.0	0.6	71.3	2.3	23.5	7.7	63.3	Inclined boring toward 85 deg. Azimuth
MG-309	C2 to C10	7.0	59.0	45	65	45	65	55.9	2.0	9.0	9.0	9.0	6.9	0.5	1.5	1	1.5	1.1	3.00	4.0	4	4	4	0.66	1.00	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	0.4	16.3	0.8	1.8	1.5	52.5	Omit run C1
	C11 to C12	59.0	79.0 end	95	95	95	95	95	3.0	3.0	3.0	3.0	3.0	0.5	0.5	0.5	0.5	0.5	3.00	4.0	3	4	3.5	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	4.0	5.3	4.0	5.3	4.5	59.8	

Note:
1) N. Barton, The Influence of joint properties in modeling jointed rock masses, Keynote Lecture, 8th Congress of ISRM, Tokyo, vol.3, Rotterdam: Balkema, 1995.

BORINGS
MA: 1, 144-153, 311
MG east : 7, 9, 101, 103-105, 107, 314
MG west: 8, 8A, 10, 102, 106, 147, 207
304, 305, 309, 311

ROCK MASS CLASSIFICATION
Q-SYSTEM

Table Q3
Station 31+00 to 1052 +00

Boring Number	Core Run No.	From (ft)	To (ft)	RQD					Jn					Jr					Ja					Jw					SRF					Q					RMR 15 log Q + 50 [1]	NOTES
				Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean		
MA-3		43.0	54.0	45	45	45	45	45	9.0	9.0	9.0	9.0	9.0	0.5	0.5	0.5	0.5	0.5	6.00	6.0	6.0	6.0	6.0	0.66	0.66	0.66	0.66	0.66	2.5	2.5	2.5	2.5	2.5	0.1	0.11	0.11	0.11	0.11	35.6	Weathered rock, slickensides, loss of drill flush
		86.6	136.1	85	95	95	95	93	3.0	4.0	3.0	4.0	3.4	0.5	3.0	0.5	1.5	1.4	1.00	4.0	3.0	4.0	3.2	0.66	1.00	0.66	0.66	0.66	2.5	2.5	2.5	2.5	2.5	0.7	38.0	0.78	4.18	3.16	57.5	Slickensides
	Other			55	75	75	75	68	1.0	9.0	9.0	3.0	7.8	0.5	1.5	1.0	1.5	1.1	2.00	4.0	4.0	4.0	3.5	0.66	1.00	0.66	0.66	0.66	2.5	2.5	2.5	2.5	2.5	0.2	22.5	1.65	0.83	0.72	47.9	
MA-140				85	95	95	95	95	0.5	4.0	3.0	4.0	2.5	1.0	1.5	1	1	1.1	1.00	2.0	1	1	1	0.66	1.00	1.00	1.00	1.00	2.5	2.5	2.5	2.5	2.5	2.8	114.0	9.50	12.67	16.72	68.3	
MA-142				75	95	85	95	88	4.0	9.0	4.0	6.0	5.3	1.5	1.5	1.5	1.5	1.5	1.00	6.0	1	4	2.6	0.50	1.00	0.50	1.00	0.70	2.5	2.5	2.5	2.5	2.5	0.4	14.3	1.06	14.25	2.68	56.4	
MA-143			73.0	35	55	35	55	47	4.0	9.0	4.0	9.0	7.0	1.5	1.5	1.5	1.5	1.5	2.00	4.0	2	4	3.3	0.50	0.50	0.50	0.50	0.50	2.5	2.5	2.5	2.5	2.5	0.3	2.1	0.29	2.06	0.61	46.8	
		73.0	end	65	95	95	95	95	2.0	6.0	2.0	6.0	4.0	1.5	1.5	1.5	1.5	1.5	1.00	3.0	1	3	2.3	0.50	0.50	0.50	0.50	0.50	2.5	2.5	2.5	2.6	2.5	1.1	14.3	1.58	14.25	3.10	57.4	
MA-207	Fault	73.0	83.0	10	10	10	10	10	20.0	20.0	20.0	20.0	20.0	1.0	1.0	1	1	1	4.00	4.0	4	4	4	0.66	0.66	0.66	0.66	0.66	2.5	7.5	5.0	7.5	6.0	0.01	0.03	0.01	0.02	0.01	22.1	
	Omit fault			35	85	35	65	53	6.0	9.0	9.0	9.0	9.0	1.0	3.0	1.5	3	2	1.00	10.0	4	4	4.5	0.50	1.00	0.50	0.66	0.50	2.5	7.5	5.0	7.5	7.0	0.0	17.0	0.10	0.72	0.19	39.1	Inclined boring

Note:

1) N. Barton, The influence of joint properties in modeling jointed rock masses, Keynote Lecture, 8th Congress of ISRM, Tokyo, vol.3, Rotterdam: Balkema, 1995.

BORINGS	ROCK MASS CLASSIFICATION	STATION 1052 to 1054	Table Q4
MA 3, 140, 142, 143, 207	Q-SYSTEM		Station 1052+00 to 1054+00

Boring Number	Core Run No.	From (ft)	To (ft)	RQD					Jn					Jr					Ja					Jw					SRF					Q					RMR 15 log Q + 50 [1]	NOTES
				Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean		
MA-4		40.0	62.0	25	55	55	55	48	9.0	12.0	9.0	9.0	10.0	1.5	1.5	1.5	1.5	1.5	1.00	10.0	2.0	10.0	6.8	0.66	1.00	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	0.2	9.2	0.61	3.03	0.7	47.7	
		62.0	end	75	85	75	95	80	4.0	4.0	4.0	4.0	4.0	1.5	1.5	1.5	1.5	1.5	1.00	1.0	1.0	1.0	1.0	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	28.1	31.9	28.13	35.6	30.0	72.2	
MA-5				85	95	95	95	93	2.0	9.0	2.0	4.0	4.3	1.5	1.5	1.5	1.5	1.5	0.75	2.0	0.8	2.0	1.2	0.66	1.00	1.00	1.00	0.90	1.0	1.0	1.0	1.0	1.0	4.7	95.0	17.81	95.0	24.3	70.8	
MA-6	Omit C12-C16			85	95	95	95	93	0.5	4.0	2.0	4.0	2.4	1.0	4.0	1.0	3.0	1.9	0.75	4.0	1.0	3.0	1.8	0.66	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	3.5	1013	7.92	142.5	40.9	74.2	C12 to C16 Bit problems
MA-7				85	95	95	95	92	1.0	9.0	1.0	4.0	3.6	1.5	1.5	1.5	1.5	1.5	1.00	3.0	1.0	2.0	1.7	0.66	1.00	1.00	1.00	0.90	1.0	1.0	1.0	1.0	1.0	3.1	142.5	17.81	142.5	20.3	69.6	
MA-9				85	95	95	95	94	0.5	4.0	0.5	4.0	2.0	1.5	4.0	1.5	4.0	2.3	0.75	2.0	0.8	1.0	1.0	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	15.9	1013	35.63	1013	108.1	80.5	
MA-11				85	95	95	95	94	0.5	4.0	2.0	4.0	3.1	1.5	4.0	1.5	1.5	1.7	0.75	1.0	1.0	1.0	1.0	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	31.9	1013	35.63	71.25	51.5	75.7	
MA-12	omit 19-24'	24.0	47.0	75	85	75	85	80	4.0	4.0	4.0	4.0	4.0	1.5	1.5	1.5	1.5	1.5	2.00	3.0	2.0	3.0	2.5	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	6.2	10.5	6.19	10.52	7.9	63.5	
		47.0	end	95	95	95	95	95	0.5	1.0	0.5	1.0	0.7	1.5	4.0	4.0	4.0	3.3	0.75	2.0	0.8	0.8	1.0	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	71.3	1013	506.7	1013	447.9	89.8	
MA-13				75	95	85	95	90	0.5	4.0	4.0	4.0	3.4	1.0	1.5	1.0	1.0	1.1	0.75	10.0	2.0	4.0	5.3	0.66	1.00	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	1.2	380.0	3.51	7.84	3.6	58.4	
MA-124		85.0	113.0	65	65	65	65	65	9.0	9.0	9.0	9.0	9.0	1.0	1.0	1	1	1	1.00	1.0	1	1	1	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	4.8	4.8	4.77	4.77	4.8	60.2	
	Omit 85-113			85	95	95	95	93	1.0	4.0	1.0	4.0	2.1	1.0	1.5	1	1.5	1.2	1.00	2.0	1	1	1.1	0.66	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	7.0	142.5	23.75	142.5	48.3	75.3	
MA-126		20.0	end	95	95	95	95	95	0.5	4.0	1.0	4.0	2.1	1.0	4.0	1	1	1.3	0.75	3.0	1	2	1.4	0.66	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	5.2	1013	11.88	95.0	42.0	74.3	
MA-127		45.0	end	95	95	95	95	95	0.5	4.0	0.5	2.0	1.4	1.0	4.0	1	4	2.5	0.75	6.0	0.75	2	2	0.66	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	2.6	1013	23.75	1013	84.8	78.9	
MA-129w	C1 to C2	7.0	17.0	55	65	55	65	60	4.0	6.0	4.0	6.0	5.0	1.5	1.5	1.5	1.5	1.5	3.00	3.0	3.0	3.0	3.0	0.66	1.00	0.66	1.00	0.80	1.0	1.0	1.0	1.0	1.0	3.0	8.1	3.03	8.13	4.8	60.2	
	C3 to C25	17.0	132.0	85	95	95	95	95	0.5	3.0	0.5	1.0	1.1	1.5	4.0	1.5	4	2.4	0.75	3.0	0.75	3	1.1	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	14.2	1013	47.50	1013	188.4	84.1	Boring included in Zone 1054 to 1063, due to good-excellent quality of the rock.
	C26 to C29	132.0	152 end	65	85	65	85	70	2.0	6.0	3.0	3.0	3.5	1.5	1.5	1.5	1.5	1.5	1.00	3.0	1	3	2.3	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	5.4	63.8	10.83	42.5	13.0	66.7	
MA-130		30.0	end	95	95	95	95	95	0.5	4.0	1.0	4.0	2.1	1.0	4.0	1	1.5	1.4	0.75	2.0	1	1	1.1	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	11.9	1013	23.75	142.5	57.6	76.4	
MA-131		32.0	end	85	95	95	95	94	0.5	4.0	1.0	4.0	2.1	1.0	4.0	1	1.5	1.6	0.75	3.0	1	1	1.3	0.66	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	4.7	1013	23.75	142.5	55.1	76.1	
MA-132		46.0	end	85	95	85	95	91	2.0	4.0	2.0	4.0	2.9	1.0	1.5	1.5	1.5	1.4	1.00	4.0	1	3	2	0.66	1.00	0.66	1.00	0.90	1.0	1.0	1.0	1.0	1.0	3.5	71.3	7.01	71.25	19.8	69.4	
MA-133		34.0	end	85	95	95	95	94	0.5	4.0	0.5	4.0	2.7	1.5	4.0	1.5	1.5	2	0.75	4.0	0.75	2	1.6	0.66	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	5.3	1013	17.81	380.0	43.5	74.6	
MA-134		25.0	end	95	95	95	95	95	4.0	9.0	4.0	4.0	4.7	1.0	1.5	1.5	1.5	1.5	1.00	2.0	1	1	1.1	0.66	1.00	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	3.5	35.6	23.51	23.51	18.2	68.9	
MA-135				85	95	95	95	92	2.0	6.0	4.0	4.0	4.0	1.0	1.5	1	1	1.1	3.00	4.0	4	4	4.1	0.66	1.00	0.66	0.66	0.80	1.0	1.0	1.0	1.0	1.0	2.3	23.8	3.92	3.92	4.9	60.4	
MA-135A				65	95	85	95	88	4.0	6.0	4.0	4.0	4.6	1.0	1.5	1	1	1.1	2.00	4.0	2	3	3.3	0.66	1.00	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	1.8	17.8	4.68	7.84	4.2	59.4	
MA-136				45	95	85	95	72	0.5	6.0	1.0	6.0	3.6	1.0	1.5	1.5	1.5	1.5	1.00	4.0	2	3	2.4	0.66	1.00	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	1.2	285.0	4.68	47.03	8.3	63.7	
MA-137				85	95	95	95	95	0.5	6.0	0.5	6.0	2.9	1.0	1.5	1	1	1.1	1.00	2.0	1	2	1.3	0.66	1.00	0.66	1.00	0.90	1.0	1.0	1.0	1.0	1.0	4.7	285.0	5.23	190.0	24.9	71.0	
MA-138				55	95	95	95	88	1.0	9.0	2.0	4.0	3.9	0.5	1.5	0.5	1.5	1	2.00	8.0	2	4	3.9	0.66	2.00	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	0.3	142.5	1.96	23.51	3.8	58.7	
MA-140				85	95	95	95	95	0.5	4.0	3.0	4.0	2.5	1.0	1.5	1	1	1.1	1.00	2.0	1	1	1	0.66	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	7.0	285.0	23.75	31.67	41.8	74.3	
MA-208				95	95	95	95	95	0.5	4.0	0.5	4.0	2.1	1.5	4.0	1.5	1.5	2.1	0.75	4.0	0.75	4	2.4	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	8.9	1013	8.91	380.0	39.6	74.0	
MA-301				65	95	65	85	79	3.0	9.0	3.0	6.0	5.2	1.0	1.5	1	1.5	1.3	3.00	4.0	3	4	3.6	0.66	1.00	0.66	0.66	0.70	1.0	1.0	1.0	1.0	1.0	1.2	15.8	1.79	9.35	3.8	58.8	
MA-302		38.0	128.0	65	95	85	95	86	4.0	9.0	4.0	9.0	6.3	1.0	1.5	1	1.5	1.3	2.00	3.0	2	3	2.3	0.66	0.66	0.66	0.66	0.65	2.5	2.5	2.5	2.5	2.5	0.6	4.7	0.83	4.70	2.0	54.6	
		128.0	end	35	35	35	35	35	20.0	20.0	20.0	20.0	20.0	0.5	0.5	0.5	0.5	0.5	2.00	2.0	2	2	2	0.50	0.50	0.50	0.50	0.50	2.5	2.5	2.5	2.5	2.5	0.1	0.1	0.09	0.09	0.1	34.1	Broken pegmatite and schist
MA-306		56.0	end	45	95	85	95	89	1.0	6.0	3.0	4.0	3.8	1.0	1.5	1	1.5	1.1	2.00	4.0	2	3	2.5	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	1.9	71.3	7.08	23.75	10.3	65.2	
MA-310		35.0	end	75	95	95	95	94	0.5	6.0	1.0	4.0	2.9	1.5	4.0	1.5	1.5	1.9	0.75	4.0	2	4	2.6	0.50	1.00	0.66	1.00	0.90	1.0	1.0	1.0	1.0	1.0	2.3	1013	5.88	71.25	21.3	69.9	Inclined boring
		133.5	143.5	45	45	45	45	45	9.0	9.0	9.0	9.0	9.0	1.5	1.5	1.5	1.5	1.5	4.00	4.0	4	4	4	0.50	0.50	0.50	0.50	0.50	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.94	0.94	0.9	49.6	Sandy particles and disintegrated rock on joints

Note:

1) N. Barton, The influence of joint properties in modeling jointed rock masses, Keynote Lecture, 8th Congress of ISRM, Tokyo, vol.3, Rotterdam.

BORINGS
MA 4-7, 9, 11-13
124, 126, 127, 129-138, 140
208, 301, 302, 306, 310

ROCK MASS CLASSIFICATION
Q-SYSTEM

Table Q5
Station 1054+00 to 1063+00

Boring Number	Core Run No.	From (ft)	To (ft)	RQD					Jn					Jr					Ja					Jw					SRF					Q					RMR 15 log Q + 50 [1]	NOTES
				Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean		
MA-15W				45	95	45	65	64	9.0	12.0	9.0	12.0	9.8	0.5	1.0	0.5	0.5	0.6	2.0	6.0	2.0	2.0	2.0	0.50	1.00	0.50	0.50	0.50	5.0	5.0	5.0	5.0	5.0	0.0	1.1	0.1	0.2	0.2	39.4	Brecciated Schist
MA-119		37.0	95.0	75	95	85	95	88	2.0	9.0	2.0	4.0	4.3	1.0	1.5	1.5	1.5	1.4	2.0	4.0	4.0	4.0	3.6	0.66	1.00	0.66	1.00	0.80	5.0	5.0	5.0	5.0	5.0	0.3	7.1	1.1	3.6	1.3	51.6	
		95.0	141.0	45	95	65	95	73	9.0	9.0	9.0	9.0	9.0	1.0	1.5	1.0	1.0	1.1	1.0	4.0	4.0	4.0	3.3	0.50	0.66	0.50	0.50	0.50	5.0	5.0	5.0	5.0	5.0	0.1	2.1	0.2	0.3	0.3	41.5	
MA-123A		83.0	118.0	95	95	95	95	95	4.0	4.0	4.0	4.0	4.0	1.5	1.5	1.5	1.5	1.5	3.5	3.5	3.5	3.5	3.5	0.66	0.66	0.66	0.66	0.66	5.0	5.0	5.0	5.0	5.0	1.3	1.3	1.3	1.3	1.3	51.9	
	Omit 83-118			45	75	45	75	64	4.0	9.0	9.0	9.0	8.4	1.0	1.5	1.0	1.5	1.3	2.0	4.0	4.0	4.0	3.8	0.50	0.66	0.50	0.66	0.60	5.0	5.0	5.0	5.0	5.0	0.1	1.9	0.1	0.4	0.3	42.4	
MA-125		36.0	end	65	95	65	75	76	4.0	9.0	9.0	9.0	8.3	1.0	1.5	1	1.5	1.3	2.0	6.0	2	3	3.7	0.50	0.66	0.66	0.66	0.60	5.0	5.0	5.0	5.0	5.0	0.1	2.4	0.3	0.8	0.4	43.8	
MA-209W		65.0	end	35	85	55	85	58	4.0	20.0	12.0	12.0	12.0	1.0	2.0	1	1.5	1.3	3.0	8.0	3	8	5	0.50	0.50	0.50	0.50	0.50	5.0	5.0	5.0	5.0	5.0	0.0	1.4	0.1	0.4	0.1	36.5	Rock at 42', sheared and fractured
MA-304		47.0	end	0	93	25	76	50	3.0	9.0	6.0	9.0	7.6	0.5	1.0	0.5	1	0.8	2.0	5.0	2	4	3.6	0.66	1.00	0.66	1.00	0.80	5.0	5.0	5.0	5.0	5.0	0.0	3.1	0.05	1.3	0.2	40.5	
MA-322		46.0		45	95	45	85	71	9.0	9.0	9.0	9.0	9.0	0.5	1.5	0.5	1.5	1.1	2.0	6.0	2	4	3.9	0.50	0.50	0.50	0.50	0.50	5.0	5.0	5.0	5.0	5.0	0.0	0.8	0.1	0.7	0.2	40.2	
MA-325W		35.0	65.0	95	95	95	95	95	6.0	9.0	9.0	9.0	8.0	1.0	1.5	1.5	1.5	1.3	2.0	6.0	4	4	5.3	0.66	1.00	0.66	0.66	0.70	5.0	5.0	5.0	5.0	5.0	0.2	2.4	0.5	0.5	0.4	44.2	
		65.0	152.0	5	75	55	75	65	9.0	12.0	9.0	9.0	9.3	1.0	1.5	1.5	1.5	1.4	3.0	6.0	3	7	4.4	0.50	0.66	0.50	0.50	0.50	5.0	5.0	5.0	5.0	5.0	0.0	0.6	0.1	0.4	0.2	40.2	

Note:
1) N. Barton, The influence of joint properties in modeling jointed rock masses, Keynote Lecture, 8th Congress of ISRM, Tokyo, vol.3, Rotterdam:

BORINGS
MA 15W
119, 123A, 125
209W, 304, 322, 325W

ROCK MASS CLASSIFICATION
Q-SYSTEM

Table Q6
Station 1063+00 to 1066+00

Boring Number	Core Run No.	From (ft)	To (ft)	RQD					Jn					Jr					Ja					Jw					SRF					Q					RMR 15 log Q + 50 [1]	NOTES
				Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean		
MA-105W			76.0	65	85	75	75	75	2.0	9.0	9.0	9.0	7.6	1.5	1.5	1.5	1.5	1.5	2.0	4.0	2.0	4.0	3.2	0.66	0.50	0.66	0.66	0.60	1.0	1.0	1.0	1.0	1.0	1.8	15.9	2.1	4.1	2.8	56.7	Alteration on open joints with chlorite
		76.0	156.0	95	95	95	95	95	2.0	4.0	2.0	4.0	3.3	1.5	1.5	1.5	1.5	1.5	1.0	4.0	1.0	2.0	2.1	0.66	1.00	0.66	1.00	0.90	1.0	1.0	1.0	1.0	1.0	5.9	71.3	11.8	71.3	18.5	69.0	Chlorite on joints
MA-107				55	95	65	85	76	3.0	9.0	6.0	9.0	7.1	1.0	1.5	1.0	1.5	1.2	2.0	6.0	2.0	4.0	3.7	0.50	1.00	0.50	0.66	0.60	1.0	1.0	1.0	1.0	1.0	0.5	23.8	0.9	7.0	2.1	54.8	
MA-108				55	85	55	75	68	9.0	9.0	9.0	9.0	9.0	1.0	2.0	1.0	1.5	1.3	1.0	8.0	1.0	4.0	3.9	0.50	0.66	0.66	0.66	0.60	1.0	1.0	1.0	1.0	1.0	0.4	12.5	1.0	8.3	1.5	52.7	
MA-109				75	95	75	95	87	4.0	9.0	4.0	9.0	7.0	1.0	1.5	1.5	1.5	1.5	2.0	6.0	2.0	6.0	3.8	0.50	1.00	0.50	0.66	0.60	1.0	1.0	1.0	1.0	1.0	0.7	17.8	1.0	11.8	2.9	57.0	
MA-112A		55.0	end	95	95	95	95	95	1.0	2.0	1.0	2.0	1.4	1.0	1.5	1.0	1.5	1.2	1.0	3.0	1.0	3.0	2.0	0.66	1.00	1.00	1.00	0.90	1.0	1.0	1.0	1.0	1.0	10.5	142.5	15.8	142.5	36.6	73.5	
MA-113		45.0	end	85	95	95	95	93	2.0	4.0	2.0	4.0	3.3	1.0	1.5	1.0	1.5	1.3	1.0	6.0	1.0	6.0	3.3	0.50	1.00	0.50	1.00	0.70	1.0	1.0	1.0	1.0	1.0	1.8	71.3	2.0	71.3	7.8	63.4	
MA-114		10.0	end	95	95	95	95	95	0.5	4.0	3.0	4.0	2.9	1.5	4.0	1.5	1.5	2.0	0.8	4.0	0.8	4.0	2.0	0.50	1.00	0.50	1.00	0.80	1.0	1.0	1.0	1.0	1.0	4.5	1013	4.5	63.3	26.2	71.3	
MA-115		20.0	end	85	95	95	95	93	4.0	4.0	4.0	4.0	4.0	1.5	1.5	1.5	1.5	1.5	2.0	3.0	2.0	3.0	2.4	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	7.0	11.8	7.8	11.8	9.6	64.7	
MA-116				85	95	95	95	94	2.0	9.0	3.0	6.0	6.8	1.0	1.5	1.0	1.5	1.3	2.0	2.0	2.0	2.0	2.0	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	4.7	35.6	7.9	23.8	9.0	64.3	
MA-117		0.0	50.0	65	95	95	95	85	1.0	6.0	1.0	6.0	3.5	1.5	2.0	1.5	1.5	1.3	2.0	4.0	4.0	4.0	3.7	0.66	1.00	0.66	0.66	0.80	1.0	1.0	1.0	1.0	1.0	2.7	95.0	3.9	23.5	6.8	62.5	
		50.0	end	55	75	55	75	65	9.0	9.0	9.0	9.0	9.0	1.0	1.0	1.0	1.0	1.0	4.0	4.0	4.0	4.0	4.0	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	1.0	1.4	1.0	1.4	1.2	51.1	
MA-211W		26.0	65.0	45	85	45	55	60	4.0	9.0	9.0	9.0	7.8	0.5	1.0	1	1	0.9	4.0	6.0	4	6	5	0.50	0.50	0.50	0.50	0.50	7.5	7.5	7.5	1.0	7.5	0.0	0.4	0.4	0.1	0.1	34.5	
		65.0	end	65	95	85	95	87	4.0	9.0	4.0	4.0	4.6	1.5	1.5	1.5	1.5	1.5	1.0	4.0	1	4	2.9	0.66	1.00	0.66	1.00	0.80	5.0	5.0	5.0	1.0	5.0	0.4	7.1	5.3	7.1	1.6	52.9	
MA-312		64.5	80.0	77	77	77	77	77	9.0	9.0	9.0	9.0	9.0	1.0	1.0	1	1	1	2.0	2.0	2	2	2	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	2.8	2.8	2.8	2.8	2.8	56.8	Slickensided, brecciated pegmatite, intensely folded, healed fractures
MA-313		121.0	131.0	53	53	53	53	53	9.0	9.0	9.0	9.0	9.0	1.5	1.5	1.5	1.5	1.5	3.0	3.0	3	3	3	0.50	0.50	0.50	0.50	0.50	1.0	1.0	1.0	1.0	1.0	1.5	1.5	1.5	1.5	1.5	52.5	
MA320		60.0		85	95	95	95	93	4.0	9.0	4.0	9.0	6.8	1.5	1.5	1.5	1.5	1.5	1.0	3.0	2	3	2.2	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	3.1	23.5	3.5	11.8	6.2	61.8	
		90.5	94.8	75	75	75	75	75	15.0	15.0	15.0	15.0	15.0	1.5	1.5	1.5	1.5	1.5	6.0	6.0	6	6	6	0.50	0.50	0.50	0.50	0.50	1.0	1.0	1.0	1.0	1.0	0.6	0.6	0.6	0.6	0.6	46.9	Alteration effects. Healed joints, silty deposits
MA321W		52.0		55	95	75	95	79	2.0	9.0	4.0	9.0	7.1	1.0	3.0	1.5	1.5	1.6	2.0	2.0	2	2	2	0.50	0.66	0.50	0.66	0.60	1.0	1.0	1.0	1.0	1.0	1.5	47.0	3.1	11.8	5.3	60.9	
	C-1 & C-2	43.0	52.0	15	50	15	50	30	4.0	9.0	4.0	9.0	6.5	1.5	1.5	1.5	1.5	1.5	2.0	3.0	2	3	2.5	0.50	0.50	0.50	0.50	0.50	1.0	1.0	1.0	1.0	1.0	0.4	4.7	0.4	4.7	1.4	52.1	Rock missing,healed fractures
	C-3 to C-13	52.0	136.0	46	97	65	95	80	2.0	12.0	3.0	9.0	5.9	1.5	1.5	1.5	1.5	1.5	2.0	4.0	2	3	2.5	0.50	0.66	0.50	0.66	0.57	1.0	1.0	1.0	1.0	1.0	0.7	24.0	1.8	15.7	4.6	60.0	Slickensided, brecciated pegmatite, healed fractures, non-softening infilling materials
MA-322		46.0		45	95	45	85	71	9.0	9.0	9.0	9.0	9.0	0.5	1.5	0.5	1.5	1.1	2.0	6.0	2	4	3.9	0.50	0.50	0.50	0.50	0.50	2.5	2.5	2.5	1.0	2.5	0.1	1.6	0.3	1.4	0.4	44.7	

Note:

1) N. Barton, The influence of joint properties in *modeling* jointed rock masses, Keynote Lecture, 8th Congress of ISRM, Tokyo, vol.3, Rotterdam: Balkema, 1995.

BORINGS
MA 105w, 107-109, 112A-117
211w
312, 313, 320-322

ROCK MASS CLASSIFICATION
Q-SYSTEM

Table Q7
Station 1066+00 to 1076+50

Boring Number	Core Run No.	From (ft)	To (ft)	RQD					Jn					Jr					Ja					Jw					SRF					Q					RMR 15 log Q + 50 (1)	NOTES
				Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean	Min	Max	Typical range		Mean		
MA-18				75	95	95	95	90	1.0	9.0	1.0	4.0	3.6	1.0	4.0	1.0	3.0	2.0	1.00	4.0	1.0	4.0	2.2	0.66	1.00	0.66	1.00	0.90	1.0	1.0	1.0	1.0	1.0	1.4	380.0	3.9	285.0	20.5	69.7	Decomposed rock 137.1-138' and 141.4-144.75' omitted.
MA-102		21.0	76.0	75	85	75	95	79	3.0	4.0	4.0	4.0	3.8	1.5	3.0	1.5	3.0	2.4	1.00	3.0	1.0	3.0	2.0	0.66	1.00	0.66	0.66	0.80	1.0	1.0	1.0	1.0	1.0	6.2	85.0	6.2	47.0	20.0	69.5	
		76.0	eobh	95	95	95	95	95	2.0	4.0	2.0	4.0	2.9	1.5	1.5	1.5	1.5	1.5	1.00	4.0	1.0	2.0	1.9	0.66	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	5.9	71.3	17.8	71.3	25.9	71.2	
MA-103W		85.0	100.0	63	63	63	63	63	9.0	9.0	9.0	9.0	9.0	1.0	1.0	1.0	1.0	1.0	3.00	3.0	3.0	3.0	3.0	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	1.5	1.5	1.5	1.5	1.5	52.8	Pegmatite
	Omit 85-105'	65.0	end	95	95	95	95	95	1.0	4.0	1.0	4.0	2.5	1.0	2.0	1.0	1.5	1.4	1.00	4.0	1.0	1.0	1.4	1.00	1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	5.9	190.0	23.8	142.5	38.0	73.7	
MA-104		142.0	153.0	44	44	44	44	44	4.0	4.0	4.0	4.0	4.0	1.5	1.5	1.5	1.5	1.5	3.00	3.0	3.0	3.0	3.0	0.50	0.50	0.50	0.50	0.50	1.0	1.0	1.0	1.0	1.0	2.8	2.8	2.8	2.8	2.8	56.6	Joint cluster
	Omit 142-153'			85	95	95	95	93	0.5	6.0	4.0	6.0	3.4	1.0	4.0	1.0	1.5	1.7	0.75	3.0	1.0	3.0	2.1	0.50	1.00	0.50	1.00	0.80	1.0	1.0	1.0	1.0	1.0	2.4	1013	2.6	35.6	17.7	68.7	
MA-312		34.5		95	95	95	95	95	1.0	4.0	1.0	3.0	2.3	1.0	1.5	1.5	1.5	1.5	1.00	4.0	2	2	2.2	0.66	1.00	1.00	1.00	0.90	1.0	1.0	1.0	1.0	1.0	3.9	142.5	23.8	71.3	25.3	71.1	
		64.5	80.0	77	77	77	77	77	9.0	9.0	9.0	9.0	9.0	1.0	1.0	1	1	1	2.00	2.0	2	2	2	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	2.8	2.8	2.8	2.8	2.8	56.8	Slickensided, brecciated pegmatite, intensley folded, heaed fractures
		154.5	end	95	96	95	95	95	1.0	4.0	1.0	3.0	2.3	1.0	1.5	1.5	1.5	1.5	2.00	2.0	2	2	2	0.66	0.66	0.66	0.66	0.66	1.0	1.0	1.0	1.0	1.0	7.8	47.0	15.7	47.0	20.4	69.7	
MA-313		61.0	end	75	95	95	95	93	3.0	9.0	4.0	6.0	5.3	1.0	1.5	1.5	1.5	1.4	2.00	3.0	2	3	2.3	0.50	0.66	0.66	0.66	0.60	1.0	1.0	1.0	1.0	1.0	1.4	15.7	5.2	11.8	6.4	62.1	
		121.0	131.0	53	53	53	53	53	9.0	9.0	9.0	9.0	9.0	1.5	1.5	1.5	1.5	1.5	3.00	3.0	3	3	3	0.50	0.50	0.50	0.50	0.50	1.0	1.0	1.0	1.0	1.0	1.5	1.5	1.5	1.5	1.5	52.5	
MA-314		37.0	end	25	95	75	95	84	3.0	9.0	3.0	6.0	4.4	1.0	1.5	1	1.5	1.2	1.00	3.0	2	3	2.3	0.66	1.00	1.00	1.00	1.00	1.0	5.0	1.0	1.0	1.5	0.1	47.5	4.2	23.8	6.6	62.3	
MA-318W		45.0	end	85	95	95	95	94	1.0	6.0	3.0	6.0	3.7	1.5	3.0	1.5	3	1.9	0.75	4.0	1	2	1.7	0.66	1.00	0.66	1.00	0.90	1.0	1.0	1.0	1.0	1.0	3.5	380.0	7.8	95.0	25.6	71.1	

Note:

1) N. Barton, The influence of joint properties in modeling jointed rock masses, Keynote Lecture, 8th Congress of ISRM, Tokyo, vol.3, Rotterdam: Balkema, 1995.

BORINGS
MA 18
102-104
312, 313, 314, 318W

ROCK MASS CLASSIFICATION
Q-SYSTEM

Table Q8
Station 1076+50 to 1084+00