Assessment

of an

Alleged Differing Site Condition Claim

Submitted by Michels Pipeline

Associated
with

The Underwood Creek High Flow Diversion Sewer
Elm Grove, Wisconsin

And

The Village of Elm Grove v. Michels Corp., et al,
pending in
Waukesha County Wisconsin, case number 08-CV-1481.

At the Request of Attorney McClean

by

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Draft Report
22-Oct-09

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22-Oct-09

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Re: *The Village of Elm Grove v. Michels Corp*., *et al*,
pending in Waukesha County Wisconsin, case number 08-CV-1481.

Dear Mr. McClean,

In response to your request dated 3-Jun-09, I have reviewed relevant documents to arrive at a preliminary conclusion. There remains additional information for me to conclude my study, namely a number of issues which I have asked you to explore during depositions.

I always insist that I provide my opinion with the caveat that they shall be independent and may change as additional information provided.

Sincerely yours,

Peter J. Tarkoy

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Geotechnical and Tunnel Consultant

PJT/wfw

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EXECUTIVE SUMMARY

To date, our investigation has revealed the following:

1. Contract and geotechnical documents provide strong indications that boulders should be anticipated along with **"boulder obstructions"**,

2. Contract required selection of means, methods, equipment, and associated construction performance for removal of boulders from granular soils by contractor using contract specified "supervision",

3. Contractor had difficulty getting the shafts (Sienko Diary 2006-03-28) down and the ground surface settled as soon as TBM was begun,

4. Contractor ignored the nature and behavior of the coarse granular materials prone to running and/or flowing as indicated in the contract and geotechnical study,

5. Surface settlement of the ground at startup (Sienko Diary 2006-04-25) illustrates that the problem was with the coarse granular soils and not the removal of boulders. Subsequently, the crew overcompensated and limited the soil intake and pushed the boulders (Anderson Deposition) keeping them ahead of the TBM cutterhead, concentrating them until they could progress no more at which time they removed a massive number of boulders that had collected in front of the cutterhead. This massive removal of boulders was associated with further settlement,

6. Contractor claims that he encountered unanticipated boulders,

7. Subsequently, between the first encounter of boulders and prior to returning to work grouting was done in Nov. 2006, the work was stopped for an extended time (9 months) with a notable lack of the contract required supervision;

8. After re-start, boulder removal continued to cause subsidence except in some places where effective grouting had been done to prevent subsidence,

9. Contractor ignored problems inherent to excavating and removing boulders from granular materials prone to running and/or flowing,

10. The sodium silicate grouting was poorly done and ineffective,

11. The contractor's selection of means, methods, and equipment was inconsistent with the:

    a. Anticipated coarse granular material,
    b. Requirement to remove boulders, and
    c. Shallow cover over the tunnel,

    indicated in the geotechnical study and the contract.

12. All of the problems experienced by the contractor are attributable to a poor selection of means, methods, and equipment for the excavation of:

    a. Coarse granular materials,
    b. Boulders from a matrix of coarse granular materials, and
    c. High rate of excavation.

13. The contractor was so unprepared for the conditions indicated in the contract and the geotechnical study that even if it were possible to show that more boulders were encountered

than anticipated, it would be impossible for the contractor to prove that their means, methods, and equipment could excavate, without subsidence:

a. The coarse granular material,
b. The boulders from coarse granular materials, and
c. With the shallow cover over the tunnel alignment.

14. The contractor's problems are entirely self-inflicted, and

15. There is no basis for entitlement under aforementioned conditions.

INTRODUCTION

Initial Contact, Assignment, and Issues

I was contacted by Matthew McClean on 3-Jun-09 and was requested to provide an independent review of a differing site condition claim submitted by Michels Pipeline in the case of ***The Village of Elm Grove v. Michels Corp., et al, pending in Waukesha County Wisconsin, case number 08-CV-1481***. I accepted the assignment with the caveat that I would provide a completely independent opinion and that I would reserve the right to modify my opinions as additional information become available.

The contractor's claim was based on alleged unanticipated boulders and alleged associated costs.

This document is a draft report, pending the receipt of additional information from depositions and inspection of the TBM, and a more detailed incorporation of project data into the report.

Project Description

The project involves the following:

1. Approximately 52 acre-feet of wet detention storage in the Village Park that will be created by extending the horizontal limits of the existing Village Park Pond.

2. Modification of certain elements of the Village Park to accommodate the disposal of excess soil resulting from pond construction, including soccer and baseball fields, parking lots and access roads, and drainage features.

3. The removal and naturalization of the concrete channel lining that currently forms the bed of Underwood Creek immediately north of Juneau Boulevard to the Village Park Pond.

4. A lowered area, providing six acre-feet of temporary floodwater storage immediately south of Juneau Boulevard, in the location formerly occupied by the Legion Post and currently occupied by the former TV John building.

5. Approximately 2,130 feet of overflow underground culvert, consisting of the following subcomponents:

    a. Approximately 140 feet of trenched 4-foot by 8-foot concrete box culvert and 535 feet of 8-foot by 10-foot concrete box culvert extending from the Legion Post Pond to Watertown Plank Road.

    b. Approximately 875 feet of tunneled 108-inch diameter reinforced concrete pipe, extending from the North side of Watertown Plank Road to tile south side of the Canadian Pacific Railroad tracks.

    c. Approximately 590 feet of trenched 6-foot by 9-loot concrete box culvert, extending from the south limits of circular concrete pipe to an open channel that will discharge directly into Underwood Creek.

6. A lowered area, providing 33 acre-feet of temporary floodwater storage, located at the current Villager Apartments and Sleepy Hollow Motel properties.

Of more particular interest is the driving of 491 ft + 381 ft = 872 ft of jacked pipe from manholes at STR-5 to STR-4 and subsequently from STR-3 to STR-4 with a 130-inch diameter Lovat TBM with flood doors selected by the contractor.

Available Documents

Available documents consisted of the following:

1. Pre-Bid:
    a. "Geotechnical Study" by Earth Tech, Inc. dated June 2005,
    b. "Project Manual" (Specifications),
        i. Addenda 1
        ii. Addenda 2,

2. Post-Award:
    a. Various daily logs, diaries, and progress notes (from contractor and owner),
        i. Sienko journal,
        ii. Michel's Progress Notes,
    b. Contractor's:
        i. Bid file,
        ii. Work plan,
        iii. Claims,
        iv. Construction Schedule,
        v. Progress Notes,
    c. Various Correspondence,
    d. Court filings,
    e. Reports from the contractor's consultant Ron Heuer,
    f. Depositions:
        i. William Weltin,
        ii. Ron Heuer,
        iii. Richard Klein,
        iv. Dennis Anderson,
        v. Richard Bloomer,
        vi. David Shuenemann,
    g. 2007-01-03 Conversation with Michels foreman (10549373).doc

We have reviewed all of the pre-bid documents, many of the post-award documents, some of the depositions, various diaries, progress reports,

Context / Content of DSC Entitlement

The establishment of entitlement is the sole responsibility of the contractor. The contract requirement under the differing site condition clause and industry standards for establishing entitlement for differing site conditions dictate the following:

1. There must be a difference demonstrable between reasonable indicated (anticipated) and well documented encountered conditions;

2. There must be a difference demonstrable between reasonable anticipated and well documented encountered construction performance;

3. There must be a cause-and-effect relationship demonstrable between differences in conditions and differences in construction performance;

4. There must be a demonstrable impact in time & space on costs;

5. All contract conditions must be fulfilled:

    a. Reliance,
    b. Notice, and
    c. Mitigation;

6. No other factors (self-inflicted) can have caused the additional time and costs.

Notably, the first five elements must be fulfilled and no other factors may have caused the additional time and costs.

The foregoing industry standards for entitlement have been published by Tarkoy (1988, 1998, and 2008).

The review of the alleged differing site condition claim submitted by the contractor shall be analyzed according to the reconciliation of the foregoing industry standards in with the project differing site condition clause as illustrated in **Exhibit 1**. Furthermore, the consideration of the geotechnical information and the plans and specifications shall be made within the **context of the law** as it applies to this project specifically.

When encountering an unanticipated condition to be presented as a differing site condition claim, **it is the contractor's responsibility to establish entitlement** based on irrefutable factual evidence consistent with the geotechnical information available, the contract specifications, and the context of the applicable laws. In order to prove entitlement, a complete and incontrovertible survey of:

1. Anticipated conditions,

2. Encountered conditions,

3. Anticipated performance, and

4. Encountered performance

must be compiled, documented, and presented by the contractor for independent analysis.

It is further necessary, for the contractor to provide a cause and effect relationship, illustration of impact, confirmation of fulfilling all contractual obligations, and assuring that no other conditions were the cause of the claimed time and cost overruns.

Definitions

Definitions are necessary for identifying essential distinctions of materials anticipated / indicated, as follows:

1. Cobbles > 3 inches

2. Boulders >12 inches

    "As detached rock mass….. being somewhat rounded or otherwise distinctly shaped by abrasion in the course of transport"; (AGI Glossary of Geology, 1974)

"A boulder is a rock fragment that was dislodged from bedrock, transported and deposited within soil and that has a size (largest dimension) of 12 inches or more. Rock fragments that have a size ranging from 3 to 12 inches are cobbles." (The Underwood Creek High Flow Diversion Sewer, Elm Grove, Wisconsin, 2005).

3. Boulder Obstructions

"A boulder obstruction occurs when a boulder is encountered at the heading of a tunnel that stops or significantly inhibits toward progress because it is too large to be broken or ingested through the TBM cutting wheel or tunnel mucking system. The obstructing boulder requires removal by supplementary means such as drilling and splitting through the heading or from an excavation made from outside of the tunnel. Boulders that have a size of 20 percent or more of the excavated tunnel diameter will be considered boulder obstructions. Boulders that have a size less than 20 percent of the excavated tunnel diameter will not be considered boulder obstructions." (Project Manual, 1.04 Definitions)

GEOTECHNICAL CONDITIONS

A difference in conditions between reasonable anticipated/indicated conditions and well-documented encountered conditions must be demonstrated.

The geotechnical conditions will be examined solely for the tunnel alignment portion of the project as depicted on the plan in **Exhibit 2**.

Anticipated Conditions

The anticipated conditions, contractual obligations, and contractor responsibilities have been:

1. Reported in the borings and the geotechnical report prepared by Earth Tech Inc.,
2. Specifically indicated in the contract plans & specifications, and
3. Known to contractors experienced in subsurface conditions in the locality, especially the contractor's experience in the area.

The area has been glaciated and therefore glacial material will be encountered. This area of Wisconsin is full of moraines, drumlins, and eskers as illustrated in **Exhibit 3.** These glacial features contain soils including clay, silt, sand, gravel, cobbles, and boulders. The local granular material conditions are known to contractors performing local work (Shuenemann Deposition) and defined in the project documents. Local bedrock depth is summarized in **Exhibit 4**.

The foregoing general conditions are specifically verified in the boring logs and the narrative in the geotechnical report prepared by Earth Tech, Inc. The conditions were summarized in Figure 3 of the geotechnical report and are illustrated in this report in **Exhibit 5**. Notably, the conditions within the tunnel envelope are depicted as **poorly graded sand with trace of some gravel and poorly graded sand and gravel**.

The tunnel has a shallow cover ranging between 4 and 16 ft over the crown of the pipe and will pass under the Canadian Pacific Railroad. Groundwater is expected to be at the pipe invert.

The soils along this alignment are described as:

> ***"Native soils encountered immediately below the fill/possible fill generally consisted of dense to very dense poorly graded sand and gravel with cobbles and/or boulders."*** (Geotechnical Study, Section 4.4.2.)
>
> ***"The anticipated soil conditions through the tunnel zone are predominantly dense to very dense poorly graded sand and gravel, with occasional cobbles and boulders."*** (Geotechnical Study, Section 5.4.2.1.)

The potential behavior was also address as follows:

> ***"This is an important since unsaturated granular soils 'will have a tendency to "run" during tunnel boring, whereas saturated granular soils will have a tendency to "flow"'"*** (Geotechnical Study, Section 5.4.2.1.)
>
> ***"Controlling or mitigating the potential to "run" is much more straightforward (and less costly) than controlling or mitigating the potential of "flowing" soils. Generally controlling flowing ground necessitates special tunneling techniques and/or groundwater pumping /control."*** (Geotechnical Study, Section 5.4.2.1.)

> ***"Ultimately, running or flowing soils result in lost ground, which can cause undesirable settlement at the surface***." (Geotechnical Study, Section 5.4.2.1.)

It is undeniable that the geotechnical information contained more than adequate indications that coarse granular soils prone to running or flowing behavior were indicated and should be anticipated, including the occurrence of boulders that had to be removed from the face.

Heuer's original calculation of anticipated boulders every 2.6 ft of tunnel would yield a total number of 343 anticipated boulders.

Encountered Conditions

The encountered conditions have been defined by records maintained by:

1. Michels and

2. Field representatives of the Village of Elm Grove.

These encountered conditions consisted of coarse granular soils with boulders.

Dr. Heuer claims to have gone through the records and reported that the contractor encountered 155 boulders with 31 "boulder obstructions".

Difference in Conditions

We have been unable to find a difference between conditions indicated in the contract and geotechnical report and encountered conditions. Both the contract and geotechnical study are replete with indications of boulders, the need to excavate them, and the need to select means, methods, and equipment to deal with the anticipated boulders.

Comparing Heuer's anticipated total number of 343 boulders with Heuer's 155 encountered boulders from the construction records; it becomes apparent that the contractor encountered fewer boulders than could have been anticipated.

EXCAVATION PERFORMANCE

Selection of Means, Methods, and Equipment

All construction estimates and bids fundamentally rely on the selection of means, methods, equipment, and associated construction performance. As a result, this aspect is of prime relevance and importance in the consideration of entitlement for a differing site condition claim.

Geotechnical Basis

The Geotechnical Study directly addresses the issue of selection of means, methods, and equipment as follows:

> ***"…… face support is a separate issue that will require at a minimum an open face tunnel boring machine (TBM) with an outer shield with <u>face breasting capabilities</u>. Given unsaturated conditions, an open face machine of this type should adequately hold the face and minimize ground loss."*** (Geotechnical Study, Section 5.4.2.1.)
>
> ***"Another consideration in selecting a TBM for this project in the possibly that boulder obstructions could be encountered during the tunneling operation. The investigative borings strongly indicated the presence of boulders, which should be a consideration by the Contractor when selecting a TBM, as well as in planning stages. Having access to the face of the tunnel for boulder retrieval or blasting (if allowed) may be beneficial."*** (Geotechnical Study, Section 5.4.2.1.)

Furthermore, the statement "should adequately hold the face" in not a guarantee and the contractor cannot rely on the opinions expressed in the geotechnical report. The contractor is responsible for selecting means, methods, and equipment.

Project Manual

The selection of tunneling means, methods, and equipment in the Project Manual requires that the contractor include in his bid, the following:

> ***"2. Include cost of:"***
>
> ***k. Removal of obstacles and debris blocking progress of tunneling and jacking operation, including but not limited to rock, timbers, or construction debris."*** (Project Manual, Section 01270 Measurement and Payment, Section 1.04, D., 2.)

The Project manual further specifies that:

> ***"Section includes Work necessary for tunnel and workshaft construction. This includes, but may not be limited to excavation; ground support; control, handling, and disposal of water; lighting; ventilation; tunnel boring machine and shield; and specific Canadian Pacific Railway (CPRR) crossing requirements."*** (Project Manual, Section 02445, Part I, 1.01, A.)
>
> ***"The CONTRACTOR shall construct the tunnels by jacked, one-pass pipe method. Alternative methods of tunneling, ground support and final lining may be***

submitted to the ENGINEER for consideration, but may not be approved." (Project Manual, Section 02445, Part I, 1.01, B.)

"The CONTRACTOR shall determine means and methods to control groundwater within and around the tunnel zone and within and around workshaft excavations to minimize lost ground and maintain excavation face stability." (Project Manual, Section 02445, Part I, 1.02, A.)

"1.03 RESPONSIBILITY

A. The CONTRACTOR has all responsibilities with regard to ground support systems." (Project Manual, Section 02445, 1.03, A.)

With regard to boulders, the Project Manual provided definitions as follows:

"1.04 Definitions

C. Soil Excavation

Soil excavation is defined as the removal of natural soil-like or fill materials covering the tunnel heading and not requiring special excavation methods as defined in Article BOULDER OBSTRUCTION. In-place fill material may contain debris or abandoned foundations or structures as described in the Geotechnical Report included in the Appendix. Cobbles and boulders may be encountered within this definition in either natural or man-made fill material.

D. Boulder

A boulder is a rock fragment that was dislodged from bedrock, transported and deposited within soil and that has a size (largest dimension) of 12 inches or more. Rock fragments that have a size ranging from 3 to 12 inches are cobbles.

E. Boulder Obstruction

A boulder obstruction occurs when a boulder is encountered at the heading of a tunnel that stops or significantly inhibits toward progress because it is too large to be broken or ingested through the TBM cutting wheel or tunnel mucking system. The obstructing boulder requires removal by supplementary means such as drilling and splitting through the heading or from an excavation made from outside of the tunnel. Boulders that have a size of 20 percent or more of the excavated tunnel diameter will be considered boulder obstructions. Boulders that have a size less than 20 percent of the excavated tunnel diameter will not be considered boulder obstructions.

K. Tunnel Boring Machine

1. A tunnel-boring machine (TBM) combines a shield with mechanical excavating and face-breasting equipment. Rotary wheel TBMs have a rotating head with cutting bits and openings for muck (cut soil) to pass into the shield. Open-face TBMs may have some face breasting capability, but do not have doors or pressurized plenums that can seal the heading from soil and groundwater inflows. Closed-faced TBMs either have doors that may be closed to seal the heading and/or include a sealed plenum behind the face that has doors or a bulkhead. Closed-face TBMs are general considered to be of three types:

a. earth pressure balance (EPB),
b. slurry shield machines, and
c. mix-shield machines.
(Project Manual, Section 02445, 1.04,)

"1.05 SUBMITTALS

B. Shop Drawings

e. General information on type of TBM or shield, including method of excavating, removing muck, providing face support and providing groundwater isolation, if required. (Project Manual, Section 02445, Section 02445, 1.05, C., 1.)

"The CONTRACTOR'S selection of means and methods is integral to the planning and execution of the Work under this Contract. Accordingly, the ENGINEER will review the submittal and may offer comments for the CONTRACTOR'S consideration. However, for this specific submittal, neither response nor lack of response by the ENGINEER shall be considered to represent approval or rejection of the CONTRACTOR'S means and methods for accomplishing tunnel and workshaft construction for the project or any specific work site. Neither the ENGINEER nor OWNER accept any responsibility for the adequacy of the CONTRACTOR'S means and methods nor for any damages to public or private property resulting therefrom, such responsibilities remaining with the CONTRACTOR." (Project Manual, Section 02445, Section 02445, 1.05, C., 3.)

"A. Tunnel Shields and Tunnel Boring Machines:

1. The tunnel excavation system shall be compatible with ground conditions. The tunnel shield or tunnel boring machine (TBM) shall include the following features, as a minimum.

a. Capability to full support or breast the face during periods of excavation and periods of shutdown to maintain face stability, control of groundwater and prevent uncontrolled ground loss." (Project Manual, Section 02445, Section 02445, PART 2, 2.01, A.)

"3.01 TUNNELING

A. General Excavation Requirements:

1. The CONTRACTOR'S selection of means and methods for excavation is integral to the planning and execution of the Work of the project specified. The selection of means and methods is the responsibility of the CONTRACTOR and the selected means and methods shall be capable of coping with subsurface conditions encountered. Design of the initial ground support for tunnel and workshaft excavation is the CONTRACTOR'S responsibility, and the initial ground support shall be installed as necessary."

B. Classification of Excavation:

Excavation is classified as soil excavation or <u>boulder obstruction excavation</u>, as defined previously in this Section. …….. The CONTRACTOR shall review the Geotechnical Report, make a site visit, and make his won interpretation of the kind

and extent of the various materials that will be encountered in the excavation as well as the presence or absence of water.

D. Minimize Ground Movement:

1. Perform tunnel and workshaft excavation, including installation of initial ground support systems, in a manner that will minimize the movement of the ground in front of and surrounding the excavation, and minimize subsidence of the surface, structures, and utilities above and in the vicinity of the excavation. Support the ground in a manner to prevent loss of ground and keep the perimeters and faces of the tunnel, passages, and bottoms of workshafts stable. Support the face of the excavation by positive means during all shut down periods. No face support used during shut down periods shall rely solely on hydraulic pressure."

O. Tunneling

1. …….. The CONTRACTOR shall excavate and install initial ground support (including jacking or placing pipe, injecting bentonite slurry, injecting contact grout and removing boulders) in sequence designed to maintain the face in a stable condition. The face of the excavation shall be controlled to prevent loss of ground, using methods appropriate to the ground and groundwater conditions encountered." (Project Manual, Section 02445, Section 02445, PART 3, 3.01.)

Michels Choices

Michels' Lovat 130 machine does not have breasting capabilities because **"flood control doors"** cannot and do not serve a "breasting" function since they cannot apply a positive pressure to the face. **"Flood control doors"** are designed and intended to prevent an inrush of water and prevent **"flooding"**.

It should be noted, that the forward facing surface of the "**flood control doors"**, when closed, are about 12 inches or more behind the forward surface of the tool mount bars and 23 inches behind the cut surface of the tunnel face. Even the permanent cutterhead face is behind the cut surface of the tunnel face, disallowing any support of the tunnel face. Consequently, there is more than adequate space for the virgin soil to slough, slump, begin to run, and for the ground disturbance to progress forward and to the surface, causing collapse holes at the surface. Michels' work plan statement that:

"The cutting head is capable of full face closure to maintain face stability, control groundwater, prevent uncontrolled ground loss…"

is a gross misrepresentation of this machine's capability in the indicated ground conditions.

The cutterhead is capable of cutting a gauge of 130.5 to 129.5 inches. The internal diameter of the pipe is 108 inches with a wall thickness of 10.75 inches for a total outside diameter of 129.5 inches. At best when the maximum gauge is 130.5 inches, there is only 0.5 inches of annular space on the radius.

The selection of the Lovat 130 **by itself does not fulfill the needs of project conditions**. It does not deal with the need for the removal of boulders from a coarse granular matrix prone to running or flowing with shallow cover. This can only be done with an EPB machine with a crushing chamber. With the Lovat 130 supplementary means and methods of stabilization to prevent running, flowing, and surface settlement would be necessary.

Nothing in the ***Tunnel Work Plan*** addresses:

1. Excavation of coarse granular material,
2. Splitting and removal of boulders from coarse granular materials that are prone to running and/or flowing,
3. Shallow cover,
4. Window penetration launching out of the shaft, or
5. Means, methods, and equipment to prevent surface subsidence.

The photo in **Exhibit 6** illustrates the machine used on this project after it had been painted after completion of the second tunnel drive. It should be noted, that the cutting tools are mounted on the cutting bar located in the middle of the opening of the flood doors. As a result, the openings are barely large enough to admit the smallest boulder, unless encountered in the outer portion of the cutterhead opening. As a result, even small boulders may be considered "boulder obstructions" if they occur in front the narrowest portion of the flood door openings. Furthermore, it would not be prudent to use these openings at full aperture to remove a boulder from coarse granular material prone to running or flowing at such a shallow cover.

A quote for the work from Lowe Construction Co. (October 20, 2005, ET001246) very directly spells out that which was ignored by Michels', as follows:

> ***"The amount of settlement is not a function of removing too much material during the mining operation but is a result soils inability to bridge the TBM's diameter of cut and the non uniform OD of the pipe being placed."***

Anticipated Performance

Michels work schedule (Jan 10, 2006) claims they will excavate:

1. Tunnel 3 to 4 (491 ft) in 20 workdays (24.55 ft/day) and
2. Tunnel 5 to 4 (381 ft) in 12 workdays (31.75 ft/day).

Anticipated excavation rates are summarized in **Exhibit 8**.

Encountered Performance

Even prior to tunneling, the shaft excavation disturbed the "dense" ground by allowing the sheet piles to bend in and resulted in lost ground which ultimately developed into the tunnel envelope and to the surface. Subsequently, when a window was cut into the shaft sheet piles to allow the TBM to mine into the ground, the already disturbed ground around the shaft deteriorated further resulting in lost ground and large voids at the surface.

The encountered performance is complex and attributable to various factors. For example, some of the workdays were short of the 10.5 hours anticipated for various contractor chosen reasons, lack of planning, or breakdowns. A to date examination of the records indicates that the encountered excavation rates were as follows:

1. Drive from STR-5 to STR-4 ~10 ft/day (exclusive of the 9 months when nothing was done and equipment was taken to another project;)

2. Drive from STR-3 to STR-4 ~35 ft/day (removal of boulders did not delay; lost ground did not delay;)

Encountered excavation rates are summarized in **Exhibit 8.**

In addition, it is notable that the surface settlement was immediate as the TBM was started, indicating problems pre-existing either in the penetration of the tunnel window or around the entire shaft.

Report indicate that the operation of the TBM was such that it could not allow boulders to come in, that the boulders were not removed (pushed as per Dennis Anderson deposition), the boulders kept being pushed forward disturbing the ground, and therefore the boulders accumulated until the machine could progress no more as corroborated by Dennis Anderson (Deposition).

A section of tunnel where jet grouting was effective was excavated with limited problems, primarily with the difficulty of excavating hard grouted ground. Another tunnel section where sodium silicate grout was utilized was disastrous because the grouting was poorly done.

Difference in Performance

The difference in excavation rates are summarized in **Exhibit 8** and **Exhibit 9**.

The encountered performance in the Drive from Shaft 5 to 4 is substantially less than the contractor's anticipated rate.

The encountered performance in the Drive from Shaft 3 to 4 is nearly the same as the contractor's anticipated rate. The difference in performance for the Drive from shaft 3 to 4 is inconsequential, since boulders were no longer an issue since grouting and the building of a trestle had been used to protect the critical structures, even though settlement continued almost over the entire drive except where jet grouting was properly done and effective. It amply illustrates that had Michels prepared to deal with indicated conditions, none of the problems would have occurred.

CAUSE AND EFFECT

The data available to date does not allow the examination of a relationship between the occurrence of boulders and the excavation rate. Yet, based on **Exhibit 8** and **Exhibit 9,** it does not appear that relationships between differences in conditions and differences in performance can be demonstrated. This relationship may be examined further when the additional information becomes available from documents and depositions.

To further examine cause and effect relationships, annotations shall be added to the Time-Progress charts in **Exhibit 8** and **Exhibit 9.**

An attempt shall be made to examine possible relationships of cause and effect between a difference in conditions and a difference in performance.

To date, the poor progress sustained by the contractor appears to be a result of:

1. Being unprepared to deal with the indicated ground conditions,

2. A number of downtimes unrelated to ground conditions and related to poor selection of means, methods, and equipment, and

3. Ineffective “supervision”.

It is notable that as soon as the critical structures (i.e.-railroad) were protected, the tunnel went at the planned rates yet still caused surface settlement. Allowances for this protection should have been included in the construction estimate.

IMPACT

The impact (delay) sustained by the contractor is clearly self-inflicted and unrelated to the occurrence of boulders. The impact is the result of the contractor's selection of the means, methods, and equipment inappropriate to the conditions indicated in the geotechnical report and the contract specifications (Project Manual). The contractor's 9-month delay is directly related to the contractor's inability to deal with the excavation of coarse granular soils (as indicated by the surface settlement) immediately upon the start of tunnel excavation and his other simultaneous ongoing projects.

Furthermore, the 9-month inactivity denies any effective supervision on the project as required by contract. During this time, some of the equipment was removed from site to be used at another project.

FULFILLMENT OF CONTRACT CONDITIONS

Reliance

Reliance by Michels has not been confirmed since there is no evidence that they considered the impact of:

1. Excavating a coarse granular soil,
2. Removing boulders from a coarse granular soil with shallow cover, and
3. The likely and indicated behavior of raveling and running ground.

When these conditions were encountered, Michels responded with 9 months of inactivity.

Notice

By letter dated June 20, 2006, Michels notified the owner that they had encountered a differing site condition and were making a claim under Article 4.02. However, this notice was 55 days late because the contract required notice within 30 days.

Mitigation

Mitigation seems to have been entirely ignored when indicated conditions were encountered. Therefore, the contractor sustained self-inflicted delays that were substantially longer than what would have been reasonable to deal with the indicated and encountered conditions.

Other Contract Requirements

The contract requires the contractor to select means, methods, and equipment to deal with indicated conditions as defined by the geotechnical report and contract project manual. The contract also calls for contractor supervision of the work.

Michels was not prepared to deal with indicated conditions as illustrated by the settlement as soon as the TBM began excavation. However, supervision was invisible, inactive, or at least ineffective as indicated by a 9-month hiatus with no improvement of the excavation performance, creation of voids, and surface settlement.

The following contract requirements were not fulfilled:

1. Responsibility for maintaining stability in indicated conditions and
2. Effective supervision.

OTHER CAUSES

All of Michels' delays were a result of self-inflicted problems associated with the:

1. Selection of means, methods, and equipment,
2. Inability to deal with coarse granular materials without subsidence,
3. Inability to remove boulders from coarse granular materials without subsidence, and
4. Lack of hands-on supervision and inaction.

The anticipation that flood doors would provide breasting to a coarse granular soil above the water table is patently false in the manner this TBM was operated.

Additional delays were suffered by a lack of planning, unavailability of supplies, unavailability of equipment, and absence of labor. They looked for numerous causes attributable to and compensable by the owner (boulder causing failures in the pipe when actually caused by flaws in the pipe or the jet grouting). Each time they were proven wrong, they sought yet newer methods to burden the owner for their own self-inflicted problems.

From the very start, it is sorely apparent, that Michels was not properly prepared to remove a single boulder obstruction from the coarse granular matrix.

After ground stabilization and protection of the railroad, mining continued, ground settlement continued in unprotected areas. In the end, when tunneling resumed, the encountered boulders were excavated and evidence that boulders were the sole cause of delays is notably missing.

We must conclude that the primary cause of the delays were nothing more than the contractor's self-inflicted choices of means, methods, and equipment and inaction when problems developed.

FLAWS IN CONTRACTOR'S CLAIM

Heuer

Hunt Method of Estimating Boulders

The contractor's consultant Heuer (2006-07-25) makes a series of calculations for justifying unanticipated quantity of boulder anticipated based on Hunt (1999, 2002). However, the Hunt method:

1. Was not part of the contract documents,

2. Was not used by the contractor to estimate boulders,

3. Does not justify the contractor's assumption:

    a. that they would encounter 1 boulder per day (after the fact),
    b. that excavating "running" sands and gravels would not require stabilization,
    c. that removal of a boulder daily would have no consequence on productivity or ground stability.

4. Contradicts a long established standard whereby conditions in one boring are applied to the midpoint between two borings,

5. Contradicts a long established standard whereby like conditions in two adjacent borings are connected by a straight line and those conditions applied between the borings,

6. Fails to take into account the geological variability of various tills and outwash deposits and their boulder frequencies, and

7. Fails to define the probabilities and variability inherent in his method.

Using Dr. Heuer's application of Hunt's correlation curve yielded a 0.56% boulder volume that would be about 146 ft^3 of 1 ft^3 boulders. However, if one were to apply a valid variation shown in the graph used by Dr. Heuer, the volume could be as much as 1.6% and 418 ft^3 of 1 ft^3 boulders as summarized in **Exhibit 10** and **Exhibit 11**.

Using the Hunt method, Dr. Heuer has calculated that one boulder will occur every 2.6 ft of tunnel, yielding roughly 343 boulders for the entire length of the tunnel as opposed to only 30-60 boulders admitted by Weltin in his deposition as summarized in **Exhibit 12**.

Heuer (2006-07-26) further states:

> ***"Based on my review of the job, I believe it will not be possible to complete the tunnel construction under the terms of the Contract technical specifications. This conclusion is discussed below."***

This judgment is made without considering the contractor's selection of means, methods, and equipment being inconsistent with indicated:

1. Coarse granular soils,

2. Boulders in coarse granular soils, and

3. A shallow cover above the tunnel crown,

Dr. Heuer's opinion and the underlying bases are inconsequential under the circumstances. At best, they confirm the contractor's methods being inappropriate for the project conditions.

Despite Dr. Heuer's vast experience in glacial materials, he finds no relevance in the interaction of the selected means, methods, and selection of equipment to be of any consequence worth mentioning.

Conclusions

In the end (25-Jul-06), Dr. Heuer states:

> ***"My conclusion is that the raw boring data could be interpreted to indicate frequent boulder encounters, similar to what has actually been encountered, and to what STS now says could be expected. But that type of interpretation would be made by a geotechnical specialist, not by a normal tunneling contractor."***

We agree with Dr. Heuer's conclusion that frequent encounter with boulder could have been anticipated, however we disagree that only a geotechnical specialist could make that interpretation. In our experience, our clients have learned to interpret geotechnical reports, learned to estimate construction performance from sophisticated relationships with geotechnical properties, and have required fewer to no pre-bid reports for even complex projects.

Michels

The real issue is how Michels, the contractor, arrived at:

1. The anticipated conditions,
2. The selection of means, methods, equipment, and
3. The construction estimate,

given the geotechnical and contract indications regarding excavation of:

1. Coarse granular materials and
2. Boulders from coarse granular materials.

Weltin

Mr. Weltin's (Michels **Tunnel Division Manager)** revelations in his deposition are astonishing because:

1. In his deposition, Weltin testified that he had extensive experience with glacial soils as follows:

   "City of Waukesha. I worked there nine years and left there in 1973 as chief underground engineer – or chief sewer engineer is what they called it." (Deposition p8-9)

   "Q During your time with Waukesha, were you involved with any projects that included dealing with glacial soils?
   A Yes."

"Q 20 per year?" (9 x 20 = 180 projects)
A Yes." (Deposition p10)

"Fox Point where I was city engineer and director of public works . I was in Fox Point until 1979" (Deposition p9)

"Q In addition to that project in Fox Point, have you done other projects at Michels in glacial soils?
A Yes.
Q About how many?
MR. CHRISTIANSEN: Objection. Calls for speculation.
THE WITNESS: I don't recall. I would have to go back to my records and look. In 30 years at Michels, a lot of projects.
BY MR. LYONS:
Q More than one a year would you say?
A Absolutely, yes." (30 x 1 = 30) (Deposition p13-14)

"Q Do you have any idea approximately how many bids you've prepared on your own per year while you were at Michels?
MR. CHRISTIANSEN: Calls for speculation.
THE WITNESS: I'd be guessing.
BY MR. LYONS:
Q Might it be five per year?
A No. More.
Q Any idea how many bids altogether you prepared in your career?
A Hundreds.
Q Of those hundreds, what percentage would you say have been in Wisconsin?
MR. CHRISTIANSEN: Calls for speculation.
THE WITNESS: I don't know. We bid all over the United States and Canada.
BY MR. LYONS:
Q Any idea what percentage of your work during your career has been in Wisconsin and what percentage has been outside of Wisconsin?
A Of our work?
Q Sure. Strike that. Of the jobs you've bid.
A Maybe 25 percent out of the state and 75 percent in the state, and that is purely a guess.
Q Don't worry, sir, there won't be any quizzes on this later. Have you bid jobs in Wisconsin in glacial soils?
A Yes.
Q Have you bid any outside of the glacial soils areas of the southwestern driftless part of the state where there aren't glacial soils?
A No." (Deposition p15-16)

2. Weltin failed to:

    a. Read the contract specifications,
    b. Consider the nature of the indicated soils and their "running" or "flowing" behavior in the selection means, methods, and equipment,
    c. Consider the nature of the boulders, their removal, and consequences on the behavior of the "running" or "flowing" soils in the tunnel envelope,
    d. Shallow cover, and
    e. Consider need for stabilization of a "running" or "flowing" soils.

Furthermore, Mr. Weltin was deposed and said:

> ***"Q Do you know Steve Hunt?***
> ***A Yes, I do.***
> ***Q How do you know him?***
> ***A I have met him on many occasions professionally, co-authored a paper with him.***
> ***Q What was the paper?***
> ***A It dealt with boulder incidences on the tunnel construction for MMSD***." (Deposition p18)

Yet, Mr. Weltin failed to make a calculation using his co-author's method to predict boulders, a crucial element, on this project.

> ***"Q Sir, would you agree that when you're tunneling in sand and gravel, you're always concerned with the sands and gravels running or shifting depending on the moisture content of the soils?***
> ***A Yes."*** (Deposition p38)

In consideration of Mr. Weltin's vast experience in glacial materials, we conclude that the shortcoming was not that he was not a "geotechnical specialist", it was that he:

1. Did not read the specifications,

2. Did not consider all of the geotechnical data,

    a. coarse granular material,
    b. boulders in the coarse granular material, and
    c. shallow cover,

3. Did not consider the geotechnical report in its entirety, and

4. Failed to perform his responsibilities as the tunnel division manager.

We also find it curious that Mr. Weltin authored a paper with Mr. Hunt, yet is not aware of Hunt's publication relevant to work in Wisconsin.

Local Conditions

All but one of the borings for the Proposed Villager Apartments (included with the geotechnical report) was terminated due to Auger refusal on Cobbles, Boulders, or probable Bedrock. It is unlikely that borings shallower than 20 ft encountered rock since most of the rock in that vicinity is in excess of 20 ft deep.

Means, Methods, and Equipment

Based on the experience on this project, Michels failed to consider or plan to excavate the coarse granular material with or without the boulders. Michels was not prepared or had specific plans to remove even one boulder from the "running" or "flowing" sands and gravel.

Other contractors recognized the nature of the ground, ground behavior, and need for stabilization, while Michels did not.

CONCLUSION

We have found that Michels' bid was not responsible and not responsive to the call for tenders on this project. Michels failed to consider the coarse granular materials to be encountered, the shallow cover, and the need for stabilization. These conditions and necessary construction means, methods, and equipment, were recognized by other responsible bidders. Michels' failure to recognize these conditions were the sole reasons for the extensive loss of ground, associated problems, and additional costs to the contractor.

Dr. Heuer, like his client, failed to address the coarse granular materials to be encountered, the shallow cover, and the need for stabilization. He also avoids dealing with the selection of means, methods, and equipment for the conditions indicated, anticipated, and ultimately encountered.

The basis of the contractor's claim was examined in terms of the elements of entitlement and has been assessed as follows:

1. There must be a difference demonstrable between reasonable indicated (anticipated) and well documented encountered conditions; ***Not demonstrated***

2. There must be a difference demonstrable between reasonable anticipated and well documented encountered construction performance; ***Not demonstrated***

3. There must be a cause-and-effect relationship demonstrable between differences in conditions and differences in construction performance; ***Not demonstrated***

4. There must be a demonstrable impact in time & space on costs; ***Not demonstrated***

5. All contract conditions must be fulfilled:

   a. Reliance, ***Not demonstrated***
   b. Notice, and ***6/2006 (55 days late)***
   c. Mitigation; ***Not demonstrated***

6. No other factors (self-inflicted) can have caused the difference between anticipated and encountered performance. ***Self-inflicted problems***

The contractor has fulfilled none of the requirements for entitlement.

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1. **Tarkoy, P. J.** (1988). The Stuff that Claims Are Made Of. World Tunneling 1(3):249-253 (September).

2. **Tarkoy, P. J.,** (1989). Differing Site Conditions Often Generate Claims. The Military Engineer 81(531):72-75 (September/October).

3. **Tarkoy, P. J.** (1990). Estimating and Improving Excavation Performance. 1990 Transactions of the American Association of Cost Engineers. 34th Annual Meeting, June 24-27, 1990. Boston, MA. pp. A.4.1-A.4.6.

4. **Tarkoy, P. J.,** (1995). Technical Elements for Entitlement of a Differing Site Condition Claim, Congresso Mexicano Ingenieríera de Túneles y Obras Subterraneas, Mexico City, 8-11 Oct, **in press.**

5. **Tarkoy, P. J.,** (1995). PLIEGO DE CONDICIONES PARA CONSTRUCCIÓN DE TÚNELES Y CONSTRUCCIÓN SUBTERRANEA para tratar con Asuntos Geotécnicos para Evitar y Resolver Disputas, Congresso Mexicano Ingenieríera de Túneles y Obras Subterraneas, Mexico City, 8-11 Oct, **in press.**

6. **Tarkoy, P. J.,** (1995). Contract Documents For Tunneling and Underground Construction for Dealing with Geotechnical Issues to Avoid and Resolve Disputes, 13th Canadian Tunneling Conference, Montreal, 18-20 Oct.

7. **Tarkoy, P. J.** (1998). Differing Site Conditions, World Tunneling (March).

8. **Tarkoy, P. J.** (2006). Entitlement for Differing Site Conditions, Annual Meeting of the AEG, Boston, Nov.

9. **Tarkoy, P. J.** (2008). Managing the Unforeseen, World Tunneling (March).

EXHIBITS

Exhibit 1: Elm Grove Differing Site Condition Clause

4.03 Differing Subsurface or Physical Conditions

A. Notice: If Contractor believes that any subsurface or physical condition at or contiguous to the Site that is uncovered or revealed either:

1. is of such a nature as to establish that any "technical data" on which Contractor is entitled to rely as provided in Paragraph 4.02 is materially inaccurate or

2. is of such a nature as to require a change in the Contract Documents or

3. differs materially from that shown or indicated in the Contract Documents; or 4.03

4 . is of an unusual nature, and differs materially from conditions ordinarily encountered and generally recognized as inherent in work of the character provided for in the Contract Documents;

then Contractor shall, promptly after becoming aware thereof and before further disturbing the subsurface or physical conditions or performing any Work in connection therewith (except in an emergency as required by Paragraph 6.16.A), notify Owner and Engineer in writing about such condition. Contractor shall not further disturb such condition or perform any Work in connection therewith (except as aforesaid) until receipt of written order to do so.

B. Engineer's Review: After receipt of written notice as required by Paragraph 4.03.4 Engineer will promptly review the pertinent condition, determine the necessity of Owner's obtaining additional exploration or tests with respect thereto, and advise Owner in writing (with a copy to Contractor) of Engineer's findings and conclusions.

C. Possible Price and Times Adjustments

1. The Contract Price or the Contract Times, or both, will be equitably adjusted to the extent that the existence of such differing subsurface or physical condition causes an increase or decrease in Contractor's cost of, or time required for, performance of the Work; subject, however, to the following:

a. such condition must meet any one or more of the categories described in Paragraph 4.03.A; and

b. with respect to Work that is paid for on a Unit Price Basis, any adjustment in Contract Price will be subject to the provisions of Paragraphs 9.07 and 11.03.

2. Contractor shall not be entitled to any adjustment in the Contract Price or Contract Times if:

a. Contractor knew of the existence of such conditions at the time Contractor made a final commitment to Owner with respect to Contract Price and Contract Times by the submission of a Bid or becoming bound under a negotiated contract; or

b. the existence of such condition could reasonably have been discovered or revealed as a result of any examination, investigation, exploration, test, or study of the Site and contiguous areas required by the Bidding Requirements or Contract Documents to be conducted by or for

c. Contractor failed to give the written notice as required by Paragraph 4.03.A.

3. If Owner and Contractor are unable to agree on entitlement to or on the amount or extent, if any, of any adjustment in the Contract Price or Contract Times, or both, a Claim may be made therefore as provided in Paragraph 10.05. However, Owner and Engineer, and any of their Related Entities shall not be liable to Contractor for any claims, costs, losses, or damages (including but not limited to all fees and charges of engineers, architects, attorneys, and other professionals and all court or arbitration or other dispute resolution costs) sustained by Contractor on or in connection with any other project or anticipated project.

Comment [PJT1]:

Comment [PJT2]:
1. Difference in Conditions

Comment [PJT3]:
5. Contract Conditions
b. notice

Comment [PJT4]:
3. Cause & Effect

Comment [PJT5]:
4. Impact

Comment [PJT6]:
2. Difference in Performance

Comment [PJT7]:
5. Contract Conditions
b. reliance

Comment [PJT8]:
5. Contract Conditions
b. reliance

Comment [PJT9]:
5. Contract Conditions
b. notice

Exhibit 2: Plan of Geotechnical Study Area for the Tunnel Section

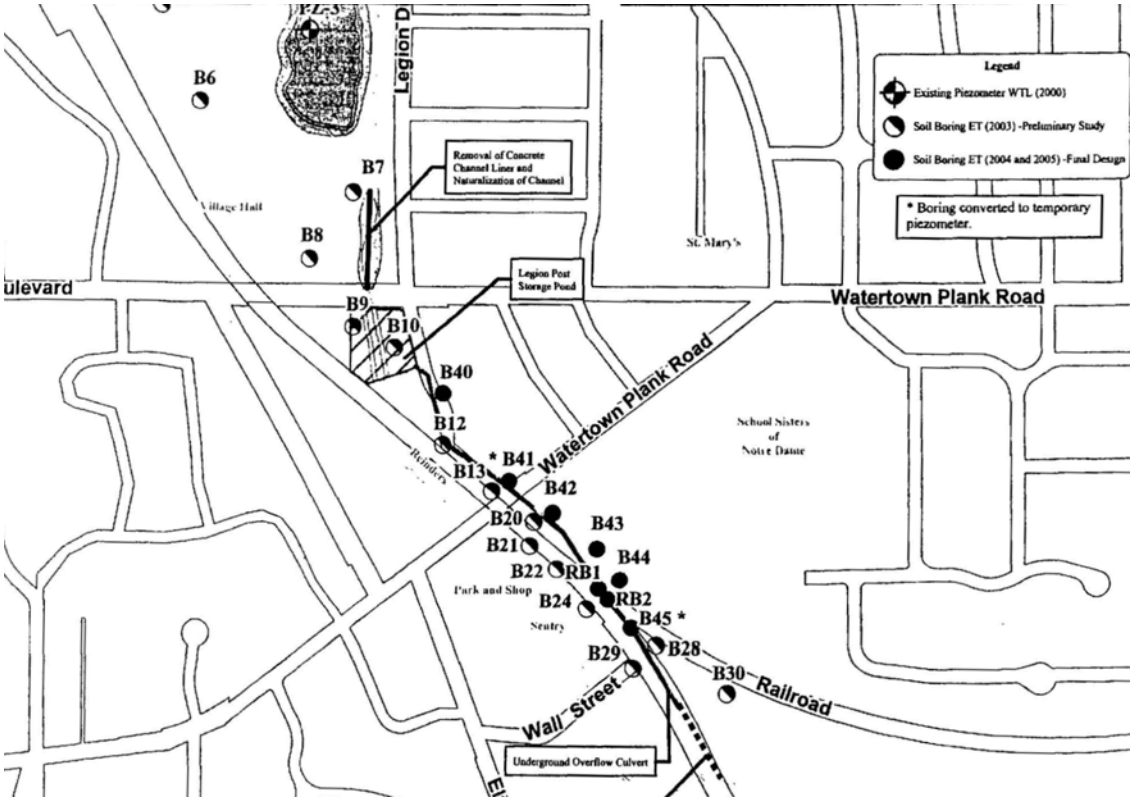


Exhibit 3: Anticipated Conditions – Known Local Conditions – Surface Conditions

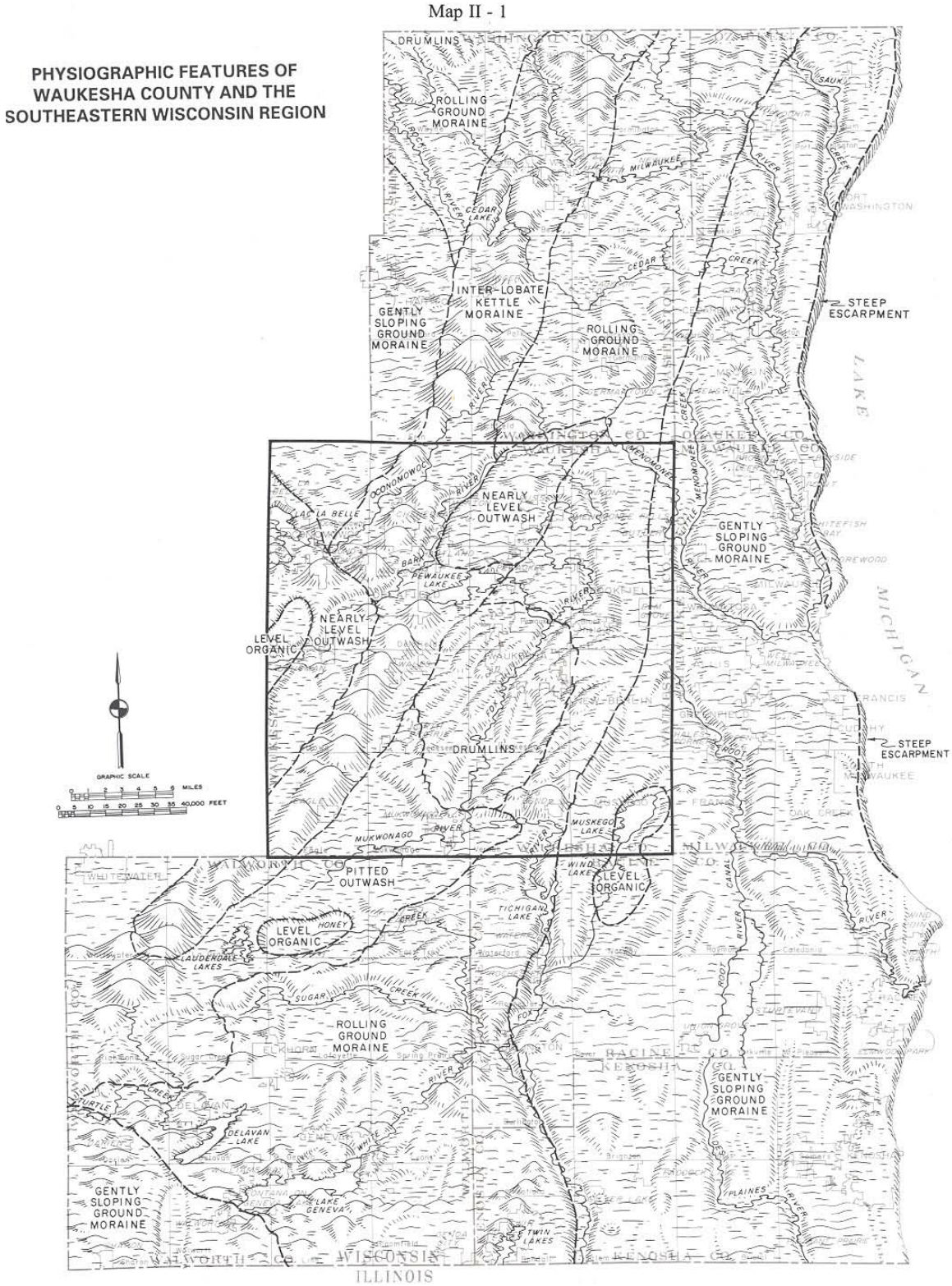


Exhibit 4: Anticipated Conditions – Known Local Conditions –Depth to Bedrock

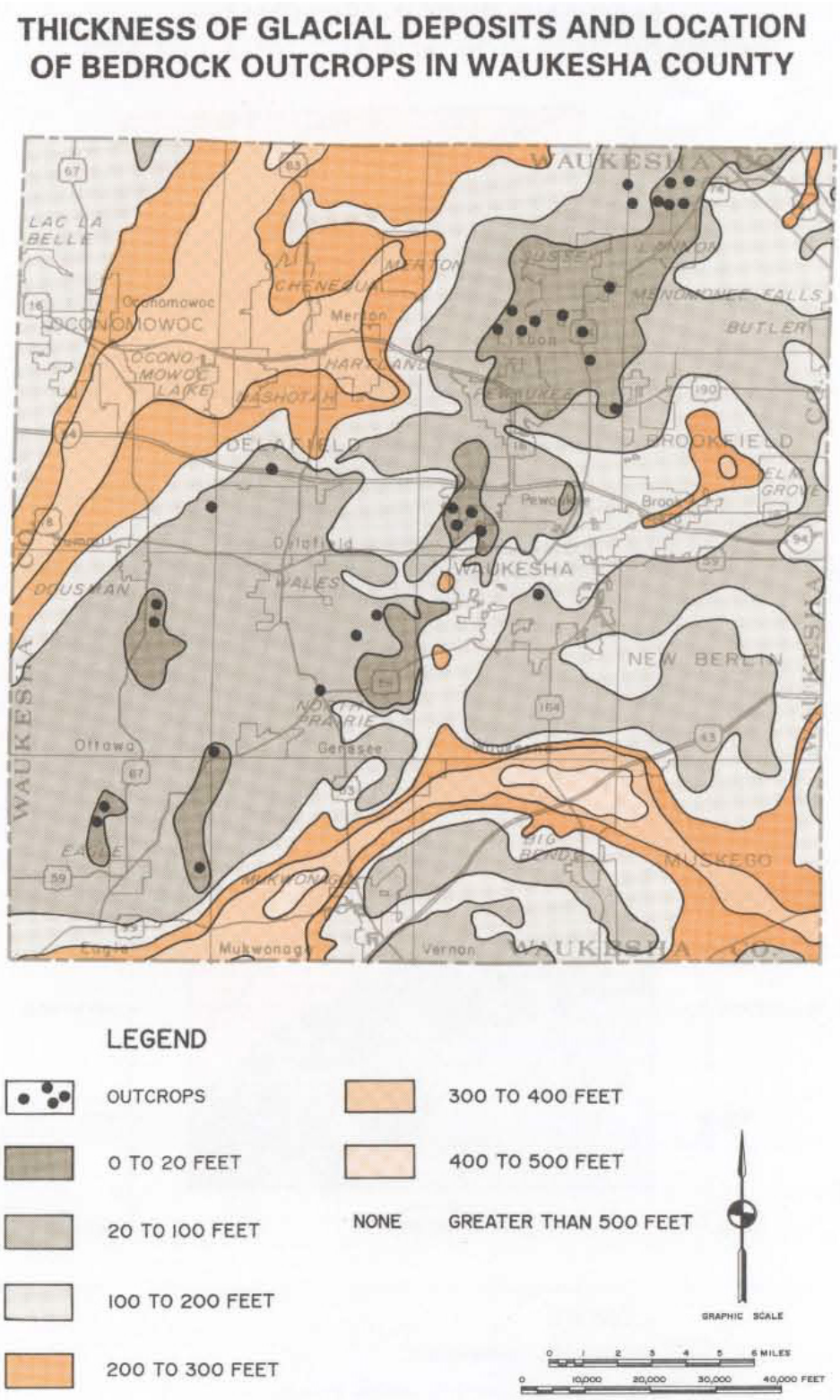
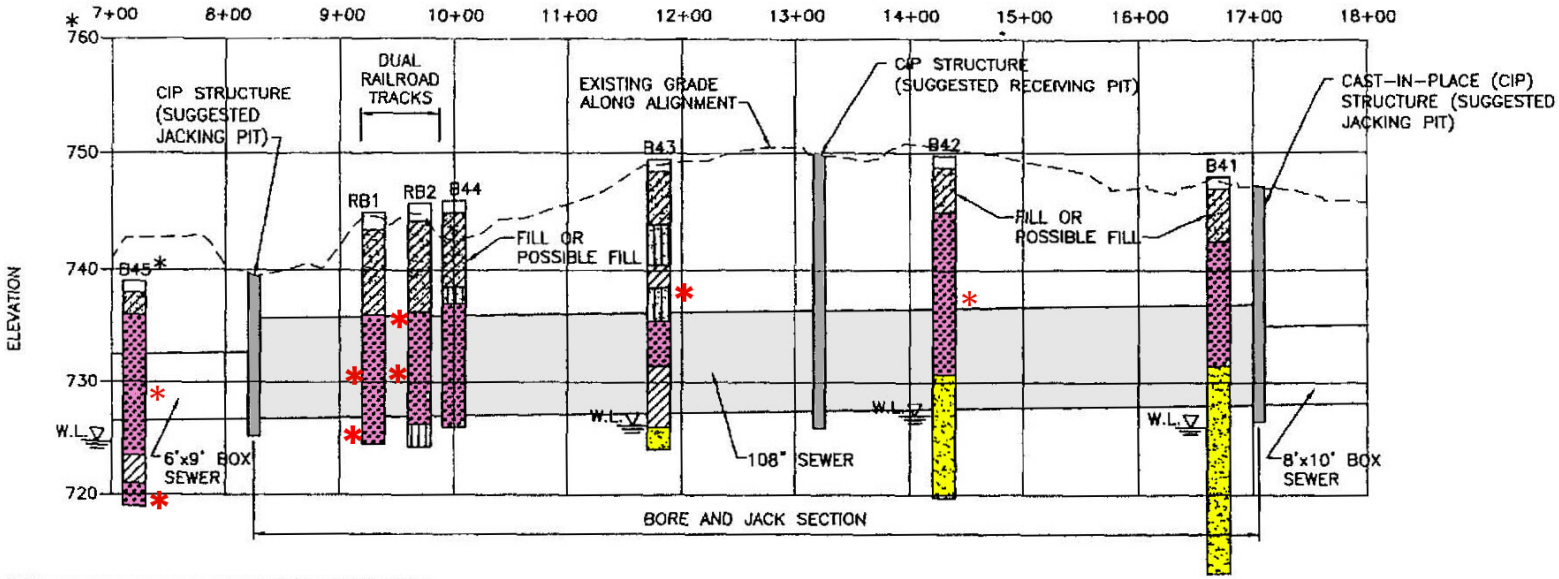


Exhibit 5: Anticipated Conditions in Profile Based on Borings



* BORING B45 CONVERTED TO A TEMPORARY PIEZOMETER. WATER LEVEL MEASUREMENT ON 6/4/04.
* BORING B41 CONVERTED TO A TEMPORARY PIEZOMETER. WATER LEVEL MEASUREMENT ON 6/4/04.

BORING FENCE DIAGRAM – BORE AND JACK SECTION

LEGEND

- SURFACE (TOPSOIL OR PAVEMENT)
- LEAN CLAY (CL)
- SANDY LEAN CLAY TO CLAYEY SAND (CL–SC)
- SILTY SAND (SM)
- SILT (ML)
- POORLY GRADED SAND WITH TRACE TO SOME GRAVEL (SP)
- POORLY GRADED SAND AND GRAVEL (SP–GP)

BORING	ELEVATION (FT)	OFFSET FROM ALIGNMENT
B41	748.1	14 FT
B42	749.7	27 FT
B43	749.3	18 FT
B44	745.7	55 FT
RB2	746.0(EST)	∠10 FT
RB1	745.5(EST)	∠10 FT
B45	739.3	∠10 FT

*** Boulders / Cobbles**

Exhibit 6: Selection of Means, Methods, and Equipment (TBM Configuration Type)

Exhibit 7: Distance from Tunnel Face to Flood Doors

Exhibit 8: Difference in Excavation Performance (Drive Shaft 5 to 4)
(annotations to be added)

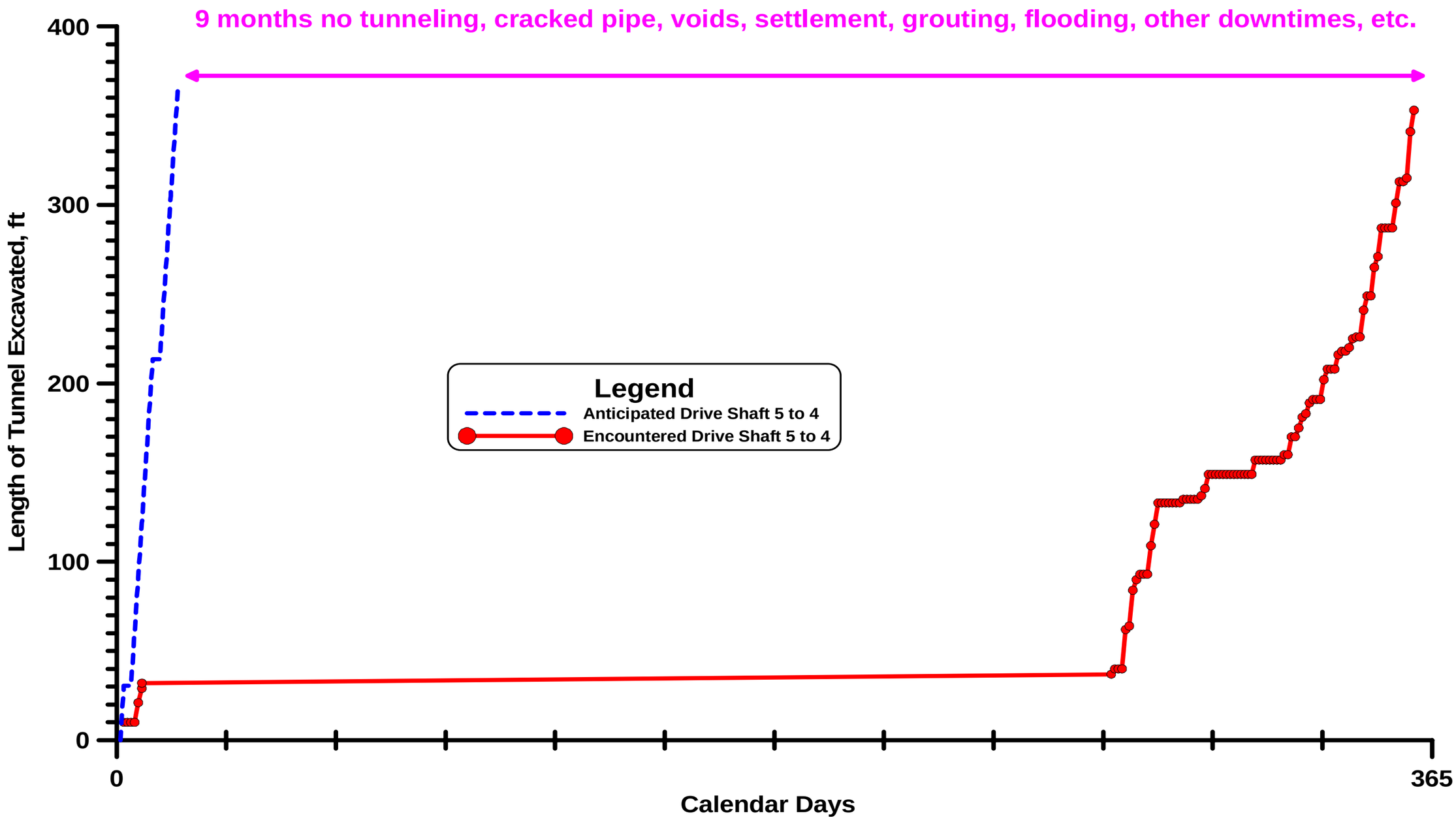


Exhibit 9: Difference in Excavation Performance (Drive Shaft 3 to 4)
(annotations to be added)

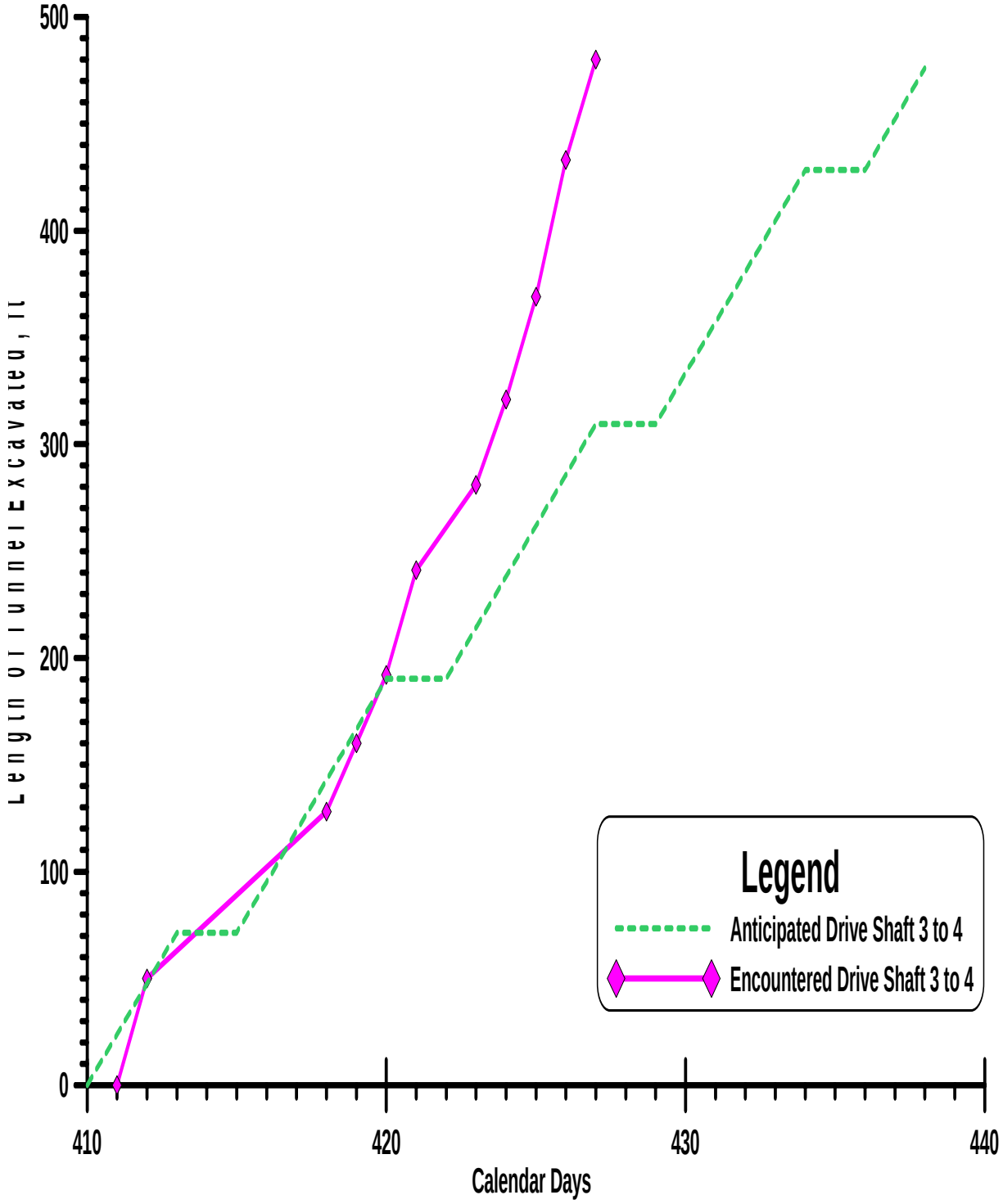


Exhibit 10: Summary of Calculated Boulders as per Heuer / Hunt

Tunnel Diameter, in	Tunnel Length, ft	Tunnel Length, in	Tunnel Volume, in^3	Boulder Volume, %	Boulder Volume, in^3	Boulder Volume, ft^3
130	891	10,692	45,173,700	0.56%	252,973	146
130	891	10,692	45,173,700	1.60%	722,779	418

Exhibit 11: Summary of Calculated Boulders as per Heuer / Hunt

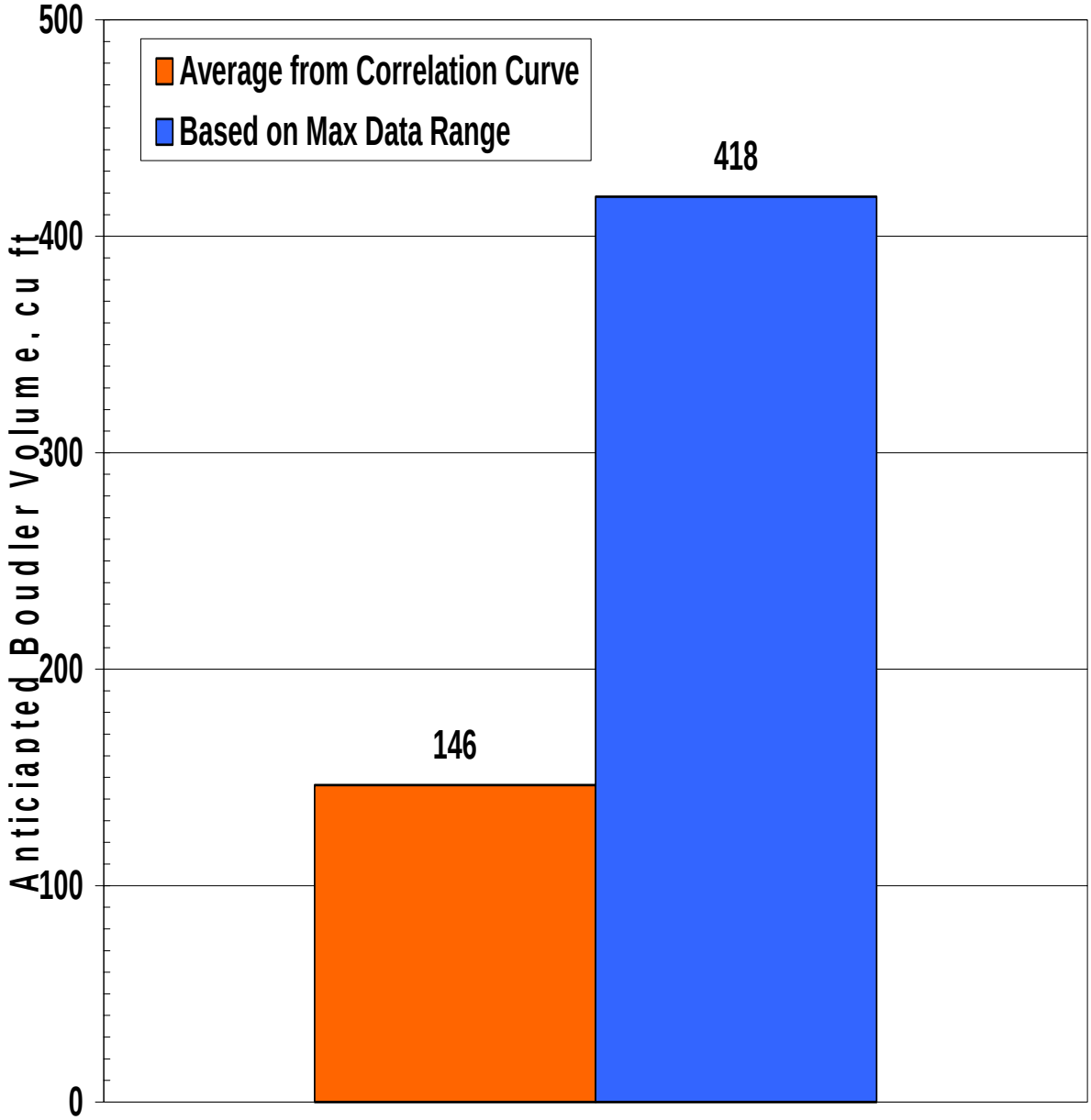
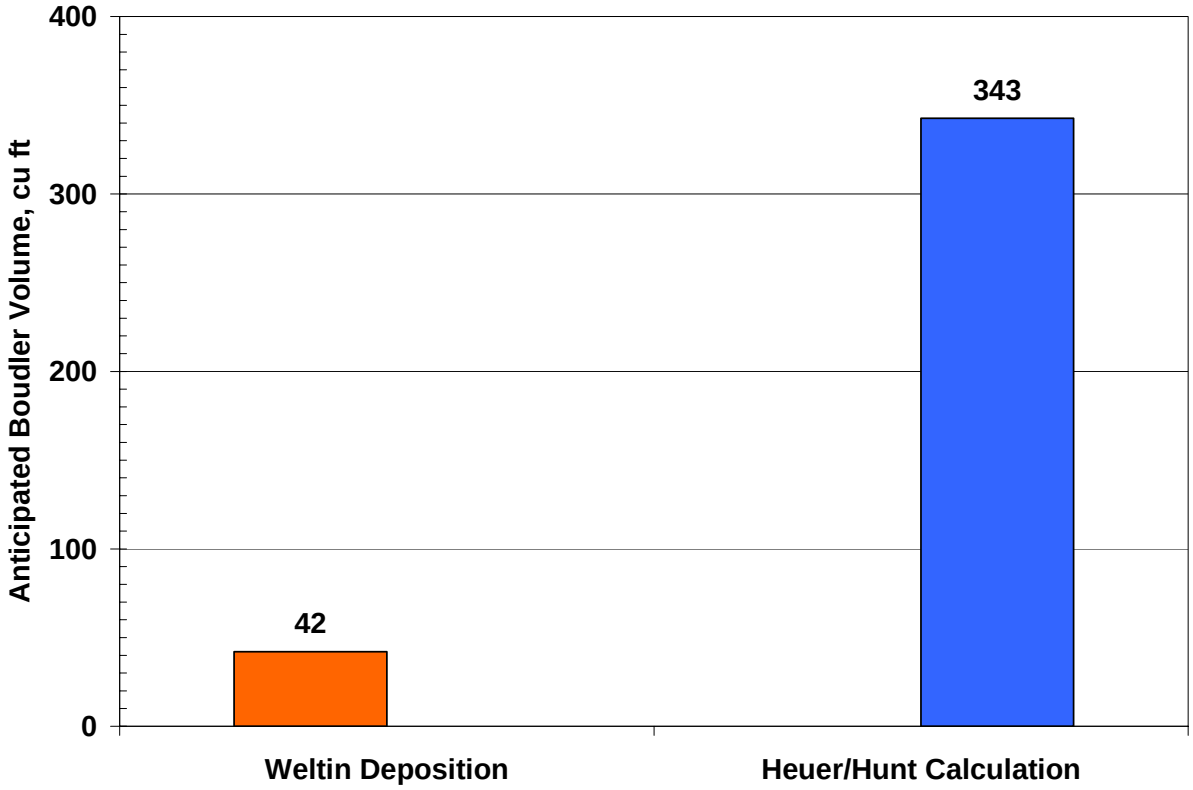


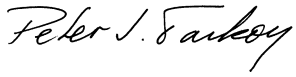
Exhibit 12: Summary of Number of Boulders Anticipated



APPENDICES

Appendix A: Resume of Peter J. Tarkoy

Resume - **Peter J. Tarkoy, Ph.D.**
Geotechnical and Tunnel Construction Consultant
(Tunnel Boring Machines, EPB Machines, Microtunneling Machines)
GeoConSol, Inc.
176 Western Avenue, Sherborn, MA 01770 USA
Fax to E-mail: 509-479-5400 / Telephone: (508) 650-3600
http://www.GeoConSol.com / http://www.TBMExchange.com
e-mail: PJT@ GeoConSol.com



EDUCATION

City College of New York, NYC	**B.Sc.**, Geology	1964
University of Tennessee at Knoxville	**M.Sc.**, Geology	1967
University of Illinois @ Urbana-Champaign	**Ph. D.**, Civil Eng.	1975

FORMER PROFESSIONAL LICENSES

Reg. Prof. Geologist California (1978); Georgia (1978); Idaho (1972);

LANGUAGES

Fluent English and Hungarian; Rusty French & German; Comprehension of Spanish

FORMER AFFILIATIONS

Member of Disputes Review Board Foundation (Education Committee); Member American Society of Civil Engineers; Boston Society of Civil Engineers; Geological Society of America; International Association of Engineering Geologists; Association of Engineering Geologists; British Tunnelling Society; Tunnel Association of Canada; International Tunneling Association; Society of Mining Engineers;

ACCOMPLISHMENTS

Honorary

Nominated "**Man of the Year**" and cited by the Publishers and Editors of Engineering News-Record as one of those who made marks in 1984 "for resolving changed-conditions disputes out of court with computerized geological records", and "from among the many who serve the best interests of the construction industry, February 13, 1985". **Member, Editorial Board, Trenchless Technology Magazine, No-Dig Engineering, Directional Drilling, and Tunnel Business Magazine.**

Professional

Dr. Tarkoy developed the **Total Hardness series of tests** for predicting tunnel boring machine excavation penetration rates and cutter rolling path life. He developed standards used in the industry for predicting, analyzing, and improving mechanical excavation performance and tunnel excavation efficiency. He developed and continues to enhance analytical methods to assess feasibility, select underground construction equipment, forecast, and evaluate excavation performance, and cutting efficiency, to minimize downtime, delays, difficulties with geotechnical conditions, and improve excavation efficiency. He has developed extensive studies of labor efficiencies, daily progress, and construction coordination to improve construction performance. Dr. Tarkoy has developed analytical techniques for analyzing and understanding rock comminution under difficult conditions and has published a treatise on that subject.

He has been associated with the introduction of tunnel boring in New York City and Washington, DC. **He has been instrumental in the first time use of TBMs in Hong Kong (1991) and Taiwan (1992).**

As a consultant to Sinotech Engineers Consultants (Taiwan) over a period of three months, he was instrumental in having the engineering profession, construction industry, and government of Taiwan select tunnel boring to excavate over 60 kilometers of rock tunnels in ten years. As a consultant to the Taiwan Ministry of Communication, Taipei Area National Expressway Engineering Bureau, he assessed the feasibility, resolved potential difficulties, and proposed viable alternatives to current state-of-the-art tunneling in Taiwan.

He has developed, established, and defined the technical elements of differing site condition claim for evaluation and presentation by the contractor and review and analysis by owners and engineers. His work on this subject has been published, widely accepted, and used in the industry.

EXPERIENCE - Project Stages

Thirty-five years experience in engineering geology, heavy and underground construction, microtunneling, mechanical excavation, and dredging in:

- feasibility studies and selection of most cost and time effective alternatives ,
- exploration, geotechnical interpretation, and design,
- pre-construction evaluation and pre-bid assessment,
- evaluation, recommendation, and improvement of TBMs and TBM performance,
- analysis, assessment, presentation, and adjudication of differing site conditions, and
- analysis, assessment, and solution of construction difficulties on various types of underground construction.

Feasibility & Design

Member, Board of Consultants to the Taiwan Ministry of Communications (5 tunnels, longest 13 km with a single heading and very difficult geological conditions, to be excavated by TBM; US$ 1+ billion project);

Member, Board of Consultants Taiwan Water Conservancy Board for a number of water supply tunnels.

Consultant to the designer of the Boston wastewater outfall tunnel (9 mi),

Review of feasibility, contract documents, and evaluation of tenders for a Twin Road tunnel for a gold mine in New Zealand.

Exploration, Interpretation, and Presentation of Geotechnical Conditions

Thirty-five years of experience with:

- exploration (planning, execution, and participation in all field operations),
- interpretation of tunnel exploration for design and construction,
- presentation of exploration data,
- preparation of specifications and contract documents,
- pre-bid evaluation for construction estimating, and
- design of excavation and primary rock support and anchor systems.

Pre-Bid

Pre-bid analysis for over 150 soft ground, rock, D&B, TBM, and MTBM, excavated underground construction projects throughout the world.

Dr. Tarkoy has developed a unique method of analysis and presentation of **geotechnical data for pre-bid evaluation of micro-tunneling and tunneling conditions,** specifically to lower construction costs and risk while utilizing site investigation data to produce a greater return on investment. He has developed quantitative, empirical, and practical methods to estimate anticipated conditions including establishing reasonable anticipated:

- **intact and rock mass quality**,
- rock boreability and powder factor,
- underground excavation rates,
- **water inflow**, and
- support requirements.

He has developed contract language and contractor prequalification processes for private as well as public contracts to minimize risk of spurious claims on tunnel projects.

Pre-Construction

TBM, backup system, lifeline, equipment selection for optimum performance, scheduling, and profit.

Construction

Record control, analysis, and improvement of tunnel boring machine & microtunnel penetration, utilization, daily advance, and scheduling.

He has been appointed by bid contractors as a technical advisor for a number of drill & blast and bored tunnel projects with unique problems such as unstable ground, high water inflow, critical TBM performance rates, and completion deadlines.

Forensic Investigations of Machine and Operational Problems

Investigation of machine failures, component failures, failure to perform, operational failures, loss of line and grade, failure to commission, cracking of pre-cast segments, and performing independent investigations to assign liability and responsibility for costs. These investigations included machine manufacturers and/or clients such as BRB, Coluccio, Val D'Or Gold, G&F, Confidential, Akkerman, Atlas-Copco Boretec, Herrenknecht, Jarva, Robbins, Soltau, and Wirth.

Adjudication of Construction Disputes - Differing Site Conditions

Expertise in the analysis, presentation, and **successful adjudication of over US $3 billion worth of differing site condition claims benefiting our clients** (owners & contractors) **approximately $5-10 million/year.**

Independent review, evaluation, defense, and adjudication of differing site condition claims for the Department of Justice in tunneling, dredging, and excavation.

Dr. Tarkoy has been qualified in court as an expert in geology, geotechnical engineering, various types of underground construction, construction **safety**, and in analyzing construction performance.

Forensic Investigations

Tunnels (collapses, flooding, differing site conditions, personal accidents), microtunneling (differing site conditions, machine failures, failure to perform), hydraulic dredging, HDD (differing site conditions), conduit plowing, Tunnel Boring Machines (mechanical failures, failure to perform, differing site conditions, accidents).

Resolution of Construction Disputes

Dr. Tarkoy is a panelist of the American Arbitration Association and has arbitrated a number of construction cases. He was recently serving as the Chairman of a Disputes Review Board for US$ 250 million contract in Boston.

He has been entrusted to provide independent evaluation of differing site condition claims by the:

- Washington Metropolitan Area Transit Authority,
- US Bureau of Reclamation ($8 million),
- US Army Corps of Engineers ($35 million),
- US Department of Justice ($50 million total),
- Metropolitan Water Reclamation District of Greater Chicago ($30 million),
- Massachusetts Water Resources Authority ($100 million), and
- Eurotunnel ($200 million; $2 billion consequential),
- Alaska Power Authority ($8 million), and
- on various projects for contractor clients in:
    - USA ($15-60 million),
    - England ($200 million; delay to commission $2 billion),
    - France ($20 million),
    - Italy ($50 million),
    - Indonesia ($20 million),
    - South America $35 million).

EXPERIENCE - Project Types

Heavy and Underground Construction

Dr. Tarkoy began his career in underground construction in 1967, when he was engaged in site investigations for the Washington Metropolitan Area Transit Authority. Later, in the early 1970's he participated in the University of Illinois research program that included field measurements on the initial tunnels and excavations in both soil and rock of the Washington Metro. He has applied these and subsequent experience and research results to the development and application of new techniques for assessing and improving excavation performance during tunneling, mitigating construction delays, and minimizing cost overruns. He has utilized this experience to lower construction risks and costs on major projects worldwide.

Tunnels

He has served as a consultant on hard rock and soft ground, conventionally and machine excavated tunnels throughout the world, as follows:

Subway Tunnels in Atlanta; Baltimore; Boston (TBM); Buffalo (TBM); New York City (TBM); New Jersey; San Francisco (TBM); and Washington, DC (TBM); Dallas and Houston.

Sewer and Utility Tunnels in Atlanta (TBM); Boston (Soil & Rock TBMs & TT); Chicago (TBM); Connecticut (TBM & TT); England (TBM); Detroit (TBM); Flint (Soil & Rock TBM); Hong Kong (TBM); Kansas City (Soil & Rock TBM & TT); Lackawana; Maryland (TBM); Massachusetts (Soil & Rock TBM & TT); Michigan (TBM); Milwaukee (Soil & Rock TBM); Montreal (TBM); New York (Soil & Rock TBM & TT); Cleveland, Ohio (TBM); Ottawa (TBM); Philadelphia (TBM); Rhode Island (TBM & TT); Rib Mountain, WI (Trench); Rochester & Syracuse, NY (TBM & TT) **Singapore;** San Francisco; Texas (TBM); Washington, DC (Soil & Rock TBM);

Water and Hydropower Tunnels in Africa (TBM); Alaska (TBM); Arizona (TBM); California (TBM); Canada (TBM); China (TBM); Colombia (TBM); Colorado (TBM); Connecticut (TBM); Ecuador (TBM); England (TBM); Hong Kong (TBM); Lesotho (TBM); Boston, Massachusetts (TBM); New Mexico (TBM); New York (D&B & TBM); Peru (TBM); Puerto Rico; Seabrook, NH (TBM); Taiwan (TBM); Toronto (TBM); Utah (TBM); Virginia (TBM); and Washington (TBM);

Transportation Tunnels in Boston, Canada (TBM); Channel Tunnel (TBM); Colorado; England (TBM); Hong Kong (TBM); New York City (TBM); New Zealand (TBM), and Taiwan (TBM);

SuperConductor SuperCollider Proposal for the selection of New York State; Pre-Bid analysis for a contractor / Perini (TBM); Pre-bid analysis and report for Perini Corporation; Evaluation of the fulfillment of project **safety** mandates.

Tunnels and Openings for Mining Idaho Springs Mine, Colorado; Kiena Gold Mine (TBM), Val D'Or, Canada; Star Mine (TBM), Idaho; Coal Mine (TBM), Illinois; Kansas City, limestone mine and warehouse facility, Climax Mine (TBM), Colorado; Republic Steel (TBM), Mineville, NY; Quarry, California; Oil Development, Prudhoe Bay, Alaska; Newcastle Coal Mine (TBM), UK; **New Zealand (TBM);**

Trench Excavation New York, Connecticut, and Massachusetts.
Trenchless Excavation in soil, rock, and mixed face conditions in NY, California, Connecticut, Hawaii, Illinois, Kansas, Massachusetts, Texas, Vermont, and New Hampshire.

Recommendations for detecting covert tunnels to various clients.

Machine Bored Tunnels

Dr. Tarkoy, performed field investigations and rock sampling, collected mechanical excavation performance data, and analyzed in detail, over 30 TBM tunnels to develop a rock testing system and empirical methods to establish TBM feasibility and for predicting TBM penetration rates, cutter costs, and TBM performance. He directed a program of field measurements and laboratory studies to evaluate the effect of geotechnical conditions on machine performance and to make improvements to TBM systems. This study became the topic of his doctoral thesis.

He has had personal hands-on and analytical experience with over **200 km and 100 man-years of tunnel boring and mechanical excavation.** He has applied these and subsequent research results to the development and application of new techniques for evaluating and controlling excavation performance during tunneling, minimizing lost time, and decreasing cost and risk.

He has been consulted by owners, mining, companies, designers, contractors, and government agencies on a wide variety of major underground projects throughout North and South America, the Arctic, Africa, Asia, and Europe, participating in feasibility studies, design and interpretation of exploration, development of designs, **pre-construction evaluations,** control and monitoring during construction, evaluation and correction of construction problems, and resolution of disputes.

He has investigated 300 projects worldwide, most of which consist of underground construction tunneling, with over 150 TBM excavated tunnels, for geotechnical and tunneling conditions, TBM performance, excavation efficiency, solving a variety of problems, and improving excavation performance.

He has discovered and extensively documented rock characteristics that cannot be predicted by laboratory testing and requires field-testing with the TBM to establish the unique rock mass conditions, which affect tunnel boreability.

Microtunneling, Pipe-Jacking, Trenchless Excavation

Twenty five years of innovation in trenchless excavation, including over 100 miles of 36", 48, 64", 72', and 84' and 96' diameter excavation, rock blasting, pipe-jacking, jacking forces, pipe jacking of the largest (300 ft of 10x14 ft) box culvert in the Northeast (1997), analysis of pipe-jacking productivity, study of pipe failures, machine failures, and geotechnical difficulties associated with microtunneling excavation. Experience with differing site condition claims associated with microtunneling and other problems in various and unusual geological conditions.

Papers on exploration for trenchless excavation and contract standards for trenchless excavation in preparation.

Other

Four years with the Perini Corporation, provided Dr. Tarkoy with a wide variety of field experience in heavy, underground, marine, and mining construction. He has investigated sites in most of the physiographic provinces in the United States and major rock types worldwide, making observations of geologic conditions and their effect on active projects, as well as conducting field investigations to predict the geologic conditions, and their effect on future projects. He has investigated tunneling conditions for a variety of deep tunnels excavated by tunnel boring machines in the mountain west and carried out a program of field sampling and performance analyses. He has designed, implemented, installed, and analyzed closely controlled construction blasting, vibration control, and geotechnical instrumentation.

He has been active in various other geotechnical and construction activities, such as:

- Controlled blasting design and vibration monitoring,
- Mining,
- Dredging,
- Geotechnical and construction instrumentation,
- Underground construction safety,
- Drillability / Comminution in pile socketing and slurry wall construction,
- Slurry wall construction.

Controlled Blasting and Vibration Monitoring

Dr. Tarkoy has 35 years experience with the **design, control, and monitoring of controlled blasting** of cut slopes, open cuts, shafts, tunnels, chambers. Some of the more difficult projects include:

- Peach Bottom Nuclear Power Plant (1968),
- Porter Square pilot shaft, pilot tunnel, tunnel, escalator shafts, vent shafts (1978-1981),
- Exchange Place PATH (operating) RR station in Jersey City (1988),
- Milwaukee sewer tunnel project (1988),

various pipe-jacking, tunnel, and surface excavation projects throughout the northeast.

Dr. Tarkoy has taught controlled blast design at the University of Wisconsin Extension. He has been qualified as an expert in blasting in Superior Court of Massachusetts and in arbitration by the American Arbitration Association.

Mining

Evaluated abandoned mine stability and safety for warehousing and potential subsidence after fire damage.

On assignment to the USBM Denver, we developed a rock mass surveying instrument and various methods of obtaining reliable **rock mass properties to assess stability** & caveability at the **San Manuel Mine**.

Evaluation of construction tenders for twin road tunnels for the **safety and stability over an abandoned mine with existing shafts, adits, and mine workings**.

Investigation of TBM performance, rock mass behavior, tunnel support experience, in the **Star Mine, Coeur D'Alene District, Idaho.** The study was utilized in developing a system for predicting **TBM performance** and understanding the effect of **geotectonic and mine stresses on rock comminution.** During the course of the study on rock comminution, experience from a deep gold mine in South Africa was also analyzed for the effects of stresses on rock comminution.

Investigation of intact and rock mass characteristics at the **Kiena Mine, Val D'Or, Ontario,** to **improve excavation rates** and **eliminate delays for support installation**. A detailed study of the tunnel boring operation, labor costs, and performance efficiency allowed us to make recommendations that **decreased equipment downtime, increased production, and lowered costs. Our evaluation resulted in an economic operation where before it was uneconomic**.

We have evaluated excavation performance in an Illinois Coal Mine and a decline in **very hard rock** in the **Republic Steel Mine in Mineville, NY.** Evaluated excavated conditions for proposed mechanical excavation at the Climax, Colorado.

Geotechnical and Construction Instrumentation

Dr. Tarkoy has over 35 years of instrumentation experience, including major projects as follows:

- Slope stability instrumentation at the Peach Bottom Nuclear Power Plant (1968),
- Various tunnel stability instrumentation programs on the Washington Metropolitan Area Transit Authority (1972-1975), and
- Boston MBTA Red Line Extension tunnel instrumentation (1978-1983).

Underground Construction Safety

Dr. Tarkoy has been qualified as an expert in underground, tunnel, bored tunnel (TBM), and trenchless excavation, practical theory and issues (Henson, Healy). He has also been qualified in municipal and state courts in construction blasting and excavation (Bohanon in Minneapolis; Perini in Boston; MK at Seabrook Nuclear Power plant). He has been commissioned to evaluate project wide safety mandates, safety management, organization, implemented of the safety program, gantry safety (LA, California), and execution of safety mandates at the operational level (Super Collider, Texas).

Teaching Experience

He has been a visiting Professor at Cornell and Boston Universities, and has taught continuing education courses for the University of Wisconsin, American Society of Civil Engineers (Japan Section), Assoc. of Engineering Geologists, the Hong Kong Institution of Engineers, and American Society of Civil Engineers, on topics of tunnel boring, tunnel engineering, engineering geology, underground construction, and differing site conditions.

Invited visiting university lecturer on topics related to geology, engineering geology, engineering geology, geotechnical engineering, tunneling, and heavy construction. ASCE instructor for Differing Site Condition Claims Course. Course instructor for a course on Tunnel Boring to the Japan Society of Civil Engineers.

SERVICE

Member of ASCE's Eng. Geology Committee; Member Underground Technology Research Council; Panelist, American Arbitration Association; Chairman New England section AEG Legislative Committee (1979); Session Chairman, 4th Rapid Excavation & Tunneling Conference, 1979; Reviewer of papers for the Bulletin of the Association of Engineering Geologists;

Invited visiting university lecturer on topics related to geology, engineering geology, engineering geology, geotechnical engineering, tunneling, and heavy construction.

Board of Consultants for Cornell University TBM study; Moderator of a computer short course for engineering geologists and chairman of a seminar on microcomputer applications in engineering geology at the 1984 Annual Meeting of the Association of Engineering Geologists.

CONTINUING EDUCATION

- **Differing Site Conditions** (Course Instructor) Am. Soc. Civil Engineers
- **Differing Site Conditions** (Course Instructor) Univ. of Wisconsin - Ext.
- **Microtunneling Short Course** / TT (instructor)
- **Microtunneling Short Course** / CSM (instructor)
- **Small Diameter Tunneling** (instructor) Univ. of Wisconsin - Ext
- **Rock Tunneling** (instructor) Univ. of Wisconsin - Ext
- **Controlled Blasting** (instructor) Univ. of Wisconsin - Ext
- **Interpretation of Exploration** (instructor) Assoc. of Eng. Geologists
- **Limit Damages / Controlled Blasting** (instructor) Univ. of Wisconsin - Ext.
- CPM - Project Management (participant) A. J. Waldron
- The Engineer as an Expert Witness (participant) Am. Soc. Civil Engineers
- Soft Ground Tunneling (participant) Univ. of Wisconsin - Ext
- Hydraulic Dredging (participant) John Huston, Inc.

LIST OF PUBLICATIONS

Dr. Tarkoy is the author of over 60 papers and has lectured to professional societies, conferences, international congresses, and continuing education courses on the topics of geotechnical site investigations, geotechnical conditions, state of the art of TBM performance prediction, tunnel behavior, construction performance, state-of-the-art of tunnel boring, innovations in using TBMs in difficult geologic environments, innovations in tunnel boring, tunneling case histories, differing site conditions, difficult tunneling conditions, microtunneling, and trenchless technology.

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2. **Tarkoy, P. J.** (1968). Lithostratigraphy and Petrography of the Upper Cambrian Maynardville Formation within the Clinchport Fault Belt of East Tennessee. Annual Meeting of the Southeast Section, Geological Society of America, April 4-6.

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5. Parker, H. W. and **Tarkoy, P. J.** (1972). Program for Development of Slipform Equipment for Lining Machine Bored Rock Tunnels. For OHSGT, USDOT, Washington, D.C., Contract DOT-FR-30022, December.

6. Dietl, B. and **Tarkoy, P. J.** (1973). A Study of Rock Hardness and Tunnel- Boring Machine Advance Rates in Manhattan Schist. Tunneling Technology Newsletter No.3:4-9 (September).

7. **Tarkoy, P. J.** (1973). Non-Magnetic Tool for UG Rock Measurement. Mining Engineering 25(10)42-43 (October).

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9. Dietl, B. and **Tarkoy, P. J.** (1974b). Étude de la Dureté des Roches et des Vitesses d'Avancement d'Une Machine Foreuse dans les Schistes de Manhattan. [A Study of Rock Hardness and Tunnel Boring Machine Advance in Manhattan Schist.] Tunnels et Ouverages Souterrains 2:97-99 (March-April).

10. **Tarkoy, P. J.** (1974c). Rock Index Properties to Predict Tunnel Boring Machine Penetration Rates. In: Pattison, H.C. and D'Appolonia, E. (eds.), Proceedings, Volume 1, 1974 Rapid Evacuation and Tunneling Conference, San Francisco, CA, June 24-27. Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, New York. p 415. Abstract only. Complete paper available from NTIS, Springfield, VA 22151.

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13. **Tarkoy, P. J.** and Hendron, A.J., Jr. (1975c). Rock Hardness Index Properties and Geotechnical Parameters for Predicting TBM Performance. Final Report of NSF RANN Research Grant GI-36468, available from NTIS, Springfield, VA 22151, Document number PB 246293 or RA-T-75-030. 325p.

14. McCusker, T.G. and **Tarkoy, P. J.** (1976). Feasibility of Developing Arctic Oil and Gas Reserves by Tunneling. In: Robbins, R.J. and Conlon, R.J. (eds.), Proceedings, 1976 Rapid Evacuation and Tunneling Conference, Las Vegas, NV, June 14-17. Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, New York. pp 677-695.

15. McCusker, T.G. and **Tarkoy, P. J.** (1976). Considerations Affecting Development of Arctic Oil and Gas Reserves by Tunneling. Proceedings 2nd International Symposium on Cold Regions Engineering, University of Alaska, Fairbanks, Alaska, August.

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23. McFeat-Smith, I., and **Tarkoy, P. J.**, (1980). Tunnel Boring Machines in Difficult Ground. Tunnels and Tunneling 12(1):15-19 (January/February).

24. McFeat-Smith, I., and **Tarkoy, P. J.**, (1980). Site Investigations for Machine Tunneling Contracts. Tunnels and Tunneling 12(2):36-39 (March).

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