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Technical Memorandum

To:	Kathy Arnold	**From:**	Joel Carrasco and Monica Salguero
Company:	Rosemont Copper Company	**Date:**	April 5, 2010
Re:	Rosemont Flow-Through Drain Design	**Doc #:**	100/10-320828-5.3
CC:	David Krizek, P.E.		

1.0 Introduction

This Technical Memorandum provides a summary of Tetra Tech's design analysis related to the use of flow-through drains at the proposed Rosemont Copper Project (Project). Flow-through drains are large rock structures that provide:

- A hydraulic connection between the up-gradient side of the Rosemont Ridge Landform and the down-gradient side;
- Protection of facilities during operational periods; and
- Separation between the wash areas and the dry stack tailings with waste rock.

For the purpose of this Technical Memorandum, only the design basis is presented. Other Technical Memoranda titled *Heap Leach Facility Flood Surface Analysis and Stormwater Controls* (Tetra Tech, 2010a) and *Rosemont Flow-Through Drain Sizing* (Tetra Tech, 2010b) present the actual sizing of the flow-through drains. Sizing of the flow-through drains is dependent on the contributing area reporting to the drain inlet. The flow-through drains were generally sized to accommodate the maximum contributing watershed reporting to the drain inlet during operations and/or post-mining conditions. The drain systems were also generally designed to safely convey the Local and General Probable Maximum Precipitation (PMP) events.

2.0 Methods

Flow passing through the drains will vary both spatially and temporally. Consequently, a routing model developed by Samani, J. M. V. and and Heydari, M. at the Tarbiat Modares University was used to estimate outflow from the flow-through drains.

Samani, J. M. V. and Heydari, M. (2007) proposed a method for reservoir routing through rockfill dam structures that was applied to the outflow calculations for the flow-through drains. This method is applicable to the flow-through structures since it incorporates length as one of the equation variables. This equation was deemed more appropriate for this analysis than the Leps equation since Leps assumes a constant velocity at all times as flow passes through the structure.

The term “rockfill”, as specifically related to water flow problems, is defined as any noncohesive agglomeration of natural or broken rock particles. This definition is also applied herein.

Since the proposed rockfill structures will consist of coarse particles, the flow passing through the rock fill will deviate from Darcy’s law resulting in turbulent flow within the void spaces. This means that the relationship between the flow velocity, *V*, and its hydraulic gradient, *i,* is nonlinear. The flow rating equation for one-dimensional flow passing through rockfill dam structures is:

$$Q = \left(\frac{1}{D}\right)^{\frac{1}{b+2}} \frac{\alpha w}{(3+b)^{\frac{1}{b+2}}} \left(H_{up}^{b+3} - H_{down}^{b+3}\right)^{\frac{1}{b+2}} \qquad (1)$$

To develop the flow rating equation it was shown that:

$$V = \alpha i^{\frac{1}{b+2}} \qquad (2)$$

$$\alpha = \left(\frac{2g\upsilon^{b}}{a(d_{50} - \sigma)^{b-1}}\right)^{\frac{1}{b+2}} \qquad (3)$$

Where:

- d_{50} is the particle diameter size where 50% of the total particles’ weight is smaller;
- *a* and *b* are empirical coefficients of the equation related to the flow and particles characteristics;
- υ is the kinematic viscosity;
- σ is the standard deviation of rock size distribution;
- *Q* is the outflow rate through the rockfill dam structure; and
- H is the water depth inside the structure; and
- w is the width of the flow cross section.

D is defined as:

$$D = L - 0.7S_1 \qquad (4)$$

$$S_1 = H_{up} \cot \beta \qquad (5)$$

In equation (5):

- β is the angle of the upstream and downstream face of the dam structure with the horizontal direction; and

- L is the length of the dam structure according to flow direction.

Illustration 1.0 shows the equation components applied to the flow-through drain structures.

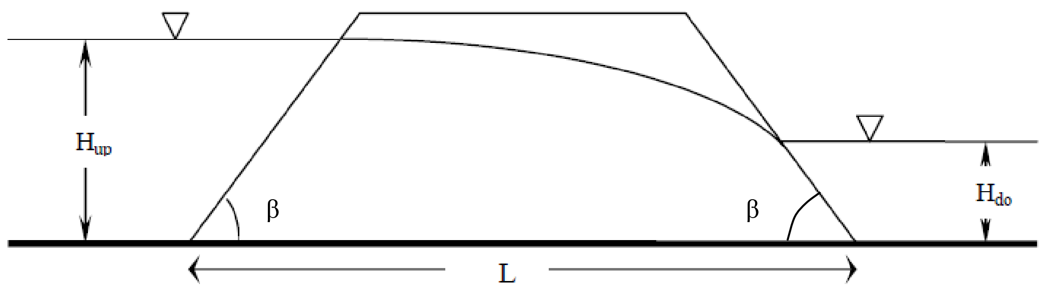

Illustration 1.0 Flow-Through Drain Structure

From equation (1), the outflow Q varies directly with the factor α [Equation (3)]. Flow increases as the difference between the d_{50} particle size and the standard deviation decreases.

3.0 Physical Parameters

The primary source of the flow-through drain material will be from select run-of-mine (ROM) rock types (Escrabosa and Glance) mined from the proposed Rosemont Open Pit. Limited amounts will come from on-site excavations, shaping operations, and surface preparation activities. As per AMEC Earth & Environmental, Inc. (AMEC), the material used in the drains shall be composed of hard, durable stone particles reasonably free from thin, flat and elongated pieces. Generally the material will have a wide range of gradations. It is anticipated, however, that the material will contain rock sizes having a d_{50} of 12 inches with rock particles less than 24 inches in size. AMEC's specifications are provided as Attachment 1. Table 1.0 provides the particle gradation limits from AMEC's Specifications.

Table 1.0 Particle Gradation Limits

Sieving size	Passing (%)
24 in	100
#200	0-10

Since AMEC's Specifications allow for a wide variation of particle sizes and distributions, a sensitivity analysis was performed assuming different distributions. This analysis was performed to determine the effect on flow characteristics. The particle size distribution provided for the Rosemont deposit [Call & Nicholas, Inc. (CNI), 2008] was used as the initial particle ranged used for determining the anticipated particle size distribution from the Rosemont Open Pit.

CNI calculated four (4) fragment size-distributions for the ore and waste rock materials in the Rosemont Open Pit. The fragment size-distributions included sulfide ore, oxide ore, and two (2) waste rock types. The only data used in the particle size analysis was the waste rock fragment size-distribution with the wider fragment size range.

The size distribution calculated for the waste rock is presented in Illustration 2.0 where d_{50} is the particle diameter size where 50% of the total particles' weight is smaller. The original data was modified to only include size distributions less than 24 inches per AMEC's drain rock specifications. The data eliminated was only about 8% of the total, resulting in a d_{50} of 14 inches.

Illustration 2.0 Modified Particle Size Distribution

Illustration 2.0 shows a d_{50} equal to 14 inches in diameter. The standard deviation, σ, and the average diameter, d, were obtained using the following relationships:

$$d = \frac{\Sigma d_i w_i}{\Sigma w_i} \quad (6)$$

Where:

- d_i is the average diameter of the rock obtained by averaging the sieve opening of two (2) succeeding sieves; and
- w_i is the percentage by weight of the rocks assigned a diameter d_i;.

$$\sigma = \left[\frac{\Sigma (d - d_i)^2}{\Sigma w_i} \right]^{1/2} \quad (7)$$

It was assumed that the particle size population followed a normal distribution.

4.0 Sensitivity Analysis and Results

Assuming that the statistical particle size distribution was normal, the results obtained from equations (6) and (7) were plugged into equations (1) and (3). This was done in order to perform a sensitivity analysis and study how the variation in particle sizes (uncertainty) affected the outflow rate. A generalized stage-storage curve was developed to evaluate and compare the different particle sizes. Illustration 3.0 shows the results obtained from the analysis using five (5) different d_{50} and Standard Deviations (SD).

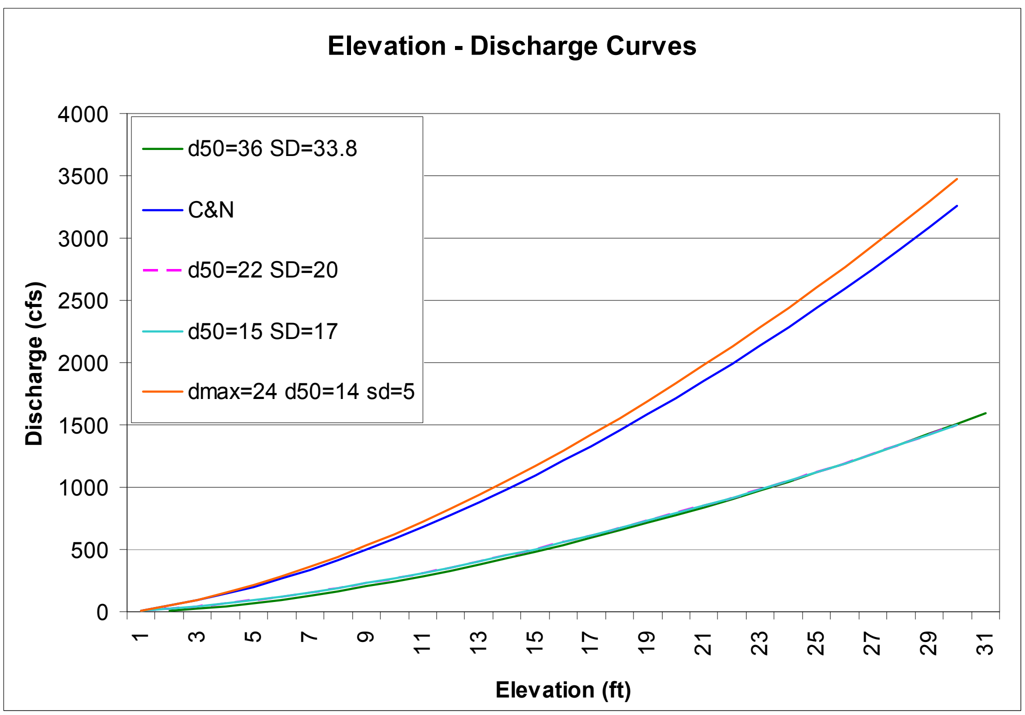

Illustration 3.0 Sensitivity Analysis Results

The sensitivity analysis showed that modifying the data to eliminate particle sizes larger than 24 inches (i.e., obtaining a smaller d_{50}) will not have a significant effect on the flow results. The analysis also showed that producing drain rock with a significantly larger standard deviation reduced the flow capacity through the drains by up to 50%. This analysis was performed to show how sensitive the capacity of the flow-through drains is to the standard deviation of the drain rock particles. Based on the CNI report, however, this large of a standard deviation is not anticipated from the Rosemont Deposit. Natural segregation due to truck end dumping is also not expected to detrimentally effect the flow characteristics of the drain since the overall particle size distribution (i.e., the standard deviation of the segregated material) is expected to be within an acceptable range.

The final results obtained from the calibration of the model for different standard deviations were used to study the flow behavior using different rock particle sizes with equivalent standard deviations. The results were shown to repeatedly follow the same curve profile when the size distribution was well distributed or 90% of the sample population was within two (2) standard deviations (Illustration 4.0).

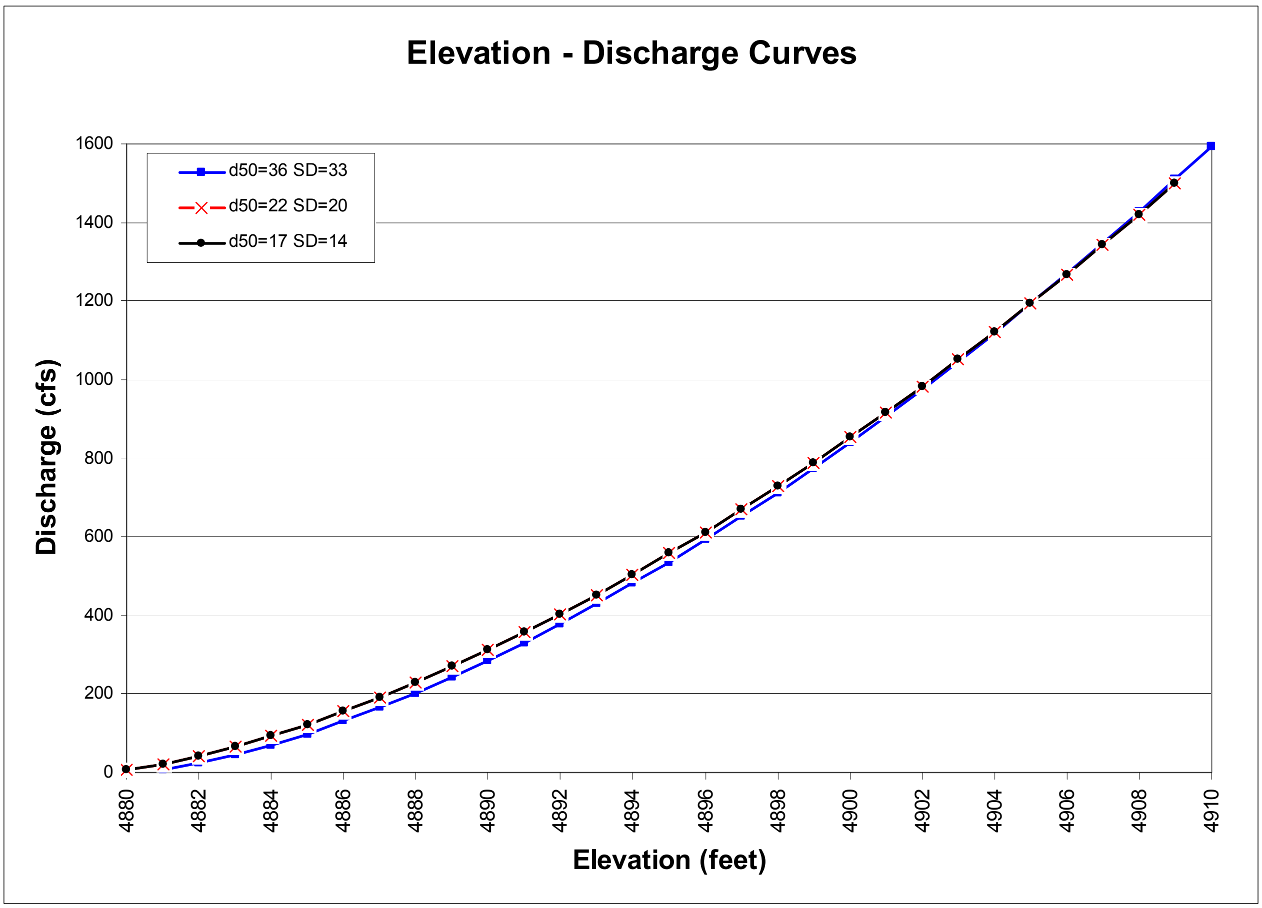

Illustration 4.0 Particle Size Distribution using 2σ

5.0 Conclusions

The relationship between flow gradient and rock particle distribution given by Samani appears to be sufficiently accurate to provide good estimates of flow passing through the proposed flow-through drain structures planned for the Rosemont Project.

A sensitivity analysis was also performed to evaluate the effect of different rockfill particle distributions on Samani's model. The analysis results indicated a direct correlation between flow and the rock size distribution. A well sorted rock distribution will result in better controlled flow at the downstream side of the drain than a rock size distribution with a standard deviation greater than two (2) times the largest rock size.

From the analyses and the CNI report, a final distribution of d_{50} = 14", with a standard deviation of σ = 5", was selected for the analysis. These numbers were determined to be the most representative of the data to design the drains.

6.0 References

AMEC Earth & Environmental, Inc. (AMEC) (2009). *Technical Specifications for Earthworks Materials and Construction*. Prepared for Rosemont Copper Company. Dated April, 2009.

Call & Nicholas, Inc. (CNI) (2008). *Feasibility-Level Geotechnical Study for the Rosemont Deposit*. Prepared for Augusta Resources. Report dated February 2008.

Leps T. M., (1973). *Flow Through Rockfill*. Embankment-Dam Engineering. Casagrande Volume. John Wiley & Sons. Dated 1973.

Samani, J. M. V., and Solimani, A. (2008). *Uncertainty Analysis of Routed Outflow in Rockfill Dams*. Journal of Agriculture Science and Technology. Vol. 10. (2008). Pgs. 55-66.

Samani, J. M. V., and Heydari, M. (2007). *Reservoir Routing through Successive Rockfill Detention Dams*. Journal of Agriculture Science and Technology. Vol. 9. (2007). Pgs. 317-326.

Tetra Tech, Barrios, F., P.E., Chee, R. and Salguero, M. (2010a) *Heap Leach Facility Flood Surface Analysis and Stormwater Controls*. Technical Memorandum to Rex Henderson (M3 Engineering & Technology Corp.). Technical Memorandum dated April 2, 2010.

Tetra Tech, Salguero, M., and Chee, R. (2010). *Rosemont Flow-Through Drain Sizing*. Technical Memorandum to Kathy Arnold (Rosemont Copper Company). Technical Memorandum dated April 5, 2010.

Attachment 1

ROSEMONT COPPER COMPANY ROSEMONT COPPER PROJECT DRY STACK TSF PIMA COUNTY, ARIZONA PROJECT NO.: 8420119100	**SPECIFICATION** TECHNICAL SPECIFICATIONS FOR EARTHWORKS MATERIALS AND CONSTRUCTION	PAGE 1 OF 20 DOC. NO.: 1191-SP-EW001-A.DOC DATE: (ORIGINAL) 03/20/2009 REVISION: B DATE: 04/15/2009

THIS TITLE SHEET IS THE FIRST PAGE OF THE DOCUMENT AND IS A RECORD OF EACH ISSUE OR REVISION.

REV	DATE	APPROVALS: DESIGN MANAGER	APPROVALS: PROJECT MANAGER	APPROVALS: ORIGINATOR	PAGES	REMARKS
A	03/20/09	JWH	DTW	JLW	20	Issued for Client Review and Comment
B	04/15/09	JWH	DTW	JLW	20	Issued for Final Design

DOCUMENT ISSUED FOR:

- ☐ ENTIRE DOCUMENT ISSUED THIS REVISION
- ☐ REVISED PAGES ONLY ISSUED THIS REVISION

- ☐ REVIEW AND COMMENT
- ☐ CLIENT APPROVAL
- ☐ INQUIRY/BID
- ☒ DESIGN
- ☐ PURCHASE
- ☐ CONSTRUCTION

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1.0 INTRODUCTION

This specification defines the requirements for the earthwork construction activities for the Rosemont Copper Co. (Owner) Dry Stack Tailings Storage Facility (Dry Stack TSF) Project. The specifications set forth in this document cover the quality of materials and workmanship for earthworks construction. The Rosemont site is located approximately 30 miles southeast of Tucson, Arizona (Townships 18 and 19 South, Ranges 15 and 16 East, Gila-Salt River Meridian).

Any alternatives or exceptions to this specification shall be submitted in writing to the Owner or its designated representative(s)/agent(s) and shall be approved by the Engineer.

1.1 Definition of Terms

- "Owner" is defined as Rosemont Copper Company or any of its authorized representative(s)/agent(s).
- "Engineer" is defined as the Consultant or Engineering Company responsible for the detailed design or any of its authorized representative(s)/ agent(s).
- "Contractor" is defined as the party(s) that has executed the contract agreement for the specified Work with the Owner or its authorized representative(s)/agent(s).
- "Specifications" are defined as this document, all supplemental addenda, and any modifications furnished by the Owner, the Engineer, or others that apply to the Work.
- "Drawings" are defined as the Drawings for the Rosemont Copper Project furnished by the Owner, Engineer, or others that apply to the Work.
- "Site" is defined as the Dry Stack TSF Project site being developed by the Owner and where the Work is to be completed as described in these Technical Specifications and detailed on the Drawings.
- "Contract" is defined as the document executed by the Owner or its authorized representative(s)/agent(s) with the Contractor to complete specified portions of the Work.

- "Work" is defined as the entire completed construction or the various separately identifiable parts thereof required to be furnished as shown on the Drawings and as described in the Specifications and Contract Documents.

- "Modifications" are defined as changes made to the Specifications or the Drawings that are approved by Owner and Engineer in writing, after the Specifications and Drawings have been issued for construction. These also refer to changes to design elements in the field to account for unforeseen conditions.

- "Plant" is defined as all equipment, supplies, accommodations, temporary offices, etc., required to complete the Work.

- "Units" – In general, these Specifications and the Drawings will utilize English units, however metric units will be used when appropriate.

- "ASTM" (American Society of Testing and Materials) is an international standards organization that develops and publishes voluntary technical standards for a wide range of materials, products, systems, and services.

2.0 EARTHWORKS

This section presents the technical requirements for the earthworks construction for the Dry Stack TSF Project.

2.1 Earthwork Specifications

2.1.1 Erosion and Sediment Control

Erosion and sediment control measures shall be implemented as necessary to minimize ground surface erosion and stream sediment loads during construction. Construction work shall not start until the earthwork Contractor has prepared and submitted a written Environmental Management Plan (EMP) and agreed to that EMP with the owner and it has been implemented.

2.1.2 Clearing and Grubbing

Clearing and grubbing shall be done within the footprint of the limits of the construction area, as delineated on the Drawings. Clearing shall extend a maximum of 15 feet and a minimum of 10 feet outside of the construction limits or as directed by Owner. Areas for clearing shall be released to Contractor by Manager. No pioneering of roads across undisturbed areas shall be allowed without prior approval of Owner. No clearing shall be performed until written permission is given by Owner and until the Contractor has provided construction staking for the proposed work. Clearing shall consist of cutting brush to the ground level, removing such material, along with wood, rubbish, tree stumps, cacti, shrubs, and any other vegetation with roots in excess of 1-inch diameter, and other deleterious materials, and disposing of all such material in the accepted manner described below.

In areas designated to be stripped of unsuitable or objectionable material, said materials shall be stripped to the full depth of organic or other unsuitable material as determined by Owner. Stripped and grubbed vegetation shall be removed and disposed in stockpiles or other approved methods in an area designated by Owner.

2.1.3 Topsoil Salvage

Topsoil is defined as an acceptable growth medium, as approved by Owner, that has no chemical or physical characteristics that will preclude its use as such. Prior to topsoil salvage, the natural ground surface is to be stripped of unsuitable and objectionable materials to the limits of the tailings storage facility or as required by the Engineer and stockpiled separately from the topsoil stockpiles. Salvage shall mean the removal of topsoil, which shall be defined as soil of any gradation or degree of plasticity that contains significant quantities of visually identifiable plant matter (including sod, leaves, stems, bark, roots, or humus) as determined by the Engineer. Over much of the tailing storage facility and associated construction areas, salvage will consist of limited removal of surface soil (approximately 12 inches) generally being required. In areas where the topsoil extends to depths greater than 12 inches, the excavations shall extend to a greater depth as directed by the Owner. The salvaged material shall be hauled to stockpile areas as instructed by the Owner. Salvaged surface soils and vegetation suitable for use for future reclamation purposes shall be stockpiled separately from material viewed as unsuitable for reclamation purposes.

Topsoil salvage will be carried out using whatever method is deemed necessary, providing it is consistent with producing an acceptable end result as determined by the Owner and the Engineer.

After salvaging soil from of the required area, the surface shall be treated as specified on the Drawings or in the Technical Specifications. Prior to any surface treatment on a salvaged area, the Engineer shall be notified to inspect the salvaged area and designate the method of treatment required for continuance of work. A survey shall be taken of the area if necessary to determine quantities and/or for verification of lift/layer thickness.

2.1.4 Stockpile Areas

Plant matter, topsoil, and unsuitable materials encountered in excavations shall be disposed of in stockpiles at locations indicated on the Drawings or specified by the Engineer and approved by the Owner. Topsoil and unsuitable materials shall be stockpiled separately.

All stockpiles shall be limited to a height of 30 feet with stable final side slopes (maximum slope of 3H:1V) and shall be shaped and graded for suitable appearance and for proper drainage. Appropriate measures shall be taken to minimize erosion.

2.1.5 Foundation Preparation/Grading

Once the work area has been cleared, grubbed, stripped, and salvaged to the satisfaction of the Engineer, the surface shall be prepared before any overlying materials are added. All work areas shall be graded according to the limits shown on the Drawings. Areas that are to receive fill shall have the exposed subgrade lightly scarified and moisture conditioned to ensure a good bond with the first lift of fill. Subgrade fill materials shall be moisture conditioned and placed in lifts not to exceed 12 inches of compacted thickness, except when thicker lifts are allowed by the Engineer such as for fill placed and compacted with mine haulage equipment. In any event, the material shall be compacted to 90 percent of maximum dry density as determined by ASTM D1557. All areas in cut shall be prepared in a similar manner except the surface shall be scarified to a depth of approximately 8 inches, moisture conditioned, and compacted to 90 percent of the maximum dry density as determined by ASTM D1557.

2.1.6 Excavations and Borrows

Excavation methods, techniques, and procedures shall be developed with consideration to the nature of the materials to be excavated and shall include all precautions that are necessary to preserve, in an undisturbed condition, all areas outside the lines and grades shown on the Drawings or as required by the Engineer. Excavation, shaping, etc., shall be carried out by whatever method is considered most suitable, providing it is consistent with producing an acceptable result as determined by the Engineer. Excavations shall be graded to provide drainage and prevent ponding. For excavations that cannot be graded to drain, the contractor shall make provisions for the equipment and labor necessary to keep the excavations free of standing water.

No excavation beyond the lines and grades shown on the Drawings or as required by the Engineer shall be completed without the prior approval of the Engineer/Owner. If such additional excavation is done without the prior approval and, in the opinion of the Engineer, requires backfilling in order to complete satisfactorily the Work, such backfilling shall be approved by the Engineer and shall be completed at the Contractor's cost. The Contractor shall protect and maintain all excavations until such time as the adjacent placement or overlying placement of material has been completed.

The Contractor shall coordinate borrow activities with the Engineer to allow the sampling and testing of materials prior to their excavation. The Contractor shall allow the Engineer adequate time to evaluate potential borrow materials. Materials recovered from excavation or borrow areas that meet the specified requirements for construction materials shall be stockpiled or placed in fill areas as directed by the Engineer/Owner. Unsuitable or excess materials shall be hauled to waste or stockpile areas.

The materials obtained from borrow pits shall be selected to ensure that the gradation requirements for the various construction materials are achieved and that the materials are as homogeneous as possible. Care shall be taken to avoid cross-contaminating different types of materials.

On-site borrow areas shall be developed within the limits shown on the Drawings or as required by the Owner. Should the Contractor wish to develop additional borrow sources, the Contractor shall receive written approval from the Owner prior to proceeding. Approval by the Owner may require that subsurface investigations be carried out to obtain samples as are required by the Engineer to make an appropriate assessment of the suitability of the borrow materials in the area for the intended use.

Borrow pit operations shall be subject to the approval of the Owner and Engineer and shall avoid waste of any suitable construction material therein. Clearing and stripping of any borrow area is to be completed with all salvageable topsoil stockpiled in areas designated on the Drawings or as directed by the Owner. Each borrow area shall be developed with due consideration for drainage and runoff from the excavated surfaces so as not to cause erosion of the adjacent terrain. Each borrow area shall be excavated in near-horizontal layers and in such a manner that water will not collect and pond except as approved by Owner. Before being abandoned, the sides of any borrow areas outside the Work area shall be brought to stable slopes (not steeper than 3H:1V) with slope intersections rounded and contoured to provide a natural, neatly graded appearance.

Waste and topsoil piles shall be leveled, trimmed, and shaped to prevent the occurrence of ponding and concentrations of surface runoff and to provide a neat appearance. Finished slopes of the waste and topsoil stockpiles shall be graded to 3H:1V for interim reclamation. All surface water runoff shall be directed to available natural drainage courses.

2.1.7 Fill Materials

2.1.7.1 Random Fill

Random fill material shall consist of all types of material free of vegetation and other deleterious materials that can be compacted to the satisfaction of the Engineer and can be placed in the lift thickness specified.

Random fill material will have a wide range of Unified Soil Classifications and may contain significant variations in gradation and compaction properties. Random fill will be placed in areas where the material is not required to be of uniform character and engineering properties.

Materials containing rock or cobbles, and gravel from required excavations may be used subject to the Engineer's approval and provided the rock be reasonably graded such that large void spaces do not result. The maximum particle size for random fill shall be no larger than 2/3 the lift thickness.

2.1.7.2 Structural Fill

Structural fill shall consist of relatively fine-grained soils that will be compacted to the satisfaction of the Engineer. This material shall be well graded with higher than average structural strength characteristics meeting compaction and moisture content when properly prepared as approved by the Engineer. Structural fill shall contain no particles larger than 6 inches nominal diameter and shall have no more than 12 percent by weight passing the No. 200 sieve and maximum Plasticity Index (PI) of 15. All materials to be used as structural fill shall be approved by the Engineer prior to placement. Structural fill shall be used in locations specified by the Engineer or presented on the Drawings.

2.1.7.3 Flow-through Drain and Rock Buttress Material

The primary source for the flow-through drain and rock buttress material will be mine waste rock from the Rosemont Pit. Limited amounts will come from on-site excavations, shaping operations, and surface preparation activities. The material shall be composed of hard, durable stone particles reasonably free from thin, flat, and elongated pieces.

Generally, the material will have a wide range of gradations and it is anticipated that it will contain rock sizes of 12 inches or less; however, larger rock sizes will be permitted. The flow through drain and rock buttress material shall meet the following gradation limits:

Sieve Size	Passing (%)
24 in. (305 mm)	100
#200 (0.075 mm)	0-10

Material used for the flow through drain and rock buttress may be approved by the Engineer by visual inspection if the rock is determined to be sound and durable. However, if in the Engineer's opinion, the material is marginal or unacceptable, the Engineer may have performed one or more of the following laboratory tests on representative samples of the flow-through drain and rock butress material in order to assess the quality of the material.

Flow Through Drain Material Laboratory Tests

Test Description	Test Method	Specification Requirement
Los Angeles Abrasion	ASTM C 535	50% Loss Maximum (after 500 revolutions)

2.1.7.4 Pipe Bedding and Pipe Backfill

Pipe bedding and pipe backfill material for concrete box culverts, steel and corrugated polyethylene circular culverts, and steel structural plate (multiplate) structures shall consist of gravel, sand, or sandy silt. The backfill material shall have the following typical characteristics:

Pipe Bedding	
Sieve Size	**Percent Passing**
1-1/2 in.	100
3/4 in.	90-100
No. 4	30-70
No. 200	20 max
Plasticity Index	10 max

Pipe Backfill	
Sieve Size	**Percent Passing**
1 in.	100
3/4 in.	90-100
No. 4	35-65
No. 16	15-40
No. 200	2-10
Plasticity Index	10 max

Bedding and backfill materials shall be free of organic material.

2.1.7.5 Low Volume Collection Fill

The low volume collection fill for the seepage collection trenches is to be constructed using select material, the source of which will be determined by the Owner. The material shall consist mainly of gravels with a fines content of 10 percent maximum. The material produced through crushing and screening shall meet the following gradation limits:

Low Volume Collection Aggregate

Sieve Size	Passing (%)
1 in.	100
3/8 in.	40-70
No. 4	5-55
No. 200	0-10

2.1.8 Fill Placement and Compaction

All material used for fill shall be loaded and hauled to the placement site, dumped, spread, and leveled to the specified layer thickness. Fill shall be moisture conditioned if required and compacted to form a dense integral fill per the Technical Specifications and the approval of the Engineer. Care shall be taken at all times to avoid segregation of the material being placed and, if required by the Engineer, all pockets of segregated or undesirable material shall be removed and replaced with material which matches the surrounding material. All oversize material shall be removed from the fill material either prior to it being placed or after it is dumped and spread but prior to compaction. No additional payment will be made to remove oversized materials unless the work is specifically identified as a payment item on the Schedule of Quantities.

For most construction conditions, the fill is to be constructed in near horizontal layers with each layer being completed over the full length and breadth of the zone before placement of subsequent layers. Each zone shall be constructed with materials meeting the specified requirements and shall be free from lenses, pockets, and layers of materials that are substantially different in gradation from the surrounding material in the same zone, as determined by the Engineer.

Except in areas approved by the Engineer, where space is limited or as otherwise specified, fill shall be placed by routing the hauling and spreading units approximately parallel to the axis of fill. The hauling equipment shall be routed in such a manner that they do not follow in the same paths but spread their travel routes evenly over the surface of the fill.

Moisture conditioning is the operation required to increase or decrease the moisture content of material to within the specified limits. If moisture conditioning is necessary, it may be carried out by whatever method the Contractor deems is suitable, provided it produces the moisture content specified in these Technical Specifications or designated by the Engineer. The moisture shall be distributed uniformly throughout each layer of material being placed immediately prior to compaction. Measures shall be adopted as are necessary to ensure that the designated moisture content is preserved after compaction until the overlying layer is placed.

All particles having dimensions that interfere with compaction in the fill as determined by the Engineer shall be removed from the zone in which they were placed either prior to or during compaction.

The rolling pattern for compaction of all zone boundaries or construction joints shall be such that the full number of roller passes required in one of the adjacent zones, or on one side of the construction joint, extends completely across the boundary or joint.

All fill materials shall be placed and compacted in accordance with the Drawings and the requirements set forth in the following sections:

2.1.8.1 Random Fill Placement

Random fill shall be conditioned to within 2 percent of the optimum moisture content, placed in 12-inch maximum loose lifts, and compacted to 90 percent of the maximum dry density (ASTM D1557). Slight variations from the specified moisture range may be subject to the acceptance of the Engineer and provided the required compacted densities are achieved. The random fill material shall be compacted with appropriate compactive equipment capable of achieving compaction through the full thickness of the lift layer. If the random fill placement and compaction utilizes 100-ton or larger haul trucks, the lift thickness can be increased up to a maximum loose material thickness of 4 feet subject to the approval of the Engineer.

2.1.8.2 Structural Fill Placement

Prior to placement of structural fill, the foundation area where structural fill will be placed shall be prepared in accordance with these specifications. Structural fill material shall be placed in lifts not to exceed 12 inches compacted lift thickness. This material shall be compacted to 95% of the maximum dry density as determined by ASTM D1557. The moisture content of the material will be maintained at 2% below to 3% above optimum moisture content. Slight variations from the specified moisture range may be acceptable subject to the acceptance of the Engineer and provided the required compacted densities are achieved. The select fill material shall be compacted with appropriate compactive equipment capable of achieving compaction through the full thickness of the lift layer.

Material shall not be placed against any concrete foundation, abutment, wing wall, or culvert until the concrete has been in place at least seven days or the compressive strength of the concrete is 75 percent of the required 28-day strength. On structures that are not permanently supported laterally and that cannot tolerate horizontal movement, internal bracing or support should be placed during backfill operations.

2.1.8.3 Flow-through Drain Placement

The primary source of material for the flow-through drain material will be rock from the Rosemont Pit. The material will be hauled and placed by the Owner using mine haul trucks.

Special attention shall be given to the material being placed over the Corrugated Polyethylene Pipe (CPeP) drain. All oversized material that may damage the underlying pipe will be removed by whatever means necessary to ensure no damage is produced. Vehicle traffic on the flow through drain shall be the minimum possible and shall be restricted to roadways and other areas where the possibility of damage is minimal. Proposed methods and equipment to be utilized in the flow-through drain construction, particularly detailing any haulage vehicle traffic requirements, shall be submitted to the Engineer for review prior to commencement of the Work.

2.1.8.4 Rock Buttress Placement

The primary source of material for the flow-through drain material will be rock from the Rosemont Pit. The material will be hauled and placed by the Owner using mine haul trucks. The Rock Buttress will be constructed using rockfill suitable for end dump construction. The material will be end dumped in lifts appropriate to the material type but generally not exceeding 50 feet.

2.1.8.5 Pipe Bedding Placement

Except as otherwise specified by the Engineer, or as otherwise shown on the Drawings, the pipe trench shall be excavated to a depth of at least 6 inches below the bottom of the pipe and to a depth which will be sufficient to provide at least 2 inches of clearance under the pipe bell.

Uniform and stable bedding shall be provided for the pipe and any protruding features of its joints and/or fittings with the exception that the middle of the bedding equal to one-third the pipe outside diameter shall be loosely placed.

Bedding shall be backfilled to the required grade of the bottom of the pipe. All pipes shall be placed directly on the bedding material unless otherwise required or approved by the Engineer. Pipe bedding shall be conditioned to within 3 percent of optimum moisture content and compacted to a minimum of 90 percent of the maximum dry density as determined by ASTM D1557 or as specified by the Engineer with exception of the middle uncompacted area.

2.1.8.6 Pipe Backfill Placement

Backfilling shall be performed as soon as possible after foundation/pipe/culvert installation/construction. Suitable backfill material free from large lumps, clods, or rocks shall be placed alongside the structure in loose layers not exceeding 8 inches thick to provide a berm of compacted earth on each side of the pipe or structure (where applicable) a minimum of 5 feet wide or the width of the pipe diameter/structure (whichever is lesser). Each 8-inch layer shall be moisture-conditioned, if required to facilitate compaction, and compacted to a minimum of 90 percent of the maximum dry density as determined by ASTM D1557 or as directed by the Engineer

Backfill shall be placed symmetrically on each side of the structure (where applicable). The side-to-side backfill differential shall not exceed 8 inches or one quarter of the diameter of the structure, whichever is less.

Prior to adding each new layer of loose backfill material until a minimum of 12 inches cover is obtained, an inspection shall be made of the inside periphery of the structure (where applicable) for local or unequal deformation caused by the backfilling operation. Only hand-operator tamping equipment shall be allowed within vertical planes 3 feet beyond the horizontal projection of the outside surfaces of the structure (or as recommended by the culvert/structure manufacturer/designer). No heavy earthmoving equipment shall be permitted over the structure until a minimum of 3 feet of compacted fill has been placed over the top of the structure (or such cover as recommended by the culvert manufacturer/designer).

Backfill material shall not be placed against any concrete foundation, abutment, wing wall, or culvert until the concrete has been in place at least seven days or the compressive strength of the concrete is 75 percent of the required 28-day strength. On structures that are not permanently supported laterally and that cannot tolerate horizontal movement, internal bracing or support should be placed during backfill operations.

2.1.9 Compaction Equipment

Sufficient compaction equipment, of the types and sizes specified herein, shall be provided as necessary for compaction of the various fill materials. If alternative equipment is to be used, a submittal shall be made to the Engineer for approval of the equipment, and the submittal shall give complete details of such equipment and the methods proposed for its use. The Engineer’s approval of the use of alternative equipment will be dependent upon completion of suitable test fills, to the satisfaction of the Engineer, to confirm that the alternative equipment will compact the fill materials to the specified density.

Compaction equipment shall be maintained in good working condition at all times to ensure that the amount of compaction obtained is a maximum for the equipment. The Contractor shall provide the Owner and Engineer a list of proposed compaction equipment to be used before commencing Work.

2.1.9.1 Smooth Drum Vibratory Roller

Smooth drum vibratory rollers shall be equipped with a suitable cleaning device to prevent the accumulation of material on the drum during rolling. Each roller shall have a total static weight of not less than 20,000 pounds at the drum when the roller is standing on level ground. The drum shall be not less than 60 inches in diameter and 78 inches in width. The vibration frequency of the roller drum during operation shall be between 1,100 and 1,500 vibrations per minute, and the centrifugal force developed by the roller, at 1,250 vibrations per minute, shall not be less than 38,000 pounds.

For compaction by the vibratory roller, a single coverage shall consist of one pass of the roller. A minimum overlap of 12 inches shall be maintained between the surfaces traversed by adjacent passes of the roller drum. During compaction, the roller shall be propelled at not more than 2 miles per hour (mph) or as approved by the Engineer. The power of the motor driving the vibrator shall be sufficient to maintain the specified frequency and centrifugal force under the most adverse conditions that may be encountered during the compaction of the fill. Propulsion equipment for the roller shall be adequate to propel the roller at speeds up to 4 mph.

2.1.9.2 Tamping-Foot (“Sheepsfoot”) Roller

The fill may be required to be compacted with a tamping-foot “sheepsfoot” roller. The sheepsfoot roller shall be self-propelled and fully ballasted with a standard tamping-foot design developing 5,000 pounds in weight per linear foot of width at rest on level ground or equivalent as approved by the Engineer.

2.1.9.3 Special Compactors

Special compactors shall be used to compact materials that, in the opinion of the Engineer, cannot be compacted properly by the specified larger vibratory roller because of location or accessibility.

Special compaction measures shall be adopted such as hand-held vibratory compactors or other methods approved by the Engineer to compact fill in trenches, around structures, and in other confined areas that are not accessible to the larger vibratory roller or tamping-foot roller. Such compaction shall be to the specified density for the particular material.

2.1.10 Quality Control

The Engineer will take samples of fill materials and perform gradation, moisture content, Atterberg Limits, and field density tests on the compacted fill and any other tests that the Engineer considers necessary to ensure that the fill being placed meets the specified requirements. The results of the tests carried out by the Engineer will be final and conclusive in determining compliance with the Technical Specifications. Test methods are listed in Table 1 of Section 3.0.

Each lift of fill will be approved by the Engineer prior to placement of further fill. Sufficient time shall be allowed by the Contractor for the Engineer to carry out the required test work and interpret the test results in order to determine the acceptability of each lift. Cooperation shall be given by the Contractor, to the Owner and the Engineer, for taking samples or making tests, and such assistance shall be rendered as is necessary to enable sampling and testing to be carried out expeditiously.

Tests carried out by the Engineer will be performed in accordance with the latest principles and methods prescribed by ASTM and other such recognized industry standards. The tests shall include Control and Record Tests.

2.1.10.1 Control Tests

Tests for gradation, moisture content, moisture density relationship, and other tests, where applicable, will be made by the Engineer on samples of fill materials taken from borrow areas and on the fill after spreading and prior to compaction at frequencies sufficient to ensure that the fill material is in full compliance with the Technical Specifications.

2.1.10.2 Record Tests

The Engineer will conduct field density, moisture content, and other tests on the compacted in-place fill and will obtain samples of the compacted fill for related laboratory testing at such frequency as the Engineer considers necessary to determine that the compacted fill is in full compliance with the Technical Specifications.

3.0 TESTING FREQUENCIES

The Engineer will carry out frequent quality control/assurance tests as described in Section 2.1.10 to determine compliance of the Work with the Technical Specifications. The latest edition of standard procedures will be used for all activities, and in general, these will be adopted from recognized organizations such as the ASTM. The following tables outline the test methods and the minimum testing requirements for the project:

Table 1 – Test Methods

Test	Type of Test	Test Method (ASTM)
C1, R1	Atterberg limits	D4318
C2, R2	Moisture content	D2216
C3, R3	Particle size distribution	D422 [a]
C4, R4	Laboratory compaction	D1557
R5	Nuclear density	D2922
C6, R6	Laboratory permeability	D5084

Notes:
C = Control Tests; R = Record Tests
[a] Hydrometer tests down to the 2-micron size will be carried out as directed by the QC Engineer but will generally not be required; all samples to be wash graded over a #200 sieve.

Table 2 – Test Frequency – Foundation Preparation

Test	Type of Test	Frequency (1 per)
R1	Atterberg limits	Lesser of soil type/10,000 yd^2
C2, R2	Moisture content	15,000 yd^2
C3, R3	Particle size distribution	15,000 yd^2
C4, R4	Laboratory compaction	Soil type/50,000 yd^2
R5	Nuclear density	15,000 yd^2

Note: Test frequencies are per unit area of foundation preparation.

Table 3 – Test Frequency – Random Fill

Test	Type of Test	Frequency (1 per)
R1	Atterberg limits	10,000 yd^3
C2, R2	Moisture content	10,000 yd^3
C3, R3	Particle size distribution	15,000 yd^3
C4, R4	Laboratory compaction	Soil type/100,000 yd^3
R5	Nuclear density	5,000 yd^3

Note: Required number of tests shall be determined by whichever method of determining the frequency requires the most tests.

Table 4 – Test Frequency – Structural Fill

Test	Type of Test	Frequency (1 per)
R1	Atterberg limits	Soil type/5,000 yd³ or 1 per structure
C2, R2	Moisture content	As per nuclear density requirements
C3, R3	Particle size distribution	5,000 yd³ or 1 per structure
C4, R4	Laboratory compaction	Soil type/25,000 yd³
R5	Nuclear density	Greater of 4 per major foundation or 500 yd³ [a]

Note:
[a] Frequency of testing for backfill for minor foundations shall be determined by the Project Field Engineer.

Table 5 – Test Frequency – Flow-through Drain and Rock Buttress

Test	Type of Test	Frequency (1 per)
C1, R1	Atterberg limits	100,000 yd³
C3, R3	Particle size distribution	100,000 yd³

Note: Sample sizes to be sampled in accordance with ASTM standards.

Table 6 – Test Frequency – Pipe Backfill and Pipe Bedding

Test	Type of Test	Frequency (1 per)
R1	Atterberg limits	Soil type/5,000 yd³ or 1 per trench
C2, R2	Moisture content	As per nuclear density requirements
C3, R3	Particle size distribution	1,000 yd³ or 1 per trench
C4, R4	Laboratory compaction	Soil type/5,000 yd³
R5	Nuclear density	500 yd³ [a]

Note:
[a] Frequency of testing for backfill for minor foundations shall be determined by the Project Field Engineer.