LA-SUB--94-14

**COST AND SCHEDULE ESTIMATE TO
CONSTRUCT THE TUNNEL AND SHAFT
REMEDIAL SHIELDING CONCEPT**

**LOS ALAMOS MESON PHYSICS FACILITY
LOS ALAMOS NATIONAL LABORATORY
LOS ALAMOS NEW MEXICO**

Contract No. 2470J0013-9Q

FINAL REPORT

Revision 0

NOVEMBER 30, 1993

MASTER

**Prepared by
Pye Construction Technologies Inc.,
2690, Via Caballero D. N.
Santa Fe, New Mexico**

**COST AND SCHEDULE ESTIMATE TO CONSTRUCT THE TUNNEL AND SHAFT
REMEDIAL SHIELDING CONCEPT**

Abstract

The report provides an estimate of the cost and associated schedule to construct the tunnel and shaft remedial shielding concept. The cost and schedule estimate is based on a preliminary concept intended to address the potential radiation effects on Line D and Line Facilities in event of a beam spill.

The construction approach utilizes careful tunneling methods based on available excavation and ground support technology. The tunneling rates and overall productivity on which the cost and project schedule are estimated are based on conservative assumptions with appropriate contingencies to address the uncertainty associated with geological conditions.

The report is intended to provide supplemental information which will assist in assessing the feasibility of the tunnel and shaft concept and justification for future development of this particular aspect of remedial shielding for Line D and Line D Facilities.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Acknowledgments

Pye Construction Technologies Inc., wish to record their gratitude to Dr.R.J. Macek. Program Manager LANSCE/WNR Beam Delivery, for his considerable help, on-going support and assistance during the preparation of this report and for the continued opportunity to participate in such a challenging project.

Meson Physics Division Office for their support in funding the activities leading to the development of the cost and schedule report.

Dr.D.H. Fitzgerald, Group Leader and Dr.R.D. Ryder, Deputy Group Leader, Accelerator and Beam Line Development, for their assistance with facility drawings and development of remedial shielding concepts

Dr.C. Wilkinson, Dr.S Frankle and Dr.R. Hutson, Technical Staff Members, MP-5 Group, for their help and participation, during the preparation of this report.

Ms Virginia Fiske, Secretary MP-DO, for her help and assistance with project administration.

Mr.M. Zamora, Senior Contract Administrator for his help and assistance in preparing and facilitating this contract.

TABLE OF CONTENTS

Section	Title	Page
Abstract		(i)
Acknowledgments		(ii)
Table of Contents		(iii)
1.0	Introduction	1
2.0	Scope of Cost and Schedule Estimate	2
2.1	Proposed Tunnel and Shaft Configuration	2
2.2	Feasibility	6
3.0	Assumptions and Constraints	7
4.0	Technical Basis for Cost and Schedule Estimate	11
4.1	Geological Background	11
4.2	Site Rock and Soil Conditions in Vicinity of ER-1 Facility	14
4.3	Deformation Characteristic of Soil and Rock	16
4.4	Rock Support Requirements	17
4.5	Soil and Rock Parameters for Shaft and Tunnel Concept	21
5.0	Case Studies	22
5.1	Weapons Neutron Research Facility	22
5.2	Proton Storage Ring	24
6.0	Tunnel and Shaft Construction Risks	25
7.0	Tunnel and Shaft Construction	28
7.1	Construction Approach	28
7.2	Construction Options	33
7.2.1.	Excavation Alternatives	33
7.2.2	Ground Support System Alternatives	34
7.2.3	Muck Removal and Handling System Alternatives	34
7.2.4	Excavation Sequence Alternatives	35

DISCLAIMER

**Portions of this document may be illegible
in electronic image products. Images are
produced from the best available original
document.**

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

TABLE OF CONTENTS cont'd

Section	Title	Page
8.0	Construction Sequence	35
8.1	Mobilization	36
8.2	Site Preparation	36
8.3	Establish Survey Controls for Construction	36
8.4	Perform Pre-Construction Testing	36
8.5	Layout Portal Structure	37
8.6	Stabilize Exposed Soil/Rock Face with Shotcrete	37
8.8	Geotechnical Drill Hole	38
8.9	Construct Portal	38
8.10	Construct Access Tunnel	40
8.11	Curved Section of Access Tunnel	41
8.12	Geotechnical Drill Hole	43
8.13	Beam Delivery Tunnel	44
8.14	Construct Beam Extraction Tunnel Under Existing Beam-Stop	45
8.15	Construct Beam Delivery Tunnel	46
8.16	Shaft Lining	52
8.17	Transition Section (Arch)	53
8.18	Transition (Invert)	54
8.19	Beam Extraction Tunnel (Invert)	55
8.20	Access Tunnel (Invert)	55
8.21	Portal	56
8.22	Punch List Items	56
8.23	Demobilization	57
9.0	Manpower requirements	58
9.1	Indirect Labor Requirements per Shift	58
9.1.1	Indirect Labor Requirements per Shift	58
9.1.2	Consultants	58
9.2	Direct Labor Requirements	59
9.3	Shift Schedule and Organization	60
9.3.1	Access Tunnel - First Shift	60
9.3.2	Access Tunnel - Second Shift	61
9.3.3	Beam Delivery Tunnel - First Shift	62
9.3.4	Beam Delivery Tunnel - Second Shift	63

TABLE OF CONTENTS cont'd

Section	Title	Page
9.3.5 .	Beam Extraction Tunnel - First Shift	64
9.3.6	Beam Extraction Tunnel - Second Shift	65
9.3.7	Shaft Initial and Second Phase - First Shift	66
9.3.8	Shaft Initial and Second Phase - Second Shift	67
10.0	Equipment Requirements	68
10.1	Excavation System	68
10.2	Shotcrete Placement Equipment	69
10.3	Concrete Placement System	70
10.4	Services System	71
11.0	Permanent	73
11.1	Shotcrete	73
11.2	Concrete	73
11.3	Lattice Girders	73
11.4 .	Liner Plate	73
11.4.1	Portal Structure	73
11.4.2.	Shaft Structure	74
11.5	Ring Beams	74
11.6	Cementitious Grout	74
11.7	Rockbolts	74
12.0	Project Schedule and Duration	75
12.1	Critical Activities	75
13.0	Project Costs	76
13.1	Cost Summary	77
14.0	Conclusions	78
15.0 .	References	79

FIGURES

Figure No.	Title	Page
Figure 1	Beam Delivery Tunnel Alignment and Layout	4
Figure 2.	Access Tunnel Alignment and Layout	5
Figure 3.	Excavated Profile of Tunnel Sections	19
Figure 4.	Composite Ground Support System	20
Figure 5.	Completed Transition Tunnel and Lining System	31
Figure 6.	Shaft Excavation Sequence	48
Figure 7.	Shaft Shielding Installation and Lining	49

DRAWINGS

Drawing No.	Title
RS-1000-8	Site Layout
RS-1000-9	Access Tunnel and Beam Delivery Alignments
RS-1000-10	Modified beam Extraction Tunnel Configuration
RS-1000-11	Shaft and Tunnel Construction Schedule
RS-1000-12	Shaft and Tunnel Construction Task Timeline

1.0 Introduction

The following report develops construction costs and an associated schedule to complete the shaft and tunnel concept, specifically to re-align the beam delivery configuration from the Proton Storage Ring to the ER-1 Facility as described in the report[1].

The cost and schedule information provided in this report are intended to support an assessment of the overall feasibility of the concept, developed to address potential radiation hazards associated with a beam spill on Line D. The concept requires the re-alignment of a significant section of Line D and represents one part of an overall remedial shielding concept developed for Line D and Line D Facilities, described report[1].

The proposed, revised beam alignment is intended to physically separate existing beam alignments such that, in the event of a beam spill along the proposed re-alignment, the in situ tuff between the tunnel and adjacent Line D facilities is sufficient to fully shield facility personnel and equipment from radiation hazards and effects.

Since the completion of the report[1], the tunnel and shaft configuration and layout, have been reviewed and revised with respect to the construction approach developed in this associated cost and schedule report. It should be noted that the cost and schedule information presented is consistent with, and reflects the level of detail developed in the report[1]. As such, this report should be considered as conceptual, preliminary and serve as an addendum, intended for use in assessing the overall feasibility of the tunnel and shaft remedial shielding concept.

[1] Remedial Shielding Concepts for Line D and Line D Facilities, Los Alamos Meson Physics Facility, Los Alamos National Laboratory, Los Alamos New Mexico. Vol. I - VI. May 28, 1992 Contract No. 9-LQ3-2465J-1.
Pye Construction Technologies Inc.

2.0 Scope of Cost and Schedule Estimate

The intent of this report is to provide a cost and schedule estimate, to construct the tunnel and shaft concept as shown in Drawings(RS-1000-8), (RS-1000-9) and (RS-1000-10), and based on the Final Report entitled "Remedial Shielding Concepts For Line D and Line D Facilities, Los Alamos Meson Physics Facility, Los Alamos National Laboratory, Los Alamos New Mexico".

The report makes specific reference to the technical background comprised of relevant engineering and technical information contained in the final report[1], which describes the tunnel and shaft concepts used between the Proton Storage Ring and the ER-1 Facility to resolve shielding problems.

Additional drawings and sketches are used to illustrate the refined concept and adjustments to the original concept together with key construction features and sequences.

In order to develop the cost and schedule estimate from the concept it has been necessary to develop the assumptions, constraints, options and contingencies used in the preparation of the cost and schedule as shown in Drawings(RS-1000-11) and (RS-1000-12).

2.1 Proposed Tunnel and Shaft Configuration

The principal elements of the tunnel and shaft concept, shown in Drawings (RS-1000-8) through (RS-1000-10) and are described as follows:

1. Beam Extraction Tunnel

Inclined at -15° , located partly below the PSR structure and directly under the Beam Stop Tune Up, this tunnel section permits extraction of the PSR beam as shown in Figure(1).

2. Beam Delivery Tunnel

Inclined at -30° , this tunnel section diverts the beam deep into the in situ tuff under the ER-1 Facility as shown in Figure(1). The configuration is intended to provide sufficient natural shielding to protect ER-1 Facility personnel and equipment should a beam spill occur on the alignment.

3. Transition Tunnel

The section of Beam delivery tunnel that grades-out to the horizontal and contains the intersection to the Access Tunnel, before entering the adjoining shaft as shown in Figure(1).

4. Access Tunnel

The tunnel section necessary for construction and of subsequent importance for personnel access and facility maintenance as shown in Figure(1).

5. Shaft

The vertical structure which permits the beam to be diverted upwards from the horizontal, through the ER-1 Facility footing and into the modified target cell as shown in Figure(1).

The revised configuration as shown in Drawings(RS-1000-8) through (RS-1000-10) is seen as having distinct advantages over the original concept. Specifically that the construction can be initiated and continued without disrupting operation of Line D and Line D Facilities up to the point of breakthrough into both the PSR and ER-1 Facility.

	SLOPE DISTANCE	PLAN DISTANCE	VERTICAL INTERVAL	
A - B	28.33'	27.53'	6.67'	6920.82'
				<u>6914.15</u>
				6.67'
B - C	60.00'	51.87'	30.15'	6914.15'
				<u>6884.15</u>
				30.15'
C - D	58.33'	58.33'	0.0'	
C - F	66.00'	66.00'	0.0'	
D - G	49.38'	49.38'	0.0'	

TOTAL SLOPE DISTANCE

$$(A - B) + (B - C) + (C - D)$$

$$28.33' + 60.00' + 58.33' = 146.66'$$

SHAFT DEPTH

$$D - E = 36.32'$$

$$6920.32'$$

$$\underline{6884.00'}$$

$$36.32'$$

Figure(1) Beam Delivery Tunnel Alignment and Layout

	SLOPE DISTANCE	PLAN DISTANCE	VERTICAL INTERVAL
A - B	119.47'	112.27'	6.67'
B - C	60.00'	51.87'	30.15'
A - C	153.37'	144.12'	52.46'
A - A'	60.00'		
			6939.77
			<u>6884.15</u>
			55.67'

Figure(2) Access Tunnel Alignment and Layout

2.2 Feasibility

The labor, materials and equipment selected to complete the tunnel and shaft concept layout as shown in Drawing(RS-1000-8) are based on the application of currently available mining and ground support technology. Although constraints are identified in Section(3.0) of this cost and schedule estimate, none significantly impact the overall feasibility of the project as reflected in Drawings(RS-1000-11) and (RS-1000-12).

To implement this construction concept requires an experienced mining or tunneling contractor. The contractor will be required to provide, a typical level of effort comprised of two work crews, excavation and ground support equipment, working two shifts per day and five day work week.

All labor, material and equipment resources inherently contain a modest contingency of between 7 - 9 %, which is factored in terms of conservative cost and schedule estimates. Progress is based on a tunnel advance rate equivalent to an 8 foot section of excavated and supported tunnel during each work day when scheduled.

The use of explosive based excavation methods are considered to be inappropriate, due to the adverse effects associated with blast vibration and the potential for damage to adjacent structures.

Mechanical excavation methods are expected to produce a more consistent tunnel profile, when excavated in relatively soft, weak and variable material such as tuff. In addition the tunneling method selected can be more readily adapted to changing conditions as they are encountered.

Three work elements essential to the implementation of the tunnel and shaft concept which are not included in the scope of this cost and schedule estimate are:

- The scope of this cost and schedule assessment does not include the re-configuration of the beam line hardware and any additional operational features or upgrades that may be incorporated.
- This cost and schedule has been developed in isolation of other remedial shielding installation measures identified in the report [1] therefore the benefits of concurrent remedial shielding installation are not factored in this report.
- As recommended in the report [1], it is essential that the tunnel and shaft concept be developed into an advanced conceptual design before a definitive assessment of the overall feasibility of remedial shielding activities can be made.

3.0 Assumptions and Constraints

It is important to recognize that the key assumptions and constraints used in the development of this report have a significant bearing on the conclusions identified in Section (14).

1. Due to the physical proximity and relative elevation of the Proton Storage Ring and the ER-1 Facility as shown in Drawing (RS-1000-8), the depth and 30° inclination of the proposed beam delivery tunnel are required to provide sufficient shielding from the in situ tuff.
2. The relatively steep Beam Delivery Tunnel gradient (30°) shown in Drawings (RS-1000-9) and (RS-1000-10) has specific consequences which significantly effect the excavation and muck removal activities.

3. The constraints identified in item 1 are such that the conceptual configuration discussed in the report[1] which required an access tunnel aligned towards the PSR beam stop tune was re-configured.
4. The revised Access Tunnel shown in Drawings(RS-1000-8) through (RS-1000-10) is intended to provide a means of access in the form of a 20° ramp which permits the use of rubber tired mucking and excavation equipment.
5. The technical baseline used in the development of this report is limited to the data and information that is summarized in the report[1].
6. The tunnel and shaft concept will be constructed in a geological media comprised of tuff deposits, described in Section(4.2). This material can be excavated with hand held tools[1] but is susceptible to deterioration when exposed to water and a propensity to loosening and possibly collapse if careful tunneling procedures.
7. Without the benefit of a detailed geotechnical site investigation, assessments have been made on the basis of engineering judgment to resolve the incongruity between the apparent ease of excavation and need to provide immediate and effective support to ensure stability.
8. This single, predominant consideration has had an overriding effect on the overall feasibility of the project, on the construction approach and on the development of the cost and schedule. Further implications and effects on secondary systems and operations are discussed later in Section(7) of this report.

9. The construction approach and layout are based on available as-built drawings[2][3] and photographic information, specifically Figures(4.23)[1] through (4.33)[1] contained in the report[1].
10. During the construction of the proposed tunnel and shaft concept, the PSR and the ER-1 facilities will be breached to complete the physical interface between the two facilities.
11. The conditions required for facility breakthrough are:
 - Radioactive or contaminated materials are not encountered during construction; specifically during breakthrough into the PSR and ER-1 Facility.
 - Construction activities to facilitate breakthrough do not include any significant internal modification to either the PSR or the ER-1 Facility. Specifically, this includes partial removal of the PSR floor structure or modifications to infrastructure.
 - Further it is assumed that prior to breaching the ER-1 Facility floor slab that a pre drilled guide hole is located to aid shaft excavation. This will require that a guide hole is drilled from inside the target cell on the beam line axis and may necessitate that sufficient shielding is removed from the target cell to permit drilling operations to take place.
12. It is assumed that available as-built drawings[2][3] and preconstruction investigations will identify all near surface utilities buried on the proposed alignment of the Access Tunnel.

13. It is consequently assumed that construction can then be initiated and proceed without disruption of LANSCE/WNR facility operations until breakthrough activities are completed without significant impact on the construction activities, cost or schedule or on the operation of adjacent facilities.
14. The feasibility study assumes that a qualified tunneling contractor is employed to complete the project. Specifically, this will require experienced tunneling engineers, supervisory personnel and workforce.
15. A significant activity identified, and key to the successful implementation of the construction program is the completion of geotechnical assessments scheduled during the construction of the tunnel and shaft concept. This will require the ongoing services of a Geotechnical Engineer with tunnel construction experience.
16. Muck disposal considerations assume that a local disposal site is available for material generated or that muck material can be used in other shielding construction activities.
17. Asphalt removed from existing paved areas in vicinity of the portal structure is disposed of in an environmentally acceptable manner.
18. The cost to prepare a detailed, "for construction design" package including drawings and specifications is not included in the cost estimate.
19. The cost for LANL to provide Construction Management, inspection and any other programatic support required is not within the scope of this costs and schedule estimate.

4.0 Technical Basis of Cost and Schedule Estimate

The following background is a summary of the information described and referenced in the report[1] and includes geology, soil and rock conditions, drilling and testing, an estimate of rock support requirements and a discussion of anticipated tunneling and construction risks.

It should be noted that much of the geotechnical information referenced in the report[5], was obtained from several drilling and testing activities, subject to laboratory analysis in order to establish engineering properties or parameters used in the design of structures constructed on the Los Alamos Mesa. None of the soil and rock data referenced[6] was originally intended to be used in designing a shaft or tunnel. Care must therefore be used when assessing this data and information in the context of tunnel or shaft construction. It must be recognized this limited data and information is the only information available to support the feasibility assessment, until a complete geotechnical, basis of design can be established.

The following is a summary of information which was extensively referenced in the report[1]. It is reiterated as an essential part of the technical baseline used in engineering assessments key to completing the cost and schedule estimate.

4.1 Geological Background [4]

The Mesita de Los Alamos is composed of the Bandelier formation. The Bandelier Formation consists of ashfalls and ashflow rocks that are draped over older rocks. The Bandelier Formation is composed of three members. In ascending order they are:

Guaje Member, and ashfall pumice about 35 ft thick, found in the subsurface of the Mesa

Otowi Member, a friable ashflow about 235 ft thick, partly exposed in the lower wall of the Los Alamos Canyon adjacent to Mesita de Los Alamos;

Tshirege Member a series of ashflow tuffs which cap Mesita de Los Alamos. The ashflows vary from a non-welded to a welded tuff.

The Tshirege is about 300 ft in thickness under the ridge at the Mesita de Los Alamos. Five units of the Tshirege (units 1a, 1b, 2a, 2b and 3) are present. The units of the Tshirege Member dip gently eastward at the Mesita de Los Alamos. Units 2b and 3 form the upper part of the mesa dipping 3 to 6° toward the east-southeast. Unit 2b outcrops on alignment of the linac tunnel and are broken by a normal strike fault along which the east has moved down about 14 ft relative to the west.

Numerous joints in units 2b and 3 probably are tension joints in units 2b and 3 probably are tension joints formed during cooling of the ashflows. The most prominent and numerous joints are nearly vertical and some are slightly open. Near surface joints are filled with clay and weathered products of tuff. Units 1a and 1b of the Tshirege Member consist of two ledge-forming layers of pumiceous tuff breccia similar in lithology, but slightly different in color and weathering characteristics. The lower layer is unit 1a, a massive orange-weathering pumiceous tuff breccia forming a near vertical cliff above the Sandia Canyon.

This lower unit contains pumice fragments of obsidian and rhyolite in a fine glassy ash matrix. The weathered outer 1 to 3 inches of tuff is casehardened, protecting the unweathered rock from erosion. The thickness of unit 1a varies because of the irregular erosion surface at the top of the Otowi Member upon which it rests. It may however be as much as 80 ft in depth at the center of the mesa.

Unit 1b rests conformably on unit 1a and weathers to a dull grayish-brown. It is a tuff breccia with a fine grained pink ash matrix similar to the underlying unit 1a; however, the pumice fragments are smaller and 15 to 20 % of the material consists of granule sized quartz-crystal fragments of dense volcanic rocks.

Unit 1b is slightly less resistant to erosion than unit 1a and forms a ledge set back from the lower unit. At some places both layers form near vertical cliffs. The thickness is fairly uniform, ranging from 21 to 31 ft along the southern edge of the mesa.

The lower unit of units 2a and 2b is a light gray pumiceous tuff consisting of moderately welded pumiceous as containing fragments of pumice, dense rhyolite, and latite fragments of pumice as much as 3 inches long. The unit weathers to a dull gray with case-hardened rind several inches thick. It forms a steep smooth slope set back from unit 1 and is separate from the overlying unit 2b by an erosional unconformity. The thickness ranges from 47 to 51 ft along southern edge of the mesa.

The overlying unit 2b is a pink to brown-weathering, moderately welded tuff (porosity 30 to 50 % by volume) composed of quartz and sanidine crystals and fragments in a matrix of light-pink fine grained ash.

The unit is resistant to erosion and forms ledges and benches above the steep rounded slopes of basal unit 2a. The unit ranges from 76 to 83 ft thick along the southern edge of the mesa, where it forms the uppermost rim of the Sandia Canyon. Along the Los Alamos Canyon, unit 2b forms a bench along the wall. Unit 2b underlies the foundation of the beam line facility.

Unit 3 rests conformably on unit 2b and grades downward into it, consisting of primarily light-gray, light-tan and white non-welded to moderately welded pumiceous tuff breccias (porosity from 30 to 60 % by volume). The rock is composed of fine pumice fragments and glassy shards and contains numerous layers of pebble and cobble sized pumice fragments and some gray dense rhyolite. Most of the unit is relatively soft and has eroded to form smooth, round slopes with a veneer of case-hardened material several inches thick.

The unit has eroded along the southern and extreme eastern edges of the mesa. This unit forms the foundation of the east end of the Line D tunnel and LANSCE/WNR experimental buildings.

The bulk density of tuff unit 2b as determined by density log ranged from 100 to 120 lbs/ft³; the density of unit 3 ranged from 80 to 110 lbs/ft³. Differential cooling of an ashflow unit results in density changes of the unit results in density changes of the unit in a vertical section; rapid cooling of an ashflow after emplacement results in a more porous and pumiceous tuff at the upper and lower contacts. Penetration tests, and bearing tests indicate that the bearing capacity of tuff increases with density[2].

4.2 Site Rock and Soil Conditions in Vicinity of the ER-1 Facility.

A preliminary assessment of the soil and rock conditions immediately underlying the PSR and ER-1 Facility is essential to the design and construction of the realignment concept. Reference has previously been made to available soil and foundation reports [5][6]. Core log records obtained from 20 - 50 feet below original surface elevation 6954.0 ft, (base of shaft elev. 6884.0 ft) indicate the fractured and moderately cemented nature of the in situ tuff.

Where employed during drilling and testing[1], the Rock Quality Designation (R.Q.D.) have been reviewed. The available information is limited to three boreholes located in the vicinity of the ER-1 and WNR Facilities[5][6]. These logs indicate R.Q.D. values range 70 - 20, with an average value of 50. This average value falls between the "Poor" to "Fair" categories[7].

Typically core recovery was poor, which is a direct indication of the rock quality and is reflected the low R.Q.D. values reported. The core examined was typically weathered, porous, partially welded, friable and exhibiting diagonal seams and the presence of intrusives[5][6]

The proposed tunnel and shaft concept is located in mid to lower elevations of unit 2b of the Tshirege Member as described. Photographic information obtained prior to and during construction of the ER-1 and WNR Facilities as shown in the report[1], provide details of the near surface rocks exposed at elevation of the ER-1 Facility footing.

Further, the relative competence of unit 2b tuff is attested to [5] when it was indicated that tuff can stand nearly vertical for 80 - 100 feet in natural exposures and can be cut with a saw and easily excavated using mechanical methods of excavation. Unit 2b does exhibits numerous joints which were formed shortly after cooling following their deposition. These joints which are predominately vertical, can be slightly open and near the ground surface filled with clay and weathered products. Surfaces exposed to weathering can show the effects of case-hardening. This may be significant to portal construction and the stability of near-surface sections of the tunnel.

The units of the Tshirege Member dip gently eastward at the Mesita de Los Alamos. Units 2b and unit 3 form the upper part of the mesa dipping 3 to 6° toward the east-southeast.

The proposed alignment of the Beam Extraction and Beam Delivery tunnels will be in the direction of south-southeast, while the alignment of the Access Tunnel will be towards the east. If a clearly defined structure is present in the face of a tunnel, the strike of the structure will lie at approximately 45° to Beam Delivery Tunnel and 22° to the Access Tunnel.

The orientation of geologic structure relative to both the Access Tunnel and the Beam Delivery Tunnel has the potential to present thin wedges in the profile and face of the tunnel excavation. These features may require additional attention and supplemental support measures.

No evidence of ground water has been found during drilling and testing on the Los Alamos Mesa. The presence of water on in situ tuff is considered detrimental to the bearing capacity of floor material and is significant to the tractive efforts of excavation and mucking equipment. The implication is that it is undesirable to expose tuff to excessive amounts of water during tunneling operations[1]. This has prevented the selection of several methods of excavation and has to be considered in selecting tunneling options for excavation and muck removal equipment, rock bolt installation and dust suppression methods

4.3 Deformation Characteristics of the Soil and Rock [5][6]

The foundation material in the Los Alamos area is composed primarily of a welded volcanic ash, usually deposited as an ashflow. As such it is an anisotropic material which exhibits different characteristics depending on the orientation of the sample being tested, however this expected to be of limited concern during the tunneling process.

The bearing capacity of the more competent tuff may conservatively be estimated at 10 tons/ft² which is sufficient to support movement of rubber tired equipment on the 20° slope of the Access Tunnel.

The Modulus of Elasticity values range from 20,000 to over 150,000 psi are common, depending on the density of the material and the degree of welding which and typically exhibit uniaxial compressive strengths of approximately 700 psi. It is on the basis of these material properties and physical behavior, that careful excavation using hand mining methods is justified

The degree of welding is classified at Los Alamos as non-welded, moderately welded and welded tuff. The transition between non-welded tuff (porosity as much as 60 %) to welded tuff (porosity as small as 15%) is due to compaction and fusing by heat of the crystals, crystal fragments and ash in the matrix. The degree of welding and the amount and size of pumice, latite and rhyolite rock fragments determine the physical characteristics of the tuff; -i.e. porosity, density and bearing capacity.

The fact that it is difficult to obtain a core sample in unit 3 tuff, because the sample disintegrates when it is disturbed is a clear indication that the material is relatively soft and will be easily excavated. It also infers that it may be necessary to reduce excavation rates (< 8 ft/day) and to compensate for associated ground support difficulties and with effective, rapid ground support installation.

4.4 Rock Support Requirements

An estimate of the rock support requirements for temporary support during excavation of the tunnel was derived[1] using an empirical support selection methodology [7]. The use of mechanical and hand mining methods in conjunction with effective ground support are key to achieving tunnel stability.

The tunnel will be excavated to provide a nominal horseshoe section of 11 ft wide x 12 ft high as shown in Drawings (RS-1000-9), (RS-1000-10) and illustrated in Figure(4) and Figure(5).

This section will be supported using a combination of support elements including shotcrete, rock bolts, liner plate, lattice girder arches and placed concrete lining.

The portal structure shown in Drawing(RS-1000-8) and initial 16 ft of Access Tunnel will employ a combination of shotcrete, liner plate and lattice girders as support.

The Access Tunnel, Beam Extraction and Beam Delivery Tunnel up to the Transition Tunnel will use shotcrete and rockbolts for ground support and 12 - 18 inches of concrete slab will be placed in the tunnel invert as shown in Figure(4).

The initial Transition Tunnel ground support will be the same as described for the Access Tunnel. A final, nominal 12 inch thick concrete lining will be used to complete the support as shown in Drawings(RS-1000-9), (RS-1000-10) and in Figure(5).

When the excavation is completed, a final composite support system including arch and invert section will be placed in the Transition Tunnel while in all other tunnel sections a 6 inch shotcrete lining and rockbolts will be used and a concrete invert added to facilitate personnel access and maintenance.

A "Q" value of 1.667 falls in the category of "Fair" in the overall scheme of Rock Quality Designation, and in tunnel support category 22 (Q range: 10 - 1) identified in the rock support tables [7] which recommends the following support elements:

Rock bolts passive, grouted on 3 ft spacing shotcrete, wiremesh reinforced 2 - 3 inches.

The rock support system for the tunnel section are shown as details in Drawings(RS-1000-9) and (RS-1000-10).

Excavated Tunnel Profile

Area of Cross-Section

$$\frac{3.142(11)^2(0.5) + (7.5)(11)}{4} = 130 \text{ ft}^2$$

Volume of In situ Tuff Excavated per Foot of Tunnel Excavated CY/ft

$$(130)(1)(1.6)/(27) = 7.70 \text{ CY/ft}$$

Surface Portal Access A - D 60.00 ft

Volume of excavated materials CY

$$(0.5)(58.79)(12)(25)(1.6)/27 = 522.58 \text{ CY}$$

Access Tunnel A - C 153.37 ft

Volume of excavated materials CY

$$(153.37)(7.70) = 1,180.95 \text{ CY}$$

Beam Extraction Tunnel A - B 28.33 ft

Volume of excavated materials CY

$$(28.33)(7.70) = 218.14 \text{ CY}$$

Beam Delivery Tunnel B - F 126.00 ft

Volume of excavated materials CY

$$(126.00)(7.70) = 970.2 \text{ CY}$$

Shaft Depth E - F 36.32 ft

Volume of Excavated Material in 20 ft Dia. Shaft

$$\frac{(3.142)(20)^2(36.32)(1.6)/27}{4} = 676.16 \text{ CY}$$

Total Volume of material excavated

$$= 2,600 \text{ CY}$$

Figure(3) Excavated Profile of Tunnel Sections

Supported Tunnel Profile

Shotcrete profile length ft

$$\frac{3.242(11) + (2)(7.5)}{2} = 32.8 \text{ ft}$$

Volume of in place Shotcrete per Foot of Tunnel section CY/ft for 6" lining thickness CY/ft

$$(32.8')(6"/12")(1')(1.30)/27 = 0.80 \text{ CY/ft}$$

Volume of shotcrete to Support Surface Portal Access

$$(2)(0.5)(12)(58.79)(.5)(1.25)/27 = 16.33 \text{ CY}$$

Volume of shotcrete to support Access Tunnel

$$(153.37)(0.8) = 122.70 \text{ CY}$$

Volume of shotcrete to support Beam Extraction Tunnel

$$(28.33)(0.8) = 22.66 \text{ CY}$$

Volume of shotcrete to support Beam Delivery Tunnel

$$(126.00)(0.8) = 101.0 \text{ CY}$$

Volume of shotcrete to support shaft during multiple excavation sequence

$$\text{Raise } (3.142)(10)(36.32)(3/12)(1.3)/27 = 13.73 \text{ CY}$$

$$\text{Shaft } (3.142)(20)(36.32)(6/12)(1.3)/27 = 59.94 \text{ CY}$$

Total Volume of Shotcrete = 336.36 CY

Rockbolts 1,600

Figure(4) Composite Ground Support System

In addition the dimensions of the reinforced concrete lining and invert are identified in the tunnel section as shown in Figure(5). The purpose of the lining and invert is to ensure long term stability, provide a regular profile geometry from which support the beam line and ancillary equipment and utilities and make contribution to the overall shielding between the tunnel and adjacent facilities in the event of a beam spill.

4.5 Soil and Rock Parameters for Shaft and Tunnel Concept

Available soil and foundation reports were reviewed for the purpose of identifying soil and rock parameters[1]. These parameters were used in modeling and analysis of the existing Line D tunnel structures and shielding concepts.

Line D and Line D Facilities are located in geological unit 2b. The unit 3 geology which is found on the west end of the mesa gradually thins toward the east end of the mesa to be eventually replaced by unit 2b. To recap, unit 2b as described [4] was considered to be particularly competent with a modulus of elasticity as high as 150,000 psi. Laboratory testing resulted in the use of an average recommended value of modulus of elasticity of 25,000 psi.

Soil loads as high as 12,000 lbs/ft² have imposed on these materials, therefore for the analysis conducted in this report a maximum allowable soil pressure of 12,000 lbs/ft².

The modulus of subgrade reaction (k) used for both in situ and engineered fill is 300 psi/i. In addition construction activities requiring extensive excavation in backfill have been shown safe in trenches with vertical sidewalls to depths well in excess of 30 feet. It appears that engineered backfill and in situ tuff have engineering properties as subgrade and foundation material. The analyses performed in this report will assume situation unless specific conditions lead to significant differences in which case require further explanation will be provided.

5.0 Case Studies

The following case studies referenced in the report[1] are here briefly reviewed to determine any implications that are useful in the assessment of tunneling.

5.1 Weapons Neutron Research Facility [8]

Test borings were made prior to the construction of the facility in 1972 for the purpose of performing standard penetration tests at 2.5 - 5 ft vertical intervals to obtain a measure of the relative density or consistency of the subsurface soil encountered and to obtain samples of soil and/or rock for visual inspection and laboratory testing.

A total of ten test holes were bored and the stratigraphic section logged, together with the results of the standard penetration tests, moisture content, dry densities, grain size classifications and Atterberg limit tests made on recovered samples.

The information reported from field and laboratory testing [8] that is considered significant to portal and near surface tunnel construction can be summarized as follows. In general, the tuff rocks are overlain by a soil mantle consisting of silty to very silty, fine sands and sand-silt soil mixture of low plasticity. In some instances these soils are interspersed with broken and pulverized tuff.

Typically the thickness of the soil mantle varied within the test location in thickness from 8-11 ft and includes in part manmade backfill. Standard penetration testing in the soil mantle indicates that for the most part loose to medium dense state of relative density. If these conditions are encountered the use of careful excavation, and shotcrete with liner plate and lattice girders are considered appropriate. Below the surface mantle, tunneling conditions are expected to significantly improve when welded tuff rocks are encountered.

Test reports[8], indicate the volcanic tuff rock formations are porous and low unit weight ranging between 85 - 100 psf dry density, although the tuff is generally soft and friable. Inspection of recovered cores indicate the presence vertical, horizontal and diagonal seams and fractures.

Some portions of the core recovered was composed essentially of cohesionless materials and pulverized portions of solid tuff which are considered non-plastic. These conditions are probably indicative of relatively weaker and softer materials, further disturbed by drilling and sampling processes.

In general, the more weathered tuff was encountered in the upper elevations of the formation, however evidence of weathering was also observed in diamond core drilled specimens removed core holes. Loss of compressed air during drilling operations was indicative of fractures or joint zones.

The penetration resistance values "N", obtained from standard penetration tests conducted in volcanic tuff do not appear to provide a direct indication of density as would be expected in a cohesionless soil. The "N" values appear to be influenced by the degree of fusion of the tuff. Where "N" values in excess of 50 were encountered, core recovery was more complete in contrast to Low "N" values where instead of core, friable tuff was recovered. Intact core specimens exhibited horizontal planes of weakness which resulted in competent sections of 6 - 9 inches in length or thin sections which parted during drilling.

Unconfined compressive strengths (700 psi) obtained from tuff cores showed considerable variation in strength and elastic modulus due to marginal specimens with L/D ratios frequently less than unity. The variation in results was explained by "lack of homogeneity" within the tuff.

Specific explanations included diagonal or concoidal failure modes, but in many instances the presence of a pumice inclusion was the contributing factor which resulted in relatively lower compressive strength.

It is apparent that the inadequacies of laboratory testing due to specimen acquisition, preparation and size, cited as not being representative or atypical of in situ conditions as discussed in the previous section are not recognized in the assessment of the physical properties of in situ behavior of tuff.

5.2 Proton Storage Ring [3]

A soil and foundation investigation including test drilling, laboratory testing and analyses were performed to establish criteria for foundation design and slab support. Eleven exploratory holes were drilled to depths of 20 - 51 feet below existing grade using a combination of auger and NX diamond core drilling. Standard penetration testing and sampling were performed at intervals.

The soils encountered during drilling were visually classified and logged (R.Q.D.). In addition moisture contents were determined from soil samples. It was determined from drilling and testing that the site slopes approximately 7.5 ft down to the south west across the extent of the site. The near surface soils are comprised of 7 - 8 ft of silty sands, clayey sands and sandy clays. Below these soils, bedrock is comprised of a relatively soft, weathered and fractured tuff. Groundwater was not encountered during drilling.

The proton storage ring tunnel structure was constructed directly on the undisturbed volcanic tuff. A bearing pressure of 9,000 psf was recommended for design with the full dead load and an additional 1/3 for seismic forces.

The report[16] recommended that the modulus of subgrade reaction (k) of 250 pci be used for the design of the slabs on prepared subgrade and a modulus of subgrade reaction (k) of 600 pci be used for the design of the proton storage ring tunnel floor, bearing directly on the volcanic tuff.

These recommended subgrade moduli values are based on implementation of the site clearing, surface preparation and engineering procedures specified in the report appendix C of the report. Core logs indicate that the Rock Quality Designation range from 70 down to 9 with an overall average of 43 which is considered "poor". Unconfined compressive strength test data showed strengths ranging from 560 psi down to 136 psi with an average of approximately 270 psi.

6.0 Tunnel and Shaft Construction Risks.

The concept of re-aligning the beam delivery configuration from the PSR to the ER-1 Facility target may in principle appear to be a controversial solution. From a tunneling perspective, the tunnel and shaft concept, while unique in nature, is considered conventional tunneling since the construction approach utilizes excavation and support technology readily available technology. As with any tunneling project it carries some element of risk.

The principal risks considered in the development of a construction approach and the selection of excavation and ground support equipment and materials were:

1. The near surface location of the Portal in weathered soil or rock mantle with open and weathered joint systems. Careful excavation methods, employing hand mining, limited ground exposure for relatively short periods of time and effective support are considered to be the most effective means of ensuring tunnel stability.

2. The potential for the excavation process to encounter buried services and utilities or the effects of localized instability propagating so as to disturb buried, near-surface services, utilities and in the worst case surface buildings or structures.

This concern will be addressed during the pre-construction phase, when as-builts and site investigation are used to verify the location of buried, near surface services and utilities. The risk of encountering services and utilities is greatest during the construction of the portal and near-surface section of tunnel.

3. Development of the technical approach depends on the information contained in as-builts drawings. The accuracy of the as-builts may be questionable or at least subject to verification.

Time is taken during project set up to establish and or verify the local survey control points needed to construct the tunnel and shaft concept. Guide holes from the PSR and ER-1 Facility together with forward probing by drilling are required to supplement as-built information or generation new information used in survey control during construction.

4. The concept is base on safe and straight forward breakthrough procedures which will permit the physical access into the PSR and the ER-1 Facilities. These activities are subject to the uncertainty of survey accuracy and potential for encountering radio-active materials or conditions.

The construction approach assumes that the presence of radioactive materials are not encountered during construction and that approach is not complicated by the need to remove or work in a hazardous radioactive environment which could cause difficulties and add significantly to the cost and duration of the project.

5. The concept assumes that the Line D beam delivery hardware can be re-configured to fit in the tunnel and shaft concept and that all re-configured beam delivery system will meet and possibly improve on the associated operational and maintenance criteria.

The configuration of the proposed re-alignment from the PSR to the ER-1 Facility has been carefully considered from a shielding, operations, maintenance and safety point of view. Internal structures to support the beam line magnets while considered, are not in the immediate scope of this study but will have to be carefully designed.

6. The greatest risk associated with the development of the tunnel and shaft concept is in the area of geotechnical information. Limited information is available and what information there is was obtained in support of designing surface structures. This information has been reviewed and on the basis of engineering judgment assessed in the context of the tunnel and shaft construction.

In situ tuff can be easily excavated using mechanical and hand mining methods. Excavation is not considered to be the primary concern, however, the installation of effective ground support installation is considered to be of primary importance.

While the potential exists for small, localized blocks of rock or friable zones to loosen and possibly fall or spall, by using a combination of careful, excavation in conjunction with effective ground support the amount of unsupported tunnel exposed at any time during construction is limited and therefore the potential for an extensive fall of ground would be considered minimal.

The risk that surface facilities and structures would be exposed to is therefore be acceptable with the worst case situation being a partial tunnel collapse, propagating upward towards a surface structure with the potential for tunneling operations from to de-stabilize Line D and Line D Facilities.

7.0 Tunnel and Shaft Construction

A number of construction alternatives, options and contingencies were considered during the development of the construction approach used as the basis of the cost and schedule estimate.

7.1 Construction Approach

The original tunnel and shaft concept to re-align beam delivery from the PSR to the ER-1 as described in Section(12.0) of the report[1]. To facilitate construction, it was recognized that an Access Tunnel would be required to construct the Beam Extraction Beam Delivery Tunnel and Shaft. .

The Access Tunnel originally contemplated in the report[1] was to be initiated 40 - 50 feet east of the Line D tunnel structure, at a slight incline so as to end adjacent to the H⁰ beam stop-tune footing. The original Access Tunnel[1] then turned on the proposed Beam Delivery Tunnel alignment toward the ER-1 Facility target as described in Section(12.0)of the report[1]. This corresponded to current proposed Beam Delivery Tunnel concept is the basis the cost and schedule estimate.

The original Access Tunnel configuration[1], when subject to detailed assessment proved to be too steep and to tight a turn for practical use of heavy (25 - 50 tons) track mounted mechanical excavation and mucking equipment.

A cursory assessment of the use of explosives and expansive grouts subsequently eliminated them as viable excavation methods. This was principally due to the relatively weak strength of the in situ tuff (unconfined compressive strength of 700 psi) and very poor blasting characteristic.

Heavy mechanical excavation equipment has been considered in several previous tunnel, feasibility studies, planned for the mesa. Due to the relatively steep gradients (20° and 30°), turning radii, the need for substantial quantities of water for dust suppression, the potential for subgrade deterioration due to water and relatively high floor bearing due to the weight of the equipment more than offset the high production capacity of such equipment.

Smaller, more versatile excavation equipment, such as a track mounted Bob Cat unit with a boom mounted pavement breaker would suffice in terms of excavation flexibility, production capacity and maneuverability in the confined working space of the Access and Beam Delivery Tunnel. In addition, impact methods of rock breakage require less water for dust suppression than rotary cutter heads and a significantly reduced gross weight to damage the tunnel invert.

To compensate for the physical limitations of the Bob Cat, specifically related to maneuverability when cutting the full tunnel profile, modified excavation methods have been considered. These included benching or partial excavation of the tunnel profile to mitigate the limitations of the Bob-Cat. Benching is achieved by temporarily elevating the excavation floor, which also has the beneficial effect of limiting floor.

to material which will be ultimately removed prior to concrete placement. Further, careful excavation to achieve accurate profile control, will be achieved by using hand held 60 lb pneumatic pavement breakers.

This approach provides a more flexible approach, although a more labor intensive approach. However by operating 3 - 4 pavement breakers in the heading, satisfactory excavation rates can be achieved, together with a degree of reliability and excavation adaptability, should variable ground conditions be encountered.

In addition to pavement breakers, rock drills (jack legs) can be used for both excavation and rock bolt installation. This would also allow the use of down hole, hydraulic splitters if localized blocks or boulders of relatively resistant rock are found in the tunnel face. Hydraulic splitters would also be used to break reinforced concrete, during the initial hole through until pavement breakers could enlarge pilot holes.

The use of rock bolts as shown in Figure(4), Figure(5) and Figure(6) is one element of the composite lining structure that is considered optional. The utility of the pattern rock bolts will depend on the frequency, orientation and nature of joint systems in the tunnel profile.

If the rock excavated is weak, granular or friable and not conducive to effective rock bolting then it is reasonable to assume that they will be eliminated. The ground support system will then be supplemented by additional shotcrete.

In summary, tunnel excavation will be based on the use of 60 lb pavement breakers, rock drills with hydraulic splitters and the optional use of the Bob Cat.

Completed Transition Tunnel Profile

Average Profile length based on median Lining thickness

$$\frac{3.142(9)}{2} + (2)(7.0) + 9 = 37.14 \text{ ft}$$

Volume of in-place Concrete per Foot of Arch section CY/ft for 12" lining thickness

$$(37.14) (12"/12") (1') (1.10)/27 = 1.51 \text{ CY/ft}$$

Volume of concrete in Portal Structure and Wing walls CY

$$[(58.79)(.5)(12)(2)(1) + (20)(12)(1)]/27 = 35 \text{ CY}$$

Volume of invert concrete to line Beam Extraction Tunnel

$$(28.33)(0.41) = 12 \text{ CY}$$

Volume of invert concrete to line Beam Delivery Tunnel

$$(126.00)(0.41) = 52 \text{ CY}$$

Volume of invert concrete to line Access Tunnel

$$(153.37)(0.41) = 63 \text{ CY}$$

Volume of concrete to line shaft section

$$(3.142)(15)(2)(36.32)(1.2)/27 = 153 \text{ CY}$$

Total Volume of Concrete = 320 CY

Figure(5) Completed Transition Tunnel and Final Lining

Shotcrete application with pattern fiberglass rock bolts is expected to be adequate in terms of excavation capacity and operational flexibility given the uncertainty associated with limited available geotechnical information. The advantages of this system are considered to be:

1. The construction approach is conservative, and assumes a relatively weak material, capable of being effectively supported with shotcrete and rockbolts.
2. The average rate of tunnel excavated and supported per day is assumed to be a conservative 8 feet per day. If favorable conditions are encountered, the rate of tunneling may be increase to between 8 - 10 feet per day.
3. The use of careful tunneling methods to undermining the PSR Beam Stop Tune Up and ER-1 Facility Target is addressed by the proposed excavation and support methods.
4. The excavation methods requires only limited use of water for dust suppression and moderate ventilation requirements to comply with federal health and safety standards for tunnel/mining operations.
5. The selection of the 3.1/2 C.Y. capacity, supercharged Wagner L.H.D. would appear to have a muck removal capacity far in excess of that needed to match the proposed excavation rate. This is to compensate for the effects of altitude (7,000 ft) on the efficiency of the diesel engine and steep Access Tunnel gradients.

6. Selection of this unit is based on performance of this type of equipment at project elevation (7,000+ ft), hence the supercharged diesel H.P. which is needed to climb with a full load, the 20° gradient of the Access Tunnel, which represents the upper performance range for rubber-tired equipment.
7. A 20 H.P. electric slusher (bucket) operating on a cable winch will be used to drag (with the assistance of gravity) excavated material down the relatively steeper (30°) Beam Delivery Tunnel to the base of the Access Tunnel where it can be handle by either the Bob Cat and 3.1/2 C.Y. Wagner L.H.D.

7.2 Construction Options

The following section briefly identifies other options and alternatives considered in the cost and schedule estimate for excavation, ground support systems and muck handling systems.

7.2.1. Excavation Alternatives

1. Pavement Breakers: Hand excavation using 60 lb pavement breakers in relatively soft, weak and friable tuff.
2. Rock Drills: To be used in conjunction with and hydraulic splitter localized in locally hard materials or if sizable boulders are encountered. The combined use of rock drills and hydraulic splitters used during breakthrough into the PSR and ER-1 Facility

3. Mechanical Excavation: Use of Bob Cat with impact breaker arm or backhoe bucket attachment to remove and reduce localized hard zones. Also the bucket attachment will be used to remove invert material and excavate to install tunnel drainage system.

7.2.2. Ground Support System Alternatives

1. Composite Lining: Shotcrete and fiberglass-cementitious or epoxy-resin grouted rockbolts for the Access Tunnel, Beam Delivery and Beam Extraction Tunnel and all phases of Shaft construction.
2. Portal Structure: Preliminary support in portal using Lattice girders w/commercial shearing liner plate with cementitious grout.
3. Shaft Section: Ring beams w/commercial shearing liner plate for shaft formwork prior to installation of permanent concrete liner.

7.2.3. Muck Removal and Handling Systems Alternatives

1. Rail w/winch: Atlas Copco overshot mucker with winch assistance to address Access Tunnel gradients
2. Conveyor belt: Custom designed conveyor belt system with cleated or textured belt to assist in retaining material on steep inclined sections located in the Access Tunnel.

3. Rubber-tired: L.H.D.(Load, Haul, Dump equipment).
Various sizes(bucket) capacities and
horsepower, compatible with the excavation
rate, gradients, tunnel size and
configuration

7.2.4. Excavation Sequence Alternatives:

1. Full face: The primary excavation method will be to
remove the entire profile section
2. Benching: To protect soft floor sections.
Provide a natural working surface and
access to upper portions of tunnel profile
Reduce the volume of excavation prior to
support installation
3. Partial headings: Used where extended spans are excavated
such as the intersection of the Access
Tunnel and Beam Delivery Tunnel. Also
Transition section between the Beam
Delivery Tunnel and Shaft
3. Simultaneous Excavation of the Beam Delivery and Shaft:
To fully utilize personnel and equipment,
provide operational flexibility and reduce
overall schedule duration

8.0 Construction Sequence

The following section provides and outline of the construction steps and sequence, needed to construct the tunnel and shaft concept. Where necessary, a brief explanation provides details significant to the construction process. It is important to note that the construction approach selected is in operations terms, inherently flexible and can accommodate a wide range of tunneling conditions.

As previously noted, should the tunneling conditions encountered prove better than anticipated the excavation and support methods will be adapted to take advantage of the situation.

8.1 Mobilization

- Mobilize workforce, materials and equipment.

Following the award of the construction contract and receipt of the notice to proceed, the Contractor will obtain all necessary construction permits, insurance's and bonds etc.

8.2 Site Preparation

- Set up construction facilities and equipment at job site.

Site offices, equipment, storage facilities and work areas. Fence off construction area, establish communication system, first aid center, crew locker room, lunch and toilet facilities.

8.3 Establish Survey Controls Monuments for Construction

- Establish survey control monuments and control points.

Set up survey control system which is critical to establishing and maintaining the line and grade of tunnels and shaft. All construction drawings will be referenced against survey control points. Initial activities will include construction of survey monuments and verification of tunnel alignments and locations.

8.4 Perform Pre-Construction Testing

- Perform pre-construction testing on permanent construction materials.

Preconstruction testing will include establishing appropriate shotcrete and concrete mixes for use in construction. It normally takes at least 28 days to verify the adequacy of these materials.

The schedule anticipates that 28 day strengths for concrete and shotcrete will be achieved in approximately 14 days. Qualification and certification of construction personnel.

8.5 Layout Portal Structure

- Excavate for Portal Face (0+00, elevation 6937.77')

The portal location will be laid out from survey control points. Asphalt will be removed and the surface ramp excavated as indicated by the interval A - A' in Figure(2).

8.6 Stabilize exposed soil/rock face with shotcrete

- Stabilize soil and rock in immediate vicinity of portal.

The sides of the ramp and vertical face of exposed soil/rock sealed and supported with shotcrete.

8.7 Layout tunnel profile

- Establish center-line of Portal and tunnel profile.

Mark tunnel profile on shotcrete as shown in Figure(3).

8.8 Geotechnical Drill Holes

- Set up Longyear 38 drill unit at tunnel face.

The Longyear unit is skid mounted, electric/hydraulic drill unit capable of coring up to 1,000 ft long core holes. The drilling unit will be set up at the Portal face to core a 150 ft hole inclined down the alignment of the Access Tunnel.

- Drill core hole along Access Tunnel Alignment.

A 2 inch diameter core will be removed in 10 ft intervals per standard industry practice.

- Retrieve core and log recovered material.

The recovered core will be logged and stored in core box.

- Determine geotechnical properties and assess tunneling conditions and incorporate in construction plan.

An assessment of the core will be made to determine joint characteristics, including joint orientation, joint friction and cohesion, and joint frequency will be recorded. Estimates of the Rock Quality Designation(Q) the compressive strength of the rock will be made by the Geotechnical Engineer and be used to verify or adapt planned excavation and support measures for the Access Tunnel.

8.9 Construct Portal

- Excavate through shotcrete placed on portal face as shown in Figure(3), remove 2 ft section of soil and immediately support with 2 - 3 inches of shotcrete.

Use 60 lb pavement breakers, to excavate the tunnel profile as established on the shotcreted Portal face.

The excavation will be advanced approximately 2 ft or as conditions permit.

Soil excavated from the Portal will be removed using Bob Cat. The exposed 2 ft profile will be sealed and supported with 2 - 3 inches of shotcrete.

- Install lattice girder and liner plate section.

The first ring section of liner plates will be assembled and set in place under the shotcreted Portal profile.

The first lattice girder unit will then be set under the liner plate and secured.

- Excavate second 2 ft section of soil/rock in the Portal.

Apply shotcrete, install liner plate and lattice girder unit.

The Portal face will be advanced and supported in the same manner as described for the initial 2 ft of excavation as conditions permit.

- Repeat excavation and support sequence for 16 ft portal tunnel section

The Portal advancement sequence will be repeated for a 16 ft as conditions permit. Shotcrete will be applied to the internal surface of the liner plate until the lattice girders are enveloped in shotcrete.

- Grout any apertures/voids between liner plate and shotcrete.

In the event that shotcrete cannot be effectively applied when advancing the Portal, the aperture between the rock profile and the external surface of the liner plate will be filled with cementitious grout.

- Install tunnel lighting, power, compressed air lines and shotcrete materials lines to tunnel.

With the Portal structure partially complete, the services and utilities necessary to tunnel are set up. These include lighting power, ventilation and compressed air etc.

8.10 Construct Access Tunnel (Interval 0+16 ft - 100+19.47ft)
(CORRECT TO ACCOUNT FOR INCREASED ACCESS TUNNEL)

- Excavate in approximately 5 - 8 ft sections (as conditions permit).

Use appropriate hand mining and mechanical excavation methods to excavate and support 8 ft section of Access Tunnel. Geotechnical information in Section(4) indicates that the initial 8 - 11 ft of mantle is comprised of weathered tuff in a generally soft and friable state.

- Immediately support section with 2 - 3 inches of shotcrete. An initial application is essential in stabilizing relatively weak and friable material. This will typically mean 2 - 3 inches of shotcrete applied to exposed soil/rock profile.

- Install rock bolt pattern.

Rock bolt installation will take place approximately 24 hrs after the initial application of shotcrete. The rockbolts will be installed in regular configuration or pattern as shown in Drawings(RS-1000-9) and (RS-1000-10). Rock bolt installation may be omitted if the soil/rock structure is not amenable to effective rockbolt performance, in which case the second (3 - 6 inches) of shotcrete will be applied to complete support installation.

- Complete section 0+16 ft to 0+24 ft of the Access Tunnel with final application of 2 - 3 inches of shotcrete.

The second application of (3 - 6 inches) will be applied over the rockbolts and initial shotcrete application as shown in Figure(4).

Apply second, 2 - 3 inch shotcrete lift. Control application to provide a regular relatively smooth profile excavation.

- Repeat excavation and support sequence for Access Tunnel section 0+20 to 0+32 ft. as shown in Figure(4).

The excavation and support installation cycle will be established on the basis of experience and the Access Tunnel advanced in 8 ft intervals, as conditions permit.

- Extend ventilation fans and ducts

Ventilation in the excavation is required in compliance with federal health and safety requirements.

- Extend tunnel lighting, power, compressed air lines and shotcrete materials lines to tunnel.

The advancement of utilities so as to be in proximity to the work face is conducive to efficient tunneling.

- Repeat excavation and support sequence for Access Tunnel section in 8 ft increments from 0+24 ft to 100+19.46 ft.

The establishment of a consistent excavation and support cycle is indicative of an effective tunneling method.

8.11 Curved Section of Access Tunnel (Interval 100+19.47 ft - 200+19.37 ft)

- Establish survey controls for descending curve, as shown in Figure(2).

The accuracy of survey control is essential to the final alignment of the tunnel and shaft complex. The descending curve section ending in the shaft section is critical to the accurate location of the shaft structure under the ER-1 Facility target axis.

- Excavate in approximately 8 ft sections (as conditions permit).

Use appropriate hand mining and mechanical excavation methods based on the rock mass response and prior experience on previous tunnel sections.

As the depth of tunneling increases, the rock is expected to improve as the effects of weathering diminish and increased depth provides some confinement which improves the self-supporting capacity of the rock.

- Immediately support excavated tunnel section with 2 - 3 inches of shotcrete, as shown in Figure(4).

Shotcrete application is essential to excavation stability and to attaining a methodical excavation and support cycle.

- Install rock bolt pattern.

Rockbolt installation per the established pattern. Adjust the rock bolt location and orientation to address joint configurations if appropriate. Use supplemental bolts if specific features are evident.

- Complete section 100+19.47 ft to 100+53.37 ft of the Access Tunnel with final application of 2 - 3 inches of shotcrete.

Apply second 2 - 3 inch shotcrete lift. Control application to provide a regular relatively smooth profile excavation, as shown in Figure(4).

- Extend ventilation fans and ducting.

With the potential to generate dust using mechanical mining methods, and with limits placed on the quantity of water used during excavation and the use of diesel equipment, effective ventilation at the working face is essential. The physical location of ventilation ducting in proximity to the working face to remove dust, fumes and gases is important.

- Extend tunnel lighting, power, compressed air lines and shotcrete materials lines to tunnel.

The advancement of utilities and services is important to safety, the working environment and productivity.

- Repeat excavation and support sequence for Access Tunnel section 100+53.37 to 200+19.93 ft.

Implement excavation and support cycle systematically, as shown in Figure(4), adjusting where necessary, to localized conditions.

8.12 Geotechnical Drill Holes

- Establish survey controls for Beam Delivery Tunnel.

From external surface control points establish line and grade of Beam Delivery tunnel.

- Set up Longyear 38 drill unit on the axis of the Beam Delivery Tunnel.

Set up the core drilling unit in vicinity of point C, indicated in Figure(1) as described in Section(8.4).

- Drill core hole up Beam Delivery Tunnel Alignment.

As indicated in Section(8.4).

- Retrieve core and log.

As indicated in Section(8.4).

- Determine geotechnical properties and assess tunneling conditions. Incorporate assessment in construction plan

Assess the condition of the recovered core. Establish rock quality characteristics, including joint, orientation, friction, cohesion, and joint frequency. An estimate of Rock Quality Designation(Q), compressive strength of the rock will be made by the Geotechnical Engineer and be used in construction plan to identify excavation and support measures for the Beam Delivery Tunnel.

It should be noted that the planned schedule developed in Section(9.0) assumes that the construction of the Beam Extraction Tunnel and the Shaft are performed concurrently but are described here separately.

8.13 Beam Delivery Tunnel

- Excavate in approximately 5 - 8 ft sections (as conditions permit)

Excavation will proceed as previously described however it should be noted that the Beam Delivery is excavated at $+30^{\circ}$ in contrast to the Access Tunnel which was excavated at -20° .

The mining methods developed in the Access Tunnel will be adapted to conditions in the Beam Delivery Tunnel. In addition the positive effects of gravity will be used in conjunction with a 20 H.P. slusher to slide muck down the floor of the Beam Delivery Tunnel to the Access Tunnel where the Bob Cat and LHD (Load, Haul Dump) mucker will handle muck removal.

- Immediately support section with 2 - 3 inches of shotcrete.
Shotcrete will be pneumatically conveyed from the surface batch plant to tunnel heading for application.
- Install rock bolt pattern.
Rockbolt installation will be planned in part on the geotechnical assessment made from the core drilling and on experience to date.
- Complete section 0+00 ft to 0+05 ft of the Beam Delivery Tunnel with final application of 2 - 3 inches of shotcrete
Apply second 2 - 3 inch shotcrete lift. Control application to provide a regular relatively smooth profile excavation as shown in Figure(4).
- Extend ventilation fans and ducts.
Install ventilation ducting in Beam Delivery Tunnel.

- Extend tunnel lighting, power, compressed air lines and shotcrete materials lines to tunnel.

Advance services and utilities to support tunneling operations.

- Repeat excavation and support sequence for Beam Delivery Tunnel section 0+05 ft to 0+10 ft.

Implement careful start to tunneling cycle as conditions permit in vicinity of Access Tunnel and Beam Delivery tunnel intersection as shown in Figure(4).

- Repeat excavation and support sequence for Beam Delivery Tunnel section interval 0+10 ft to 0+18 ft in 8 ft increments from 0+18 ft to 0+60 ft.

Establish methodical tunnel cycle using 8 ft excavation and support intervals as conditions permit.

8.14 Construct Beam Extraction Tunnel Under Existing Beam-Stop

- Establish survey controls for Beam Extraction Tunnel.

It is too important to probe forward using rock drill to determine the physical location of the beam stop-tune up and PSR footing.

- Excavate in approximately 5 ft sections (conditions permitting) using hand mining and mechanical excavation methods as appropriate.

Advance the Beam Delivery Tunnel using careful mining procedures.

- Immediately support section with 2 - 3 inches of shotcrete. Apply initial 2 - 3 inches of shotcrete.

- Repeat excavation and support sequence for Beam Delivery Tunnel section 0+05 ft to 0+13 ft, as shown in Figure().
Implement methodical tunneling methods using 8 ft advance intervals.
- Extend ventilation fans and ducts
Install ventilation ducting in Beam Extraction Tunnel.
- Extend tunnel lighting, power, compressed air lines and shotcrete materials lines to tunnel.
Provide services and utilities in Beam Extraction Tunnel to support tunneling activities.
- Repeat excavation and support sequence for Beam Delivery Tunnel section interval in 8 ft increments from 0+10 ft to 0+27.53 ft, as shown in Figure(2).
Breach buried concrete piles by combination of drilling use of hydraulic splitters and 60 lb pavement breakers. Locate breakthrough point into the PSR. Drill pilot hole with rock drill. Facilitate break through from PSR to Beam Extraction Tunnel. Widen pilot hole to establish initial aperture (Final breakthrough will be completed from the PSR).
- Complete section 0+00 ft to 0+27.53 ft of the Beam Extraction Tunnel with final application of 2 - 3 inches of shotcrete.
Establish final profile of the Beam Extraction Tunnel with the controlled application of 2 - 3 inches of shotcrete.

8.15 Construct Beam Delivery Shaft

- From the transition tunnel section survey shaft centerline.
Establish survey control points to initiate shaft excavation.

- Excavate 10 ft diameter center core of shaft section 0+00 ft to 0+5 ft. as shown in Figure(6).
Using rock drills and 60 lb pavement breaker excavate vertically from transition tunnel to create a 10 ft diameter (as conditions permit) center core as shown in Figure(6).
- Support sides of exposed center core with 2 - 3 inches of shotcrete and temporary rock bolts as conditions required.
Apply 2 - 3 inches of shotcrete to walls of shaft center core and install fiberglass rock bolts as temporary support.
- Excavate 10 ft diameter center core of shaft section 0+10 ft
Extend the shaft center core upwards in 5 ft increments as shown in Figure(6). Remove muck using Bob Cat in confined section of the transition tunnel and 3.1/2 C.Y. LHD to remove facility from facility to outside muck storage area.
- Support sides of exposed center core with 2 - 3 inches of shotcrete and temporary rock bolts as conditions require
Apply 2 - 3 inches of shotcrete to walls of shaft center core and install fiberglass rock bolts as temporary support as shown in Figure(6).
- Complete excavation of center core section of shaft until base of ER-1 facility footing
Repeat excavation and support cycle as illustrated in Figure(6) until base of ER-1 Facility is encountered.
- Confirm centerline of the ER-1 target centerline.
Locate guide hole from the ER-1 Facility target. Adjust shaft survey control from target cell guide hole. Correct shaft alignment and correct subsequent shaft excavation if necessary.

Figure(6) Shaft Excavation Sequence

Figure(7) Shaft Shielding Installation and Final Lining

- Install circular mono-rail hoist on base of ER-1 footing and install 5 ton capacity electric hoist to support work deck in shaft

Drill into base of ER-1 Facility footing. Secure anchor bolts from which to attach and support circular beam monorail. Attach electric hoists used for materials and shielding (SEG) steel[23].

- Enlarge shaft diameter from 10 ft to 28* ft diameter (includes 4 ft annular aperture on periphery of the shaft to accommodate SEG shielding*) directly below the ER-1 Facility.

Excavate to enlarge the shaft diameter starting immediately below ER-1 Facility footing, limiting the extent of excavation to semi quadrants and interval 0+27.53 ft to 0+22.53 ft. Position work deck to within 6 ft of the top of center core of shaft excavation and secure against sides of shaft. Enlarge shaft diameter using 60 lb pavement breakers, rock drills and hydraulic splitters as needed and as conditions permit, subject to assessment by the Geotechnical Engineer. Complete first lift as indicated in Figure(6).

- Support sides of enlarged shaft section with 2 - 3 inches of shotcrete.

Support the walls of the excavated semi-quadrant with shotcrete and install fiber-glass bolts. Complete excavation and support of all semi-quadrants. This creates an annular working level around the work deck which extends outwards to a diameter of 20 ft. This completes the first 5 ft excavation interval as indicated in Figure(6).

- Install SEG Steel Shielding in 4 ft wide annulus around shaft. Transport SEG steel blocks into Transition Tunnel. Locate SEG steel at base of shaft center core. Lift SEG to upper work level using monorail and hoists. Stack and secure SEG in shielding annulus as shown Figure(7).

Complete shielding installation and shotcrete external face of shielding blocks to provide temporary support as shown in Figure(7).

- Excavate and enlarge shaft from 0+22.53 ft down to 0+17.53 ft in semi-quadrants.

Continue shaft enlargement by excavating the next 5 ft interval using semi-quadrant excavated sections as indicated in Figure(6), conditions permitting and subject to assessment of the Geotechnical Engineer, noting that the nominal excavation and support cycle can be adjusted as recommended by the Geotechnical Engineer.

- Support sides of enlarged shaft with initial application of 2 - 3 inches of shotcrete, installation of rockbolts and second application of 2 - 3 inches of shotcrete.

Apply 2 - 3 inches of shotcrete to the shaft walls and install pattern fiberglass rock bolts as shown in Figure(6).

- Complete shaft enlargement in semi-quadrants from 0+17.53 ft down to 0+00 ft, supporting with rockbolts and shotcrete.

Repeat the excavation and support installation until the entire shaft is enlarged to 20 ft diameter and temporary supported with shotcrete and rock bolts. Carefully excavate and support transition geometry between the shaft and Transition tunnel profiles and configurations.

This completes the excavation and temporary support of the underground excavations. Final lining systems comprised of plain and reinforced concrete will be used for invert(floor) and arch tunnel sections. The installation sequence for these structures is described as follows.

8.16 Shaft Lining

- Establish survey controls to facilitate installation of permanent lining structures relative to the beam axis as shown in Figure().
Confirm or make appropriate adjustments to facility survey for the purpose of positioning and aligning formwork for permanent concrete lining.
- Install ring beams (4 ft O.C.) and liner plate to serve as formwork.
Erect composite liner plate and ring beam structural elements in shaft. Verify alignment when complete.
- Install temporary internal supports to stiffener formwork subject to weight of pumped concrete.
Install falsework to stiffen and support as required the liner plate and ring beam units.
- Set up concrete pump at surface and install concrete pipeline from surface to shaft.
Set up on surface concrete pump and concrete materials pipe and hoses to shaft.
- Pump and place first lift of concrete 0 - 8 ft behind formwork.
Place concrete behind liner plate to fill and consolidate to a height of 8 ft ensuring liner plate is loaded in a uniform and controlled manner.
- Obtain concrete cylinders for concrete testing.
Sample and test concrete in accordance with construction specifications.
- Pump and place concrete (interval 16 - 24 ft) behind formwork.
Place additional concrete behind liner plate. Increase placement height from 8 ft to 16 ft.

- Pump and place concrete (interval 24 ft - cone section) ft behind formwork.

Place additional concrete behind liner plate. Increase placement height from 16 ft to base of conical section.

- Install cone formwork at top of shaft section and install temporary internal supports to stiffener formwork subject to weight of pumped concrete.

Lift prefabricated conceal structure to top of concreted shaft lining using hoist units. Secure cone structure in place. Remove hoist units from monorail. Complete formwork and falsework to support forms.

- Pump and place concrete behind cone section formwork.

Fill conical structure with concrete. This completes the permanent shaft lining.

- Install sump and drainage channel formwork in shaft floor.

Complete the installation of shaft sump and drainage pump mounting.

- Locate expansion joints in shaft invert section.

Install reinforcing bars and prefabricated expansion and construction control joints in shaft base.

- Pump and place shaft invert section.

Place concrete in shaft base and finish to provide smooth surface finish.

8.17 Transition Section (Arch)

- Establish survey controls to facilitate installation of permanent lining structures as shown in Drawings(RS-1000-9), (RS-1000-10) and Figure(5).

Set up survey control points to alignment Transition Tunnel formwork and invert sections.

- Install arch formwork and provide internal supports to stiffener formwork subject to weight of pumped concrete.
Move metal tunnel forms into Transition Tunnel and set on line and grade established from survey.
- Pump and place concrete behind transition formwork.
Set up concrete pump at surface and install concrete pipeline from surface to transition. Pump concrete into tunnel formwork.
- Obtain concrete cylinders and test at 3 days.
Sample and test concrete in accordance with construction specifications.
- Move Tunnel Formwork in Transition Tunnel.
Release tunnel formwork from concrete and relocate in adjacent section of Transition Tunnel. Place concrete in form and repeat until permanent concrete lining in the Transition Tunnel arch is completed.

8.18 Transition (Invert)

- Install drainage channel formwork in transition floor concrete floor to smooth finish as shown in Figure(5).
Set formwork for invert drain, install rebar and prefabricated construction joints on line and grade in the Transition Tunnel Invert Section.
- Place concrete and finish alternate sections in Transition Tunnel Sections.
Set up concrete pump at surface and install concrete pipeline from surface to transition. Pump concrete into tunnel formwork. Sample and test concrete in accordance with construction specifications.

- Complete remaining sections of concrete invert
Finish concrete floor to smooth surface.

8.19 Beam Extraction Tunnel (Invert)

- Install expansion joints and invert formwork in Beam Extraction Tunnel Section as shown in Drawings (RS-1000-9), (RS-1000-10) and Figure(4).
Set formwork for invert drain, install rebar and prefabricated construction joints on line and grade in the Beam Extraction Tunnel Invert Section.
- Place concrete and finish alternate sections in Beam Extraction Tunnel Sections.
Set up concrete pump at surface and install concrete pipeline from surface to transition. Pump concrete into tunnel formwork. Sample and test concrete in accordance with construction specifications.
- Complete remaining sections of concrete invert
Finish concrete floor to smooth surface as shown in Drawings (RS-1000-9), (RS-1000-10) and Figure(4).

8.20 Access Tunnel (Invert)

- Install expansion joints and invert formwork in Access Tunnel Section.
- Set formwork for invert drain, install rebar and prefabricated construction joints on line and grade in the Beam Extraction Tunnel Invert Section.
- Place concrete and finish alternate sections in Access Tunnel Sections.
Set up concrete pump at surface and install concrete pipeline from surface to transition. Pump concrete into tunnel formwork. Sample and test concrete in accordance with construction specifications.

- Complete remaining sections of concrete invert out to Portal.
Finish concrete floor to smooth surface.

8.21 Portal

- Complete shotcrete on face of portal.
Apply additional shotcrete to Portal face to supplement existing material and smooth portal profile.
- Excavate for portal drainage sump.
Excavate for surface sump located in front of Portal on surface access ramp. Install formwork and reinforcement. Pump in concrete. Remove formwork.
- Install drainage pipe to connect with local system.
Excavate trench to connect Portal sump to adjacent catchment basin. Install drainage pipe and connect to catchment basis piping.
- Place and compact subgrade material at portal.
Fill and compact trench fill around pipe.
- Concrete portal pavement.
Place concrete paving and wing walls on Portal structure.
- Repair/replace asphalt behind portal area.
Resurface areas where asphalt has been removed for construction purposes. Restore road and access surfaces in vicinity of portal and adjacent facilities.

8.22 Punch List Items

- Perform walk through inspection.
Construction management will inspect the constructed tunnel and shaft complex and identify all features of construction to be addressed in order to complete the contract

- Compile punch list items.

Construction Management will issue to the Constructor the punch list items developed from the inspection. The Constructor will outline how each item will be completed and develop an associated schedule.

- Address punch list items.

The Constructor will complete all punch list items.

- Complete final walk through to verify completion of punch list items.

Construction Management will make a final inspection to verify completion of the punch list items and sign-off.

8.23 Demobilization

- Remove equipment and construction facilities from site

The Contractor will systematically remove all construction equipment, facilities and materials from the site.

- Clean up site.

The Constructor will clean and restore the site to the required or pre-construction condition.

- Close out construction contract.

LANL will close out the construction contract.

9.0 Manpower Requirements

The normal eight hour shift is discounted by considering a 50 minute working hour with a 1 hour meal break.

9.1 Indirect Labor Requirements per Shift

9.1.1 Project Management, Engineers and Non-Exempt Personnel

1.	Project Manager	(1) (50%)	\$75.00/hr	\$ 600.00/day
2.	Project Engineer	(1) (50%)	\$64.00/hr	\$ 512.00/day
3.	Shift Engineer	(1)	\$58.00/hr	\$ 928.00/day
4.	Geotech. Engineer	(1) (25%)	\$75.00/hr	\$ 150.00/day
5.	Surveyor	(1) (50%)	\$42.00/hr	\$ 336.00/day
6.	QA/QC	(1)	\$35.00/hr	\$ 544.00/day
7.	Transportation	(2)	\$28.00/hr	\$ 560.00/day
8.	Administrator	(1) (50%)	\$60.00/hr	\$ 480.00/day
9.	Payroll	(1) (50%)	\$44.00/hr	\$ 352.00/day
10.	Purchasing	(1) (50%)	\$48.00/hr	\$ 384.00/day
11.	Secretary	(1) (50%)	\$24.00/hr	\$ 192.00/day
12.	Ship/Receiving	(1) (50%)	\$36.00/hr	\$ 288.00/day
13.	First Aid	(1)	\$32.00/hr	\$ 512.00/day

\$5,838.00/day

\$ 5,838.00 x 5 days x 39 weeks = \$1,138,410.00

Note: All wage rates are burdened and include workman's compensation, company medical insurances and benefits.

9.1.2. Consultants

As a contingency the services of consultant engineer will be retained.

\$20,000.00

9.2 Direct Labor Requirements per Shift

1.	Leadman	(1)	\$46.00/hr	\$ 736.00/day
2.	Mechanics	(1)	\$44.00/hr	\$ 704.00/day
3.	Electrician	(1) (50%)	\$55.00/hr	\$ 440.00/day
4.	Miners	(6)	\$40.00/hr	\$ 3,840.00/day
5.	Laborers	(4)	\$32.00/hr	\$ 3,072.00/day
6.	Equipment Operators	(2)	\$38.00/hr	\$ 1,216.00/day
				<u>\$10,008.00/day</u>

$$\$10,008.00 \times 5 \text{ days} \times 36 \text{ weeks} = \underline{\$ 1,801,440.00}$$

Note: All wage rates are burdened and include workman's compensation, company medical insurances and benefits.

Note: 36 week duration accounts for reduced workforce during initial project set up and final phase of demobilization

9.3 Shift Schedule and Organization

9.3.1 Access Tunnel (Base Tunnel and Transition)

First Shift 8 hrs (7.30 am - 11.30 am; 12.30 pm - 4.30 am)

Start Equipment 15 mins
(generators, compressors, ventilation fans)

Inspect tunnel 10 mins

Concurrently* 30 mins

Survey (Establish line and grade, mark
tunnel profile at face)*

Remove shotcrete test panels from tunnel
and transport to concrete lab for coring*

Set up excavation equipment (Bob-cat, LHD)*

Move protective canopy to face

Concurrently* 330 mins

Excavate 5 foot section of tunnel using
pavement breakers (24 CY in place)*

Remove muck on bench with Bob Cat*

Transport muck outside to muck pile
(32.5 CY Bulk w/ 35 % swell factor)*

Concurrently* 60 mins

Set up jacklegs *

Rock bolt installation in previously
shotcreted tunnel section*

Remove jacklegs, hoses and manifold* 20 mins

Clean up 15 mins

Total duration 480 mins
(8 hr's)

9.3.2 Access Tunnel (Base Tunnel and Transition)

Second Shift 8 hr's (4.30 pm - 8.30 pm; 9.30 pm - 1.30 am)

Inspect tunnel 10 mins

Concurrently*

Move back protective canopy from face 60 mins

to permit shotcrete application in heading*

Set up shotcrete system(shotcrete machine

batch plant, materials line and hoses)

(generators, compressors, ventilation fans)*

Concurrently*

Apply 3 inches of shotcrete in heading 180 mins

Apply 3 inches of shotcrete to rock bolted
tunnel section*

Concurrently*

180 mins

Clean up rebound material in tunnel*

Clean up shotcrete machine and batch plant*

Replenish cement, sand, water tanks etc.

Concurrently*

50 mins

Extend ventilation ducts in tunnel*

Extend compressed airlines in tunnel*

Extend tunnel lighting system in tunnel*

Move protective canopy to tunnel face*

Fuel up generators, compressors, Bob Cat

LHD and external light stations

Service and Maintain equipment

Shut down equipment and secure tunnel access

Total duration 480 mins
(8 hr's)

9.3.3 Beam Delivery Tunnel

First Shift 8 hr's (7.30 am - 11.30 am; 12.30 pm - 4.30 am)

Start Equipment 15 mins
(generators, compressors, ventilation fans)

Inspect tunnel 10 mins

Concurrently* 30 mins

Survey (Establish line and grade, mark
tunnel profile at face)*

Remove shotcrete test panels from tunnel
and transport to concrete lab for coring*

Set up excavation equipment (Bob-cat, LHD)*

Move protective canopy to face

Concurrently* 330 mins

Excavate 5 foot section of tunnel using
pavement breakers (24 CY in place)*

Remove muck on bench with Bob Cat*

Transport muck outside to muck pile
(32.5 CY Bulk w/ 35 % swell factor)*

Concurrently* 60 mins

Set up jacklegs *

Rock bolt installation in previously
shotcreted tunnel section*

Remove jacklegs, hoses and manifold* 20 mins

Clean up 15 mins

Total duration 480 mins
(8 hr's)

9.3.4 Beam Delivery Tunnel

Second Shift 8 hr's (4.30 pm - 8.30 pm; 9.30 pm - 1.30 am)

Inspect tunnel 10 mins

Concurrently*

Move back protective canopy from face 60 mins

to permit shotcrete application in heading*

Set up shotcrete system (shotcrete machine
batch plant, materials line and hoses)

(generators, compressors, ventilation fans)*

Concurrently*

Apply 3 inches of shotcrete in heading 180 mins

Apply 3 inches of shotcrete to rock bolted
tunnel section*

Concurrently*

180 mins

Clean up rebound material in tunnel*

Clean up shotcrete machine and batch plant*

Replenish cement, sand, water tanks etc.

Concurrently*

50 mins

Extend ventilation ducts in tunnel*

Extend compressed airlines in tunnel*

Extend tunnel lighting system in tunnel*

Move protective canopy to tunnel face*

Fuel up generators, compressors, Bob Cat

LHD and external light stations

Service and Maintain equipment

Shut down equipment and secure tunnel access

Total duration

480 mins

(8 hr's)

9.3.5 Beam Extraction Tunnel

First Shift 8 hr's (7.30 am - 11.30 am; 12.30 pm - 4.30 am)

Start Equipment 15 mins
(generators, compressors, ventilation fans)

Inspect tunnel 10 mins

Concurrently* 30 mins

Survey (Establish line and grade, mark
tunnel profile at face)*

Remove shotcrete test panels from tunnel
and transport to concrete lab for coring*

Set up excavation equipment (Bob-cat, LHD)*

Move protective canopy to face

Concurrently* 330 mins

Excavate 5 foot section of tunnel using
pavement breakers (24 CY in place)*

Remove muck on bench with Bob Cat*

Transport muck outside to muck pile
(32.5 CY Bulk w/ 35 % swell factor)*

Concurrently* 60 mins

Set up jacklegs *

Rock bolt installation in previously
shotcreted tunnel section*

Remove jacklegs, hoses and manifold* 20 mins

Clean up 15 mins

Total duration 480 mins
8 hr's)

9.3.6 Beam Extraction Tunnel

Second Shift 8 hr's (4.30 pm - 8.30 pm; 9.30 pm - 1.30 am)

Inspect tunnel 10 mins

Concurrently*

Move back protective canopy from face 60 mins

to permit shotcrete application in heading*

Set up shotcrete system(shotcrete machine
batch plant, materials line and hoses)

(generators, compressors, ventilation fans)*

Concurrently*

Apply 3 inches of shotcrete in heading 180 mins

Apply 3 inches of shotcrete to rock bolted
tunnel section*

Concurrently*

180 mins

Clean up rebound material in tunnel*

Clean up shotcrete machine and batch plant*

Replenish cement, sand, water tanks etc.

Concurrently*

50 mins

Extend ventilation ducts in tunnel*

Extend compressed airlines in tunnel*

Extend tunnel lighting system in tunnel*

Move protective canopy to tunnel face*

Fuel up generators, compressors, Bob Cat

LHD and external light stations

Service and Maintain equipment

Shut down equipment and secure tunnel access

Total duration 480 mins
(8 hr's)

9.3.7 Shaft (Initial and Second Phase)

First Shift 8 hr's (7.30 am - 11.30 am; 12.30 pm - 4.30 am)

Start Equipment 15 mins
(generators, compressors, ventilation fans)

Inspect tunnel 10 mins

Concurrently* 30 mins

Survey (Confirm raise center-line and grade*
Mark required excavation profile in raise)*
Remove shotcrete test panels from raise
and transport to concrete lab for coring*
Set up excavation equipment (Scissor lift
for personnel access, Bob-cat, LHD and raise
work deck)*
Secure work deck at the top of the excavated
raise.

Concurrently* 330 mins

Excavate 5 foot section, 10 ft diameter
raise using pavement breakers*
Drop muck through canvas chute to transition
section. Consolidate muck pile with Bob Cat*
Remove muck outside using LHD

Concurrently* 60 mins

Set up jacklegs, air hoses and manifold*
Install temporary fiber-glass rock bolts into
previously shotcreted 10 ft diameter shaft
wall

Remove jacklegs, hoses and manifold* 20 mins

Clean up 15 mins

Total duration 480 mins
(8 hr's)

9.3.8 Shaft (Initial and Second Phase)

Second Shift 8 hr's (4.30 pm - 8.30 pm; 9.30 pm - 1.30 am)

Inspect tunnel 10 mins

Concurrently*

Set up shotcrete system (shotcrete machine 60 mins
batch plant, materials line and hoses,
generators, compressors, ventilation lines and
fans)*

Concurrently*

Apply 2-3 inches of temporary shotcrete to 180 mins
raise walls
Shotcrete test panel

Concurrently*

Clean up rebound material in tunnel*
Clean up shotcrete machine and batch plant*
Replenish cement, sand, water tanks etc. 180 mins

Concurrently*

Extend ventilation ducts in raise*
Extend compressed airlines in raise*
Extend tunnel lighting system in tunnel*
Move protective canopy to tunnel face*
Fuel up generators, compressors, Bob Cat
LHD and external light stations
Service and Maintain equipment
Shut down equipment and secure tunnel access 50 mins

Total duration 480 mins
(8 hr's)

10.0 Equipment Requirements

The equipment and indirect materials used in the construction process are identified in the following sections.

10.1 Excavation System

1. Bob Cat dsl.(scrubbed) w/backhoe & ramhoe)	\$	3,800.00/mo
2. 3.1/2 CY Wagner LHD w/ supercharger	\$	7,200.00/mo
3. 20 HP elect. slusher dbl. drum w/cast bckt	\$	2,800.00/mo
4. 60 lb pavement breaker (6) w/chisel bits	\$	3,900.00/mo
5. Jacklegs (8) w/drill steel & bits	\$	8,000.00/mo
6. Dump truck 10 CY capacity	\$	4,600.00/mo
7. Protective canopy	\$	10,000.00
8. Shovels, picks etc.	\$	2,400.00
9. Shaft work deck	\$	12,000.00
10. Monorail w/ electric hoists	\$	22,000.00

Item

1. Bob Cat dsl.	\$ 3,800.00/mo x 7 mo.	\$ 26,600.00
2. Wagner LHD	\$ 7,200.00/mo x 7 mo.	\$ 50,400.00
3. 20 HP slusher	\$ 2,800.00/mo x 7 mo.	\$ 19,600.00
4. Pavement breakers	\$ 3,900.00/mo x 7 mo.	\$ 27,300.00
5. Jacklegs	\$ 8,000.00/mo x 7 mo.	\$ 56,000.00
6 Dump truck	\$ 4,600.00/mo x 7 mo	\$ 32,200.00
7. Canopy	\$ 10,000.00*	\$ 10,000.00
8. Handtools	\$ 2,400.00*	\$ 2,400.00
9. Shaft work deck	\$ 12,000.00*	\$ 12,000.00
10 Monorail w/ hoists	\$ 18,000.00*	\$ 22,000.00

\$ 258,500.00

* Item cost

10.2 Shotcrete Placement Equipment

1. Aliva 250 shotcrete machine	\$	3,300.00/mo
2. Volumetric batch plant	\$	4,200.00/mo
3. 5 HP water pump w/ spare parts	\$	1,800.00/mo

Item

1. Aliva 250	\$	3,300.00/mo x 7 mo	\$	23,100.00
2. Volumetric B.P.	\$	4,600.00/mo x 7 mo.	\$	32,200.00
3. 5 HP water pump	\$	1,100.00/mo x 7 mo.	\$	7,700.00
4. Shovels, rakes etc.*	\$			400.00
5. Visqueen 10 rolls *	\$			300.00
6. Gunny sacks *	\$			150.00
7. 500 lb capacity platform scale *	\$			1,400.00
8. Sieves 1/2" - #200 mesh and vibrator unit *	\$			1,600.00
9. Shotcrete Test panel 6 ea. *	\$			240.00
10. Elect/hydr 5 HP coring machine *	\$			2,100.00
11. Diamond Saw 18" dia. Elect 5 H.P. *	\$			1,400.00
12. Capping jigs 3" and 6" *	\$			250.00
13. Capping compound 50 lbs *	\$			125.00
14. Hand tools for clean up *	\$			1,200.00
15. Batch plant spare parts	\$			4,800.00
16. Shotcrete nozzle 2.1/2" Dia 2 ea. w/50' hose *	\$			4,200.00
17. Shotcrete machine spare parts *	\$			6,000.00
18. Shotcrete Hose 2.1/2" - 100 ft *	\$			2,500.00
19. 2.1/2" I.D. Sched 40 pipe - 400 ft *	\$			1,440.00
20. 1" Dia. high press water hose - 400 ft *	\$			1,770.00
21. 2" I.D. Bull hose w/fittings - 200 ft *	\$			4,200.00
22. Voice powered headsets 4 sets *	\$			2,400.00
23. Hose/Pipe couplers 10 ea.	\$			350.00
24. 2.1/2 Roustabout Victaulic couplers 25 ea. *	\$			1,200.00
25. Safety cables 6 ea. *	\$			300.00
27. Personnel safety equipment *	\$			9,000.00
28. Shotcrete cores tests - certif. laboratory *	\$			4,500.00
	\$			<u>114,625.00</u>

* Item cost

10.3 Concrete Placement System

1. Schwing concrete pump 40 H.P.	\$ 7,200.00/mo
2. Hany Injecto-Compact 25 H.P.	\$ 3,800.00/mo

Item

1. Schwing concrete \$ 7,200 x 2/mo.	\$ 14,400.00
2. Grout pump \$ 3,800.00/mo x 1 mo	3,800.00
3. Concrete placement pipe 4" dia, 400 ft *	\$ 1,800.00
4. Concrete hose w/fitting and couplers *	\$ 3,800.00
5. Concrete vibrators electric 220/110 6 ea. *	\$ 1,800.00
6. Elect Extens. chords h/duty 100 ft 10 ea. *	\$ 425.00
7. Steel forms tunnel sect 10 ft 2 ea. *	\$ 12,000.00
8. Invert forms tunnel sect w/ vibrators *	\$ 5,200.00
9. Bull floats, concrete finishing tools *	\$ 600.00
10. Form compound *	\$ 400.00
11 Concrete sealing compound *	\$ 750.00
12 Carpenters tools *	\$ 2,200.00
13 Miscell form mat. (Ply wood marine grade) *	\$ 2,600.00
14. Expansion joints *	\$ 1,400.00
	<u>\$ 65,925.00</u>

10.4 Services System

1. Mechanics truck w/(tools & fuel bowser)	\$ 2,400.00/mo
2. Diesel and gasoline fuel storage tanks	\$ 800.00/mo
3. Storage trailer 20 ft w/ storage shelves	\$ 800.00/mo
4. Project trailer 20 ft & office equip.	\$ 1,200.00/mo
5. Const crew locker 20 ft trailer	\$ 1,100.00/mo
6. Lunch/first aid 20 ft trailer	\$ 800.00/mo
7. Crew transportation bus 10 seater 2 ea.	\$ 3,800.00/mo
8. Porta toilets 6 ea.	\$ 800.00/mo
9. Pick up trucks 2 ea.	\$ 1,400.00/mo
10. Trailer 10,000 lb capacity 20 ft	\$ 1,500.00/mo
11. Trash dumpster 6 ea.	\$ 900.00/mo
12. Diesel fuel 5,000 gals/mo(\$1.49/gal)	\$ 7,450.00/mo
13. Gasoline fuel 750 gals/mo(\$1.40/gal)	\$ 1,150.00/mo
14. Low boy trailer	\$ 2,200.00/mo
15. Oxyacetylene torch w/ gas bottles	\$ 480.00/mo
16. Stick welder w/welding rod and supplies	\$ 650.00/mo
17. MIG welder, welding wire & gas	\$ 1,100.00/mo
18. Miscell. steel plate, structural sections	\$ 800.00/mo
19. Cap Lamps 40 ea. and charger station	\$ 1,600.00/mo.
20. Self rescuers 40 ea.	\$ 250.00/mo
21. Fork lift ATV 4,000 lb capacity	\$ 3,200.00/mo
22. Ventilation fans 40 HP w/stands 2 ea.	\$ 2,000.00/mo
23. 36 inch dia. concertina vent duct 400 ft	\$ 4,000.00/mo
24. Compressors 600 cfm 2 ea.	\$ 6,400.00/mo
26. 75 KVA diesel generator	\$ 5,200.00/mo
27. Power distrib. center 440/220/110 VAC	\$ 2,400.00/mo
28. Compressed air receiver tank 10,000 gal	\$ 600.00/mo
29. Air manifolds 3 ea.	\$ 300.00/mo
30. Water storage tanks 1,000 gals 2 ea.	\$ 450.00/mo
31. Scissor lift (30-40 ft) 2,500 lb cap.	\$ 4,000.00/mo
32. Light banks 4 ea.	\$ 1,600.00/mo
33. Tunnel light 400 ft strings 110 VAC	\$ 1,800.00/mo
34. Tunnel flood lights w/stands 10 ea.	\$ 1,800.00/mo
35. Frontend loader 3 CY capacity	\$ 3,000.00/mo

Item

1. Mechanics truck	\$ 2,400.00/mo x 8 mo	\$ 19,200.00
2. Fuel storage tanks	\$ 800.00/mo x 8 mo	\$ 6,400.00
3. Storage trailer	\$ 800.00/mo x 8 mo	\$ 6,400.00
4. Project trailer	\$ 1,200.00/mo x 8 mo	\$ 9,600.00
5. Const crew locker	\$ 1,100.00/mo x 8 mo	\$ 8,800.00
6. Lunch trailer	\$ 800.00/mo x 8 mo	\$ 8,800.00
7. Crew buses	\$ 3,800.00/mo x 8 mo	\$ 30,400.00
8. Porta toilets 6 ea.	\$ 800.00/mo x 8 mo	\$ 6,400.00
9. Pick up trucks 2 ea.	\$ 1,400.00/mo x 8 mo	\$ 11,200.00
10. Trailer	\$ 1,500.00/mo x 8 mo	\$ 12,000.00
11. Trash dumpsters	\$ 900.00/mo x 8 mo	\$ 7,200.00
12. Diesel fuel	\$ 7,450.00/mo x 8 mo	\$ 59,600.00
13. Gasoline	\$ 1,150.00/mo x 8 mo	\$ 9,200.00
14. Low boy trailer	\$ 2,200.00/mo x 8 mo	\$ 17,600.00
15. Oxy torch w/gas	\$ 480.00/mo x 8 mo	\$ 3,840.00
16. Stick welder	\$ 650.00/mo x 8 mo	\$ 5,200.00
17. MIG welder,	\$ 1,100.00/mo x 8 mo	\$ 8,800.00
18. Miscell. steel	\$ 800.00/mo x 8 mo	\$ 6,480.00
19. Cap Lamps 40 ea.	\$ 1,600.00/mo x 8 mo	\$ 12,800.00
20. Self rescuers	\$ 250.00/mo x 8 mo	\$ 2,000.00
21. Fork lift	\$ 3,200.00/mo x 8 mo	\$ 25,600.00
22. Ventilation fans	\$ 2,000.00/mo x 8 mo	\$ 16,000.00
23. 36 inch vent duct	\$ 4,000.00 *	\$ 4,000.00
24. Compres 600 cfm 2 ea.	\$ 6,400.00/mo x 8 mo	\$ 51,200.00
26. 75 KVA generator	\$ 5,200.00/mo x 8 mo	\$ 41,600.00
27. Power distr. center	\$ 2,400.00/mo x 8 mo	\$ 19,200.00
28. C/A receiver tank	\$ 600.00/mo x 8 mo	\$ 4,800.00
29. Air manifolds 3 ea.	\$ 300.00/mo x 8 mo	\$ 2,400.00
30. Water storage tanks	\$ 450.00/mo x 8 mo	\$ 3,600.00
31. Scissor lift	\$ 4,000.00/mo x 8 mo	\$ 32,000.00
32. Light banks 4 ea.	\$ 1,600.00/mo x 8 mo	\$ 12,800.00
33. Tunnel lights	\$ 250.00/mo x 8 mo	\$ 2,000.00
34. Flood lights	\$ 1,800.00/mo x 8 mo	\$ 14,400.00
35. Frontend loader	\$ 3,000.00/mo x 8 mo	\$ 24,000.00
		<u>\$ 505,520.00</u>

11.0 Permanent Materials

The following permanent materials are incorporated into the shaft and tunnel complex. The cost of these materials are estimated below:

11.1 Shotcrete

Cement 8.1/2 sacks/CY @ \$ 7.65/sack	\$	65.03
Sand/Agg 3,200 lbs @ \$14.00/ton	\$	22.40
Water 50 gals (incl. wash-down) @ 3¢/gal	\$	<u>1.50</u>
	\$	88.93

Total volume of shotcrete 337 CY

337 CY x \$89.93/CY	<u>\$30,306.00</u>
---------------------	--------------------

11.2 Concrete f'c = 5,000 psi

\$90.00/CY delivered to site w/retention	\$	90.00
--	----	-------

Total volume of concrete 320 CY

320 CY x \$90.00/CY	<u>\$28,800.00</u>
---------------------	--------------------

11.3 Lattice Girders

Commercial Pantex Sika Inc.

Lattice girder 3-bar (6/10) 9.58 lbs/ft	\$	399.00
---	----	--------

8 units x \$352.54/unit	<u>\$ 3,192.00</u>
-------------------------	--------------------

11.4 Liner Plate

11.4.1. Portal Structure

8 horseshoe sections 2 ft O.C.

24" 3 gage x 37.11/16" (full plate weight 80.2 lbs/unit)

8 sections @ \$1666.00 per section	<u>\$13,328.00</u>
------------------------------------	--------------------

11.4.2. Shaft Structure

24" x 37.11/16"- 3 gage (plate weight 80.2 lbs/unit)

21 plates per profile for 2 ft vertical section

15 profile units x \$ 2,466.00 per section \$36,995.00

11.5 Ring Beams

Shaft ring beams

15 Rings 2 ft O.C. @ \$600.00 per ring \$ 9,000.00

11.6 Cementitious Grout

Cement grout @ \$ 120.00 per CY

5 CY @ \$120.00/CY \$ 600.00

11.7 Rock bolts

1,600 rock bolt units x \$22.00/unit \$ 35,200.00

\$157,421.00

12.0 Project Schedule and Duration

The following construction schedule has been developed using the previously described construction approach and sequence, personnel and equipment resources. In addition the assumptions and constraints identified in Section(3.0) have significantly influenced the use of these resources and the final determination of project duration.

12.1 Critical Activities

The most important feature of the critical path is decision to concurrently construct both the Shaft and Beam Delivery Tunnels. The consequences of this approach is to place construction of the Beam Delivery Tunnel and Beam Extraction Tunnel on the project critical path. This is acceptable because concrete placement associated with the construction of the final shaft lining permits effective use of the available resources. the duration of the project based on two, eight(8) hour shifts and an average advance rate of eight(8) ft per day is 39 weeks. The need for each group of equipment such as excavation or shotcrete systems is estimated from the critical path analysis and factored with estimated cost rates (typically per month) to determine the associated cost as shown in Section(9) and Section(10).

Again it is emphasized, that should ground conditions prove more conducive to increased rates of excavation and support installation, then the conservatives estimates used to completed the critical path analysis would not be realized. The possibility therefore exists for the reduction in overall duration and associated total project cost. It is would then be assumed that the contingencies factored into labor, materials and equipment would not be expended, realizing further cost savings.

13.0 Project Costs

The following section provides a detailed cost estimate based on the outlined construction approach and sequence as described in Section(8), Section(9) and scheduled in Section(12).

The project cost has been broken down into the following categories:

- Labor direct/indirect
- Materials Permanent
- Equipment Capital/Rental
- Permits, Performance Bonds and Insurance's
- Profit and Taxes GRT

The following assumptions and contingencies have been used in the preparation of project costs:

- Labor (direct and indirect) 9% contingency,
- Permanent materials 7% contingency
- Construction equipment 7% contingency
- Overhead for u/g work assumes 42%
- Profit 10% excluding taxes
- Insurance's, permits, bonds etc estimated at 10 %
(labor, materials and equipment wo/profit)
- Gross Receipts Tax 6.1875 %, Los Alamos County

Note: LANL may not be subject to GRT, or require performance bond.and contingencies may not be required or used, depending on the type and terms of the construction contract.

This would be achieved by the possibly use of shared risk and the mutual benefits of effective construction and design.

13.1 Cost Summary

Labor

Direct	\$ 1,801,440.00
Consultants	\$ 20,000.00
Indirect	<u>\$ 1,138,410.00</u>
	\$ 2,959,850.00
9 % contingency	<u>\$ 266,387.00</u>
	\$ 3,226,237.00 (A)

Equipment

Excavation	\$ 258,500.00
Shotcrete	\$ 114,625.00
Concrete	\$ 65,925.00
Services	<u>\$ 505,520.00</u>
	\$ 944,570.00
7 % contingency	<u>\$ 66,120.00</u>
	\$ 1,010,690.00 (B)

Materials

Ground Support	\$ 157,421.00
7 % contingency	<u>\$ 11,019.00</u>
	\$ 168,440.00 (C)

Items A,B and C	\$ 4,405,367.00
Overhead 42 %	<u>\$ 1,850,294.00</u>
	\$ 6,255,620.00

Profit 10 %	\$ 625,562.00
-------------	---------------

Permits, bonds, licenses
and Insurance's 10 % of items
A,B and C

	<u>\$ 440,537.00</u>
	\$ 7,321,719.00

Gross Receipts Tax
at 6.1875 %

	<u>\$ 453,031.00</u>
--	----------------------

Total project Cost

	<u>\$ 7,774,750.00</u>
--	------------------------

14.0 Conclusions

- The tunneling method and construction approach developed in support of the cost and schedule estimate are considered technically feasible, based on the assumptions and constraints used and the available information
- The proposed method of construction is considered safe and the associated risks assumed, reasonable and appropriate
- The expected estimated project cost of \$7,774,750.00 includes appropriate contingencies
- The project is scheduled to take 39 weeks to complete.

15.0. References

No.	Author	Title
[1]	PCT Inc.,	Remedial Shielding Concepts for Line D and Line D Facilities, Los Alamos Meson Physics Facility, Los Alamos National Laboratory, Los Alamos New Mexico. Vol. I - VI. May 28, 1992 Contract No. 9-LQ3-2465J-1.
[2]	U.S.A.E.C.	Bidding Documents and Specifications for LAMPF, Weapons Neutron Research Facility, TA-53, Phase II, Los Alamos, New Mexico Invitation No. 291-74-16, Dec. 17, 1973
[3]	Randy Holt Assoc Inc.	Proton Storage Ring Facility, Equipment Building & Storage Ring. As Constructed Drawings (1-86)
[4]	Keller M.D.	Geological Studies and Materials Properties Investigation of Mesita de Los Alamos. Los Alamos Scientific Laboratory of the University of California. Los Alamos, New Mexico
[5]	S.H.B.	Proton Storage Ring. Soils Investigation. Los Alamos Scientific Laboratories, Los Alamos, New Mexico SHB Job No. E88-1164
[6]	S.H.B	Foundation Investigation For Bernard Johnson, Inc. Weapons Neutron Research Facility, TA-53 AT(29-1)-2195. Title 1. United States Atomic Energy Commission. Los Alamos Area Office, Los Alamos, New Mexico October 24, 1972

References cont'd

No.	Author	Title
[7]	Barton N. .	Engineering classification of rock masses for the design of tunnel support. Rock Mechanics, Vol 6, No.4, 1974, pages, 189-236.
[8]	Bernard	Weapons Neutron Research Facility, Phase II, TA-53.
	Johnson Inc.	Invitation No. 291-74-16. As Constructed Drawings. (1-99)
[9]		Scientific Ecology Group Shielding Steel Specification

NOTICE

Page(s) size did not permit electronic reproduction. Information may be purchased by the general public from the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161 (Area Code 703-487-4650). DOE and DOE contractors may purchase information by contacting DOE's Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831, Attn: Information Services (Area Code 423-576-8401).