

memorandum



To: Mr. Jim Lougheed
Maintenance Section
District #4 (Hamilton)

Date: 83 03 22

From: Pavement & Foundation Design Section
Room 315, Central Bldg.
Downsview

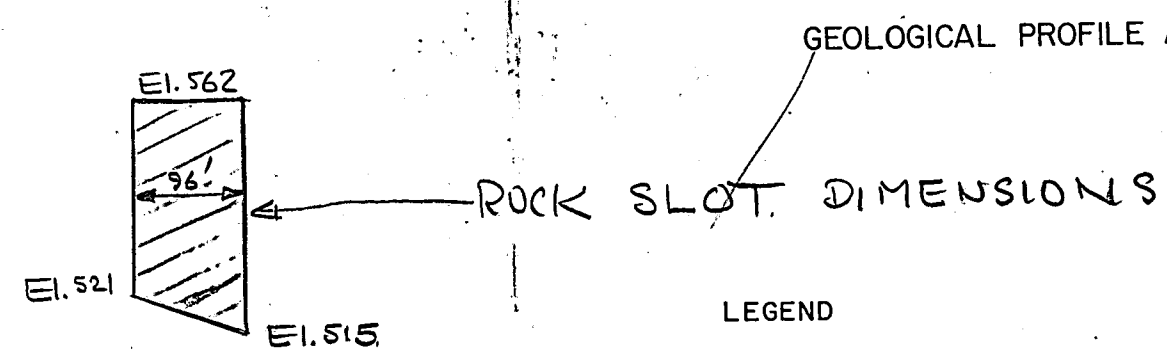
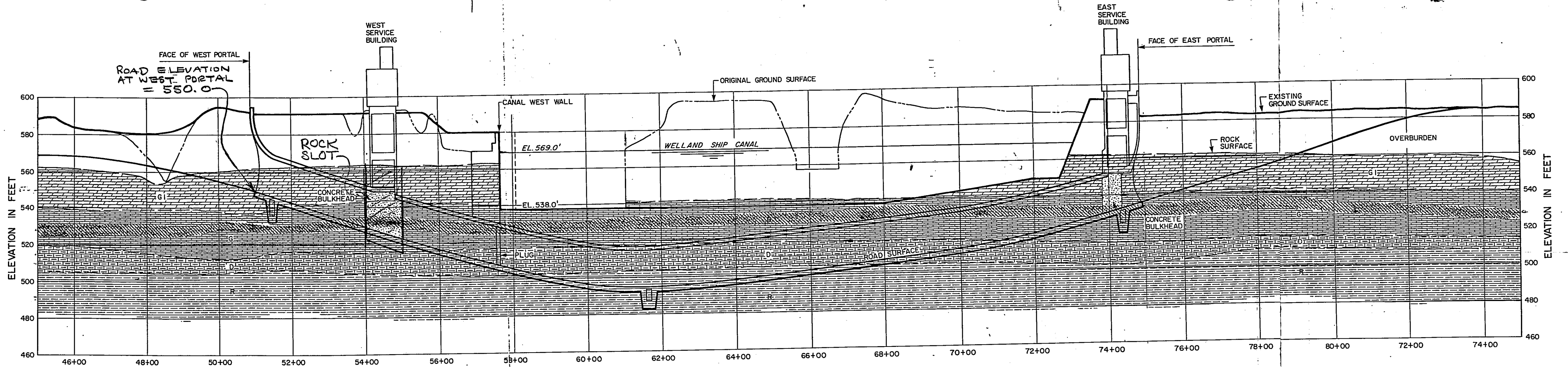
Re: Inspection of Rock Slot
South of West Service Building
Thorold Tunnel, Hwy. 58
District #4, Hamilton

Attached are two copies of the report by Acres following their inspection, at our request, of the Rock Slot at Thorold Tunnel. As you will note they conclude that the slot is in satisfactory condition and that therefore no remedial action is required. With regard to their comments on Page 10 regarding flow into the west sump our records show that for 1982 the pumping time (and hence the quantity pumped) was 12300 hours which is less by about 12 percent than the average for the previous 5 years which was about 14000 hours. There appears to be no evidence that the situation is worsening..

K. G. Selby

K.G. Selby, P.Eng.
Senior Foundations Engineer

KGS:syc



GEOLOGICAL PROFILE ALONG TUNNEL CENTRE LINE

LEGEND

MIDDLE SILURIAN PERIOD BEDROCK

YOUNGEST	G1	GOAT ISLAND MEMBER (DOLOMITE WITH SOME DOLOMITIC LIMESTONE)
LOCKPORT FORMATION	G	GASPORT MEMBER (DOLOMITIC LIMESTONE WITH SHALE)
	D	DECEW MEMBER (DOLOMITE WITH SOME DOLOMITIC LIMESTONE)
OLDEST	R	ROCHESTER FORMATION (CALCAREOUS SHALE WITH THIN LIMESTONE BEDS)
		SHALY LIMESTONE LAYER IN GASPORT MEMBER PROVIDING INITIAL LOAD ON WEST SERVICE BUILDING

NOTES

1. GEOLOGICAL BOUNDARIES ARE INTERPRETED AS BEING THOSE EXISTING ALONG THE CENTRE LINE.
2. AVERAGE DIP OF BEDDING PLANES 35 FT./MILE TO THE SOUTH.

memorandum



To: Mr. V. Mitranic
Senior Project Manager
Planning & Design
Central (5000 Yonge St.) Region

Date: 83 01 12

From: Pavement & Foundation Design Section
Room 315, Central Bldg.
Downsview

Re: Thorold Tunnel Improvements
W.P. 70-77-04

This is in reply to your memo of 82 12 17 regarding the status of the floor seepage investigation in the Thorold Tunnel.

We are in the process of requesting proposals from two geotechnical consultants, one of which will be awarded the assignment.

At the present time, the Seaway have lowered the canal level by about 10 m in order to carry out construction work. Refilling will commence about March 1st. The seepage investigation will be timed so as to cover the low level and high level water conditions in the canal therefore, we expect that fieldwork will commence on or before 83 02 01 and will be completed by 83 03 15. A final report should be available by 83 04 01.

A handwritten signature in cursive script, appearing to read "K. G. Selby".

K.G. Selby, P. Eng.
Senior Foundations Engineer

KGS:syc

cc: G.C.E. Burkhardt
C. Robertson
R. Fitzgibbon

memorandum



To: G.C.E. Burkhardt
Head, Structural Office
Central (5000 Yonge St.) Region
Attn: M. Bendayan

Date: 82 10 01

From: Pavement & Foundation Design Section
Room 315, Central Bldg.
Downsview

Re: St. Lawrence Seaway Authority
Contract 12-1826 - Extension of Approach
Wall, Lock 7 (1982), Welland Canal,
Seaway, Western Region

Attached for your information and use is a copy of a report by Acres Consulting Services Ltd., following their review, at our request, of drawings and specifications for the above-mentioned contract. Also attached is a copy of a letter from R.W. Poe, Civil Engineer, The Seaway, Transport Canada, together with Addendum No. 2 of Contract 12-1826 which shows compliance with Acres' recommendations. It will be necessary of course for the Ministry to further liaise with the Seaway and/or their contractor to ensure adequate monitoring. Please advise if we can be of any further assistance in this matter.

K.G. Selby

K.G. Selby, P. Eng.
Senior Foundations Engineer

KGS:syc

cc: C. Robertson

Atts.



October 26, 1982
P6641.00

Ministry of Transportation
and Communications
1182 North Shore Blvd East
District Office
Burlington, Ontario
L7R 3Z9

Attention: Mr. J. Nation

Gentlemen:

Report Entitled "Thorold Tunnel -
Effect on Tunnel Structure of
Constructing an Extension to the
Upper East Approach Wall, Lock 7"

Further to your telephone request of October 26, 1982, we are
pleased to submit herewith one additional copy of the subject
report for your on-site files at the Thorold Tunnel.

Yours very truly,

T. J. Bradshaw
Deputy Head,
Geotechnical Department

TJB:mjg
Encl

cc - K. G. Selby ✓

ACRES CONSULTING SERVICES LIMITED
5259 Dorchester Road, P.O. Box 1001, Niagara Falls, Ontario L2E 6W1
Telephone 416-354-3831 Telex 061-5107
Cables ACRES CAN NFS

Toronto, Burlington, Calgary, Halifax, Niagara Falls, St. John's, Vancouver, Winnipeg





The St. Lawrence Seaway
Transport Canada

La Voie maritime du Saint-Laurent
Transports Canada

File: 12-1826-1-1

Western Region
P.O. Box 370
St. Catharines, Ontario
L2R 6V8

September 21, 1982

Mr. K. G. Selby
Senior Foundations Engineer
Engineering Material Office
Ministry of Transportation
and Communication of Ontario
1201 Wilson Avenue
Downsview, Ontario
M3M 1J8

Reference: Contract 1826 - Extension to Approach Wall, Lock 7

Dear Sir:

Please find attached a copy of Addendum No. 2 for Contract 1826 with revisions reflecting the recommendations in the report submitted by Acres Consulting Services on the construction of the new wall over the Thorold Tunnel.

If you have any questions please give me a call.

Yours very truly,

R. W. Poe
Civil Engineer

RWP/mb
Attach.



Canada

ADDENDUM NO. 2

CONTRACT NO. 12-1826 - Extension of Approach Wall, Lock 7 (1982), Welland Canal, Seaway, Western Region

This Addendum modifies and forms part of the Contract Documents for this work, as follows:

SPECIFICATIONS

Section 1 - General

Subsection 1.05 - Use of explosives

Add the following paragraph to 1.05.13

"The peak particle velocity at the tunnel structure adjacent to the approach wall site shall not exceed twenty-five millimetres per second (25 mm/s)."

Add the following to 1.05.14 first paragraph line four after "blasting"

"to carry out a preblast survey of the tunnel structure and"

Subsection 1.06 - Water levels

Add the following paragraph

"Following the flooding of the reach on February 28, 1983 the water level will be maintained at elevation 172.9 plus or minus zero decimal one metres (± 0.1 m) until the opening of navigation at which time the level will be raised to the minimum operating level of 173.68 metres."

Section 3 - Demolition

Subsection 3.06 - Disposal

Line two delete the following

"as shown on the drawings and"

Section 4 - Excavation

Subsection 4.03 - Earth excavation

Add the following paragraph

"Silt material excavated from the canal bottom shall be transported in water tight boxes."

Subsection 4.04 - Bedrock excavation

Add the following to 4.04.6

"however blasting shall not be used for the excavation of the foundations for piers 2 and 3".

Subsection 4.05 - Disposal

Delete lines two and three and add the following to the sentence.

"in the designated disposal area which is located east of lock 7, northwest of the intersection of Peter Street and Davis Road. The Contractor shall build a containment area which will require the following additional work:

- .1 Removal of brush from the lower southerly portion of the designated area along Peter street.
- .2 Strip and stockpile the topsoil from the disposal area including the areas where the dykes will be placed and spread this topsoil on the disposal area at the completion of the contract.
- .3 Construct a containment dyke to a height of two to two decimal five metres (2 to 2.5 m) on the south, west and east sides of the area, as directed by the Engineer. In-situ clay from the stripped area, excavated to a maximum depth of one metre (1 m) shall be used to construct the dyke. The clay shall be placed in layers not exceeding two hundred millimetres (200 mm) maximum thickness and shall be compacted to achieve 98 percent of standard Proctor density as determined by ASTM standard D698 method 'A'.
- .4 No material larger than one hundred millimetres (100 mm) shall be disposed of within the top three hundred millimetres (300 mm) of the final disposal surface, and the disposal area shall be graded to provide good drainage.
- .5 Ditching shall be done along the northerly boundary of the disposal area and from there, southerly to Ten Mile Creek to restore the drainage pattern. The shaping, ditching and topsoiling shall all be done as directed by the Engineer.

This disposal area is for the following materials only:

- .1 Common excavation including silt material from the canal bottom
- .2 Rock excavation
- .3 Demolished concrete
- .4 Rockfill

Materials other than listed (debris etc.) shall be disposed of elsewhere by the Contractor and the Authority shall be saved harmless from all claims that may arise from such disposal.

The Contractor shall cooperate with others who will be using this disposal area."

Subsection 4.06 - Measurement for payment

Add to Item No. 6 - Excavation .3 Bedrock, the following

- "1 Piers 2 and 3
- .2 Remaining bedrock"

Add before the last paragraph the following:

"Item No. 6A - Dyke Construction for the Disposal Area

Dyke construction for the disposal area will be measured for payment by the cubic metre (m^3) for the number of cubic metres (m^3) of material actually placed and compacted as specified in the dyke.

Volumes will be calculated by the average end area method in the dyke.

Item No. 6B - Preparation of the Disposal Area

Preparation of the disposal area will be measured for payment on a lump sum basis.

The price tendered for this item shall include the removal of brush, topsoil stripping and stockpiling, drainage, final grading and replacement of topsoil.

Section 6 - Reinforcing Steel and Grouted Anchors

Subsection 6.04 - Measurement for payment

Add the following paragraph just before the last paragraph

"The price tendered for the 'No. 55M Anchors' shall include the supply of all labour, equipment and materials required to carry out anchor pull tests on two of these 55M anchors designated by the Engineer in order to prove the grouting procedure. Should the anchor pull tests fail the Contractor shall test additional anchors until the grouting procedure meets the pull test requirements."

DRAWINGS

Drawing 3568-1

Delete the disposal area from the drawing.

UNIT PRICE TABLE

The unit price table in the tender form is changed to the attached new unit price table.



The St. Lawrence Seaway
Transport Canada

La Voie maritime du Saint-Laurent
Transports Canada

File: 12-1826-1-1

Western Region
P.O. Box 370
St. Catharines, Ontario
L2R 6V8

September 21, 1982

Mr. K. G. Selby
Senior Foundations Engineer
Engineering Material Office
Ministry of Transportation
and Communication of Ontario
1201 Wilson Avenue
Downsview, Ontario
M3M 1J8

Reference: Contract 1826 - Extension to Approach Wall, Lock 7

Dear Sir:

Please find attached a copy of Addendum No. 2 for Contract 1826 with revisions reflecting the recommendations in the report submitted by Acres Consulting Services on the construction of the new wall over the Thorold Tunnel.

If you have any questions please give me a call.

Yours very truly,

R. W. Poe
Civil Engineer

RWP/mb
Attach.

Canada



ADDENDUM NO. 2

CONTRACT NO. 12-1826 - Extension of Approach Wall, Lock 7 (1982), Welland Canal, Seaway, Western Region

This Addendum modifies and forms part of the Contract Documents for this work, as follows:

SPECIFICATIONS

Section 1 - General

Subsection 1.05 - Use of explosives

Add the following paragraph to 1.05.13

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Add the following paragraph

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Section 3 - Demolition

Subsection 3.06 - Disposal

Line two delete the following

"as shown on the drawings and"

Section 4 - Excavation

Subsection 4.03 - Earth excavation

Add the following paragraph

"Silt material excavated from the canal bottom shall be transported in water tight boxes."

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Add the following to 4.04.6

"however blasting shall not be used for the excavation of the foundations for piers 2 and 3".

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Delete lines two and three and add the following to the sentence.

"in the designated disposal area which is located east of lock 7, northwest of the intersection of Peter Street and Davis Road. The Contractor shall build a containment area which will require the following additional work:

- .1 Removal of brush from the lower southerly portion of the designated area along Peter street.
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- .4 Rockfill

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Subsection 4.06 - Measurement for payment

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- ".1 Piers 2 and 3
- .2 Remaining bedrock"

Add before the last paragraph the following:

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Dyke construction for the disposal area will be measured for payment by the cubic metre (m^3) for the number of cubic metres (m^3) of material actually placed and compacted as specified in the dyke.

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Preparation of the disposal area will be measured for payment on a lump sum basis.

The price tendered for this item shall include the removal of brush, topsoil stripping and stockpiling, drainage, final grading and replacement of topsoil.

Section 6 - Reinforcing Steel and Grouted Anchors

Subsection 6.04 - Measurement for payment

Add the following paragraph just before the last paragraph

"The price tendered for the 'No. 55M Anchors' shall include the supply of all labour, equipment and materials required to carry out anchor pull tests on two of these 55M anchors designated by the Engineer in order to prove the grouting procedure.

Should the anchor pull tests fail the Contractor shall test additional anchors until the grouting procedure meets the pull test requirements."

DRAWINGS

Drawing 3568-1

Delete the disposal area from the drawing.

UNIT PRICE TABLE

The unit price table in the tender form is changed to the attached new unit price table.



September 8, 1982
P6641.00

Ministry of Transportation
and Communications
Highway Engineering Division
Central Building
1201 Wilson Avenue
Downsview, Ontario
M3M 1J8

Attention: Mr. K. G. Selby
Senior Foundation Engineer

Gentlemen:

Re: Agreement No. 4242-9082-124
Report on SLSA Proposed Works
Adjacent to Thorold Tunnel

We are enclosing herewith six copies of our report on the subject matter. The proposed SLSA works have been reviewed in the light of their potential effects on the Thorold Tunnel. Our report discusses these factors and makes recommendations regarding constraints which we feel should be placed on the contractor's operations.

If you have any questions regarding our report we would be pleased to discuss them with you at your convenience.

Yours very truly,

TJB:mjg
Encl

for R. G. Tanner
Project Manager

ACRES CONSULTING SERVICES LIMITED
5259 Dorchester Road, P.O. Box 1001, Niagara Falls, Ontario L2E 6W1
Telephone 416-354-3831 Telex 061-5107
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Toronto, Burlington, Calgary, Halifax, Niagara Falls, St. John's, Vancouver, Winnipeg

TABLE OF CONTENTS

LIST OF PLATES

	<u>Page</u>
1 - INTRODUCTION -----	1
2 - BACKGROUND INFORMATION PROVIDED -----	2
3 - EFFECT OF PROPOSED WORKS ON THE TUNNEL -----	3
3.1 - General -----	3
3.2 - New Loading Conditions -----	4
3.2.1 - New Rock Loading Conditions -----	4
3.2.2 - Disposal of Material Over the Existing Tunnel -----	5
3.3 - Effects of Blasting -----	5
3.3.1 - Effect of Blasting on Waterproofing Grout -----	6
3.3.2 - Effect of Blasting on Rock Squeeze -----	6
3.4 - Effect of New Wall Construction on Tunnel Waterproofing -----	8
4 - CONCLUSIONS -----	9
5 - RECOMMENDATIONS -----	10

LIST OF REFERENCES

PLATES

LIST OF PLATES

<u>Number</u>	<u>Title</u>
1	Existing Conditions at Tunnel Station 61+03±(Ft) - Looking East
2	Conditions at Tunnel Station 61+03±(Ft) After Proposed New Construction - Looking East

1 - INTRODUCTION

In July 1982, the Ministry of Transportation and Communications (MTC) contacted Acres Consulting Services Limited (Acres) regarding construction works which the St. Lawrence Seaway Authority (SLSA) proposed to undertake in the vicinity of the Thorold Tunnel between December 1982 and March 1983. This work involves an extension to the Upper East Approach Wall at Lock 7, a portion of which will be located over the tunnel and will replace the existing Bailey Bridge and sheet pile cells located over the tunnel at the site of the new wall.

Acres was requested to review the proposed SLSA works and to advise on the effects that the construction of this wall will have on the tunnel.

Verbal authorization to proceed with the study was given to Acres by Mr. K. G. Selby of the MTC on August 17, 1982. It was subsequently confirmed by Agreement No. 4242-9082-124 as detailed in a letter dated August 16, 1982.

2 - BACKGROUND INFORMATION
PROVIDED

During meetings with Mr. Selby on August 13 and 17, 1982 the following SLSA documents related to the proposed works were turned over to Acres.

- Preliminary full size prints of drawings 3568-1, 3, 4, 5, 6, 7, 8 and 9.
- A complete set of 28 reduced drawings for SLSA Contract No. 12-1826 together with 7 other drawings of structures presently existing in the area.
- A complete set of specifications for SLSA Contract No. 12-1826.

3 - EFFECT OF PROPOSED WORKS ON THE TUNNEL

3.1 - General

The drawings and specifications for the proposed new approach wall were reviewed together with drawings, reports and design and construction documents related to the tunnel. As a result, the following factors were identified as requiring study.

- The loads applied to the tunnel and surrounding bedrock in comparison with the site conditions and tunnel design criteria.
- A consideration of the amount of additional load which can be applied to the tunnel by materials disposed of above the tunnel roof.
- The effect of blasting on the grouting which was performed in the tunnel construction joints for waterproofing purposes.
- The effect of blasting on rock squeeze and subsequent pressures on the tunnel.
- The effect of the new wall construction on the tunnel bentonite panel waterproofing system.

Each of these items is described in detail in the following sections.

3.2 - New Loading Conditions

3.2.1 - New Rock Loading Conditions

The existing Bailey Bridge and its foundations on the east bank of the canal, as shown on SLSA drawing 3568-4, are to be demolished and be replaced by a new approach wall which will span over the existing tunnel rock cut. The new configuration is shown on SLSA drawing 3568-3.

The implications of demolishing the existing structure and constructing the new approach wall have been considered with respect to maintaining the service-ability and structural integrity of the existing tunnel.

Calculations of gravity loads from the existing Bailey Bridge and proposed new approach wall indicate that although the total load per pier for the new structure will be higher than that from the existing Bailey Bridge, the average gravity load per unit width of pier is about the same for each case, as shown on Plates 1 and 2. The vertical prestressing of the anchor rods adds a load of 691 t per pier for the new structure. This will make the average stress under the new pier approximately 1.5 times higher than the existing. The effect of this additional vertical loading on rock squeeze and bench stability is thought to be minor.

Values of ship impact loads are not available from information shown on the drawings. However, calculations for energy absorption based on velocity of approach of 2 m/sec show that a lateral load of the order of 5,000 kN could be generated by a large ore carrier striking the wall. This, in turn, would generate a load of about 2,000 kN along the length of the wall due to friction.

It is unknown if provision has been made in the design of the wall for longitudinal loads. A cursory inspection of the drawings suggests that the load path for a longitudinal load, as calculated, would likely be along the deck, to be distributed in some manner throughout the length of the structure to the bedrock.

3.2.2 - Disposal of Material Over the Existing Tunnel

SLSA drawing 3568-1 indicates a disposal area over the tunnel to the east of the new wall. The tunnel at this location was designed for a total uniformly distributed dead plus live load of 250 kN/m^2 which corresponds to the full canal water load. On this basis, any material left on the tunnel roof above canal grade, after the canal is filled, would result in an overstressing condition.

3.3 - Effects of Blasting

The SLSA documents indicate that blasting procedures may be used to prepare foundations for some of the new wall footings, remove portions of the existing canal walls and also to demolish the abutments of and ramps to the existing Bailey Bridge. Of concern is the potential effect that such blasting could have on rock squeeze and the grout waterproofing system in the tunnel construction joints. These two factors are discussed below.

3.3.1 - Effect of Blasting on Waterproofing Grout

To minimize any seepage through the tunnel construction joints, such areas were grouted using a chrome lignin based grout. On curing, this material is reported to have various properties depending on whether it is wet or dry. If dry, it can be brittle but if wet or moist it may be flexible. Since this material probably exists in very thin films in the construction joints, there is a possibility that these films may be cracked and damaged as a result of blast vibrations. Because of this, and based on blasting experience^{4*}, it is recommended that the blasting operations be controlled to limit the peak particle velocity to a value less than 25 mm/sec at the point in the tunnel closest to the blast.

3.3.2 - Effect of Blasting on Rock Squeeze

In the Acres studies reported in 1972 - 1974¹, rock squeeze was confirmed to have imposed significant loads on the west and east service buildings to the extent that it was necessary to construct a relieving slot on the south side of the west service building. In addition, some minor cracking of the tunnel was observed at the only other location where the space between the tunnel walls and the rock face was filled with concrete, i.e., at the west canal bank (Station 57+50 ft approximately) which is approximately 105 m from the location of the SLSA works..

* Numbers refer to items in List of References

Although the nature of rock squeeze is still debatable, it is most likely that it results from slippage of various layers of rock relative to underlying layers under the influence of horizontal stress. It is a time-dependent phenomenon². The only known reference to illustrate the effect of blasting on rock squeeze appears to be the movement records at the Canadian Niagara Power Company Wheel Pit in Niagara Falls when the two power tunnels were excavated for the Sir Adam Beck power station between 1951 and 1953. Observations provided by Ontario Hydro show that in the same general time as the blasting for the tunnels, the observed movement of the walls in the wheel pit showed a sudden increase.

From the time of construction in 1905 to 1953 a movement of about 28 mm occurred, whereas between 1953 and 1955 an additional 8.5 mm occurred which amounts to a 5 times increase in the rate of movement. After 1955, the rate of movement appeared to return to that which existed prior to 1953. As reported by Lee and Lo³, the power tunnels were excavated approximately 150 m away from the wheel pit at the closest point.

From the experience at the wheel pit, it is apparent that blasting may have a significant effect on the amount and rate of development of rock squeeze. No information is available regarding the vibration limits on the blasting in the power tunnels although it seems unlikely that the construction control would allow particle velocities to occur in excess of 50 mm to 100 mm/sec at a distance of 60 m since the tunnels pass at about that depth below residential areas in Niagara Falls. Based on the above assumption, it appears likely

that if the seaway construction resulted in particle velocities of 50 mm/sec or more at any of the three concrete bulkhead locations at the Thorold Tunnel, then a significant increase in the rock squeeze could occur. The west and east service buildings are located 180 m and 400 m respectively from the site of the blasting but the west canal bank is only 105 m from the blasting. If the particle velocity is limited to a maximum of 25 mm/sec, as recommended in Section 3.3.1, the particle velocity, as measured at the west canal bank, should be quite low making it unlikely that the rock squeeze problem will be aggravated.

3.4 - Effect of New Wall Construction on Tunnel Waterproofing

Based on tests performed by Acres in 1972 it was determined that as long as the existing backfill protection above the existing tunnel remains undisturbed, it will provide sufficient confinement and protection for the bentonite waterproofing so that the bentonite will not tend to swell or otherwise lose its effectiveness during the demolition and new construction phases of the proposed project. Proper precautions during blasting are, of course, necessary and are discussed above.

4 - CONCLUSIONS

- (a) The static loads imposed by the new canal wall on the bedrock and tunnel structure should not cause any problem with regard to the performance or integrity of the tunnel. The nature and magnitudes of horizontal loads imposed along the canal wall are not known nor are the methods by which they are resisted. If they are sufficiently large that the footings on the rock benches could be moved in a north-south direction, there is a possibility of movements in the rock fill over the tunnel which could result in damage to the tunnel bentonite waterproofing. Such potential for damage is, however, considered to be remote.
- (b) Materials piled over the tunnel above existing canal grade will result in overstressing the tunnel structure on refilling the canal to operating level.
- (c) The vibrations generated by blasting operations during construction of the new canal wall must be carefully controlled to avoid damage to the grout waterproofing and also additional damage as a result of accelerated rock squeeze.
- (d) Construction operations associated with the new canal wall construction are not anticipated to have an adverse affect on the main tunnel bentonite waterproofing.

5 - RECOMMENDATIONS

- (a) It is recommended that the SLSA be requested to advise if horizontal loads of significant magnitude, i.e., greater than 1,000 kN or 100 t, are expected to be transmitted to the base of the wall footings. If such is the case, it is conceivable that the ledge of rock might be in danger of failing by sliding depending on the magnitude of the load.
- (b) Materials such as rock fill or gravel may be stored above canal level over the tunnel to a depth of 3 to 4 m on a temporary basis while the canal is dewatered but it is recommended that to avoid tunnel overstressing, materials not be disposed of over the tunnel on long term basis when the canal water is at operating level.
- (c) The contractor's blasting operations should be carefully monitored using seismograph equipment and they should be carried out in such a manner as to limit the maximum particle velocities to less than 25 mm/sec in the tunnel structure adjacent to the wall site. In addition, seismograph recordings should be taken either on the bedrock floor of the canal adjacent to the west canal wall or inside the tunnel adjacent to the bulkhead to determine the magnitude of the particle velocities at this location.

It is also recommended that the tunnel be subjected to a thorough inspection prior to the blasting operations, noting such features as seepage through the walls and construction joints together with the current situation regarding wall cracks at all bulkhead locations. With

regard to the instrumentation installed at the east and west service buildings, it is recommended that a set of readings be taken before and after the blasting operations to assess whether any significant changes in conditions occur.

Concerning the wall footings on the rock bench, consideration could possibly be given to constructing these footings on the bedrock surface rather than 1 m below the surface. This would avoid blasting so close to the tunnel and would also result in a greater thickness of limestone between the footing and the weaker, squeezing shale zone in the Gasport Formation. Alternatively, it could be specified that drilling and blasting methods will not be permitted for these two footing excavations.

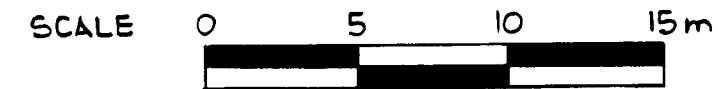
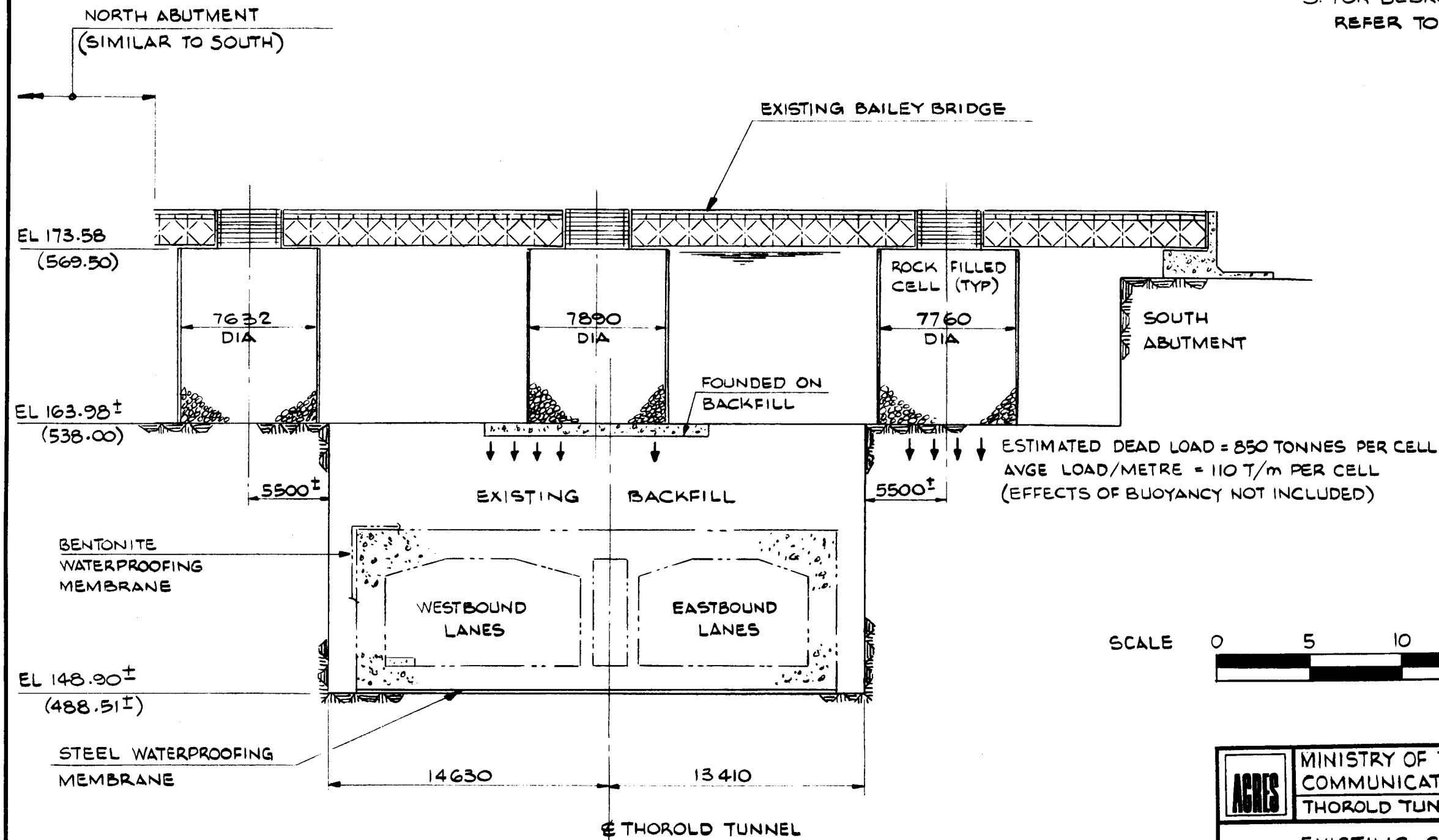
LIST OF REFERENCES

- ¹ Reports to the Ministry of Transportation and Communications, Ontario by Acres Consulting Services Limited entitled
 - Investigations to Determine the Cause of Cracking in the Structure, March 1972.
 - Supplementary Report No. 1 - West Service Building, May 1972.
 - Supplementary Report No. 2 - East Service Building, December 1972.
 - Supplementary Report No. 3 - West Service Building - Review of Observed Structural Behavior, 1971 to 1972.
 - West Service Building - Review of Observed Structural Behavior from August 1971 to September 1974, November 1974.
- ² C.F.P. Bowen, F. I. Hewson, D. H. MacDonald, R. G. Tanner. "Rock Squeeze at Thorold Tunnel", Canadian Geotechnical Journal. Vol 13, No. 2, 1976, pp 111 - 126.
- ³ C. F. Lee and K. Y. Lo. "Rock Squeeze Study of Two Deep Excavations at Niagara Falls", Proceedings of a Specialty Conference on Rock Engineering for Foundations and Slopes. University of Colorado, Boulder, August 15 - 18, 1976, New York: ASCE, 1976. Vol 1, pp 116 - 140.
- ⁴ John F. Wiss. "Construction Vibrations: State-of-the-Art". ASCE Journal of the Geotechnical Engineering Division. Vol 107, No. 6T2, February, 1981, pp 167 - 181.

PLATES

NOTES

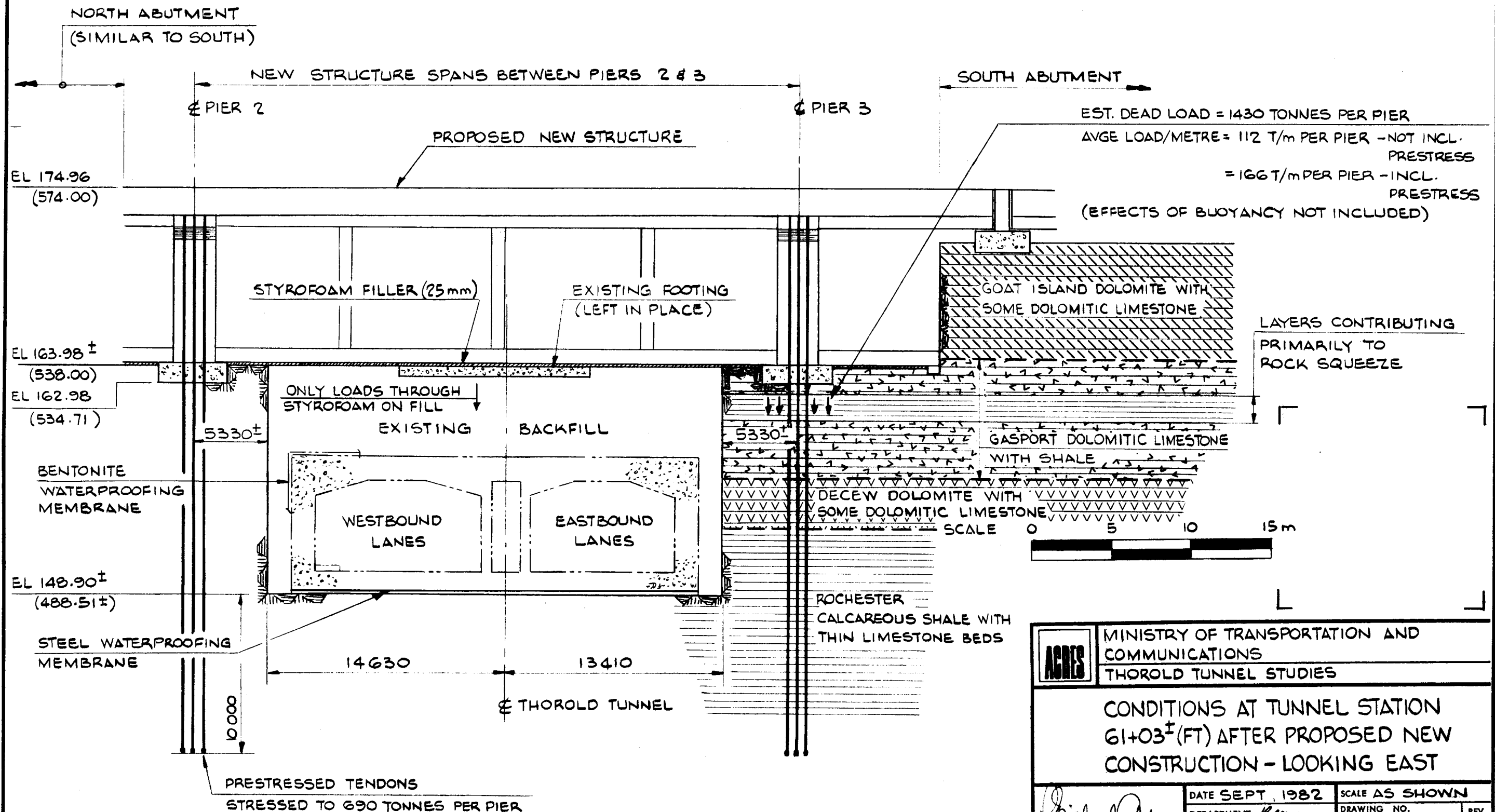
1. INFORMATION TAKEN FROM TUNNEL "AS BUILT" DRAWINGS No. 1195-SB-031, D-5578-205 AND D-5578-225.
2. ELEVATIONS SHOWN IN METRES FOLLOWED BY THE IMPERIAL EQUIVALENT IN BRACKETS (FEET)
3. FOR BEDROCK STRATIGRAPHY REFER TO PLATE 2.



ACRES	MINISTRY OF TRANSPORTATION AND COMMUNICATIONS		
	THOROLD TUNNEL STUDIES		
EXISTING CONDITIONS AT TUNNEL STATION 61+03± (FT) LOOKING EAST			
ACRES	DATE SEPT, 1982	SCALE AS SHOWN	
	DEPARTMENT	DRAWING NO.	REV.
PROJECT	PLATE 1	SHEET OF	

NOTES

1. INFORMATION ON PROPOSED CONSTRUCTION TAKEN FROM SLISA DWGS FOR CONTRACT 12-1826
2. ELEVATIONS SHOWN IN METRES FOLLOWED BY THE IMPERIAL EQUIVALENT IN BRACKETS (FEET)



ACRES	MINISTRY OF TRANSPORTATION AND COMMUNICATIONS	
	THOROLD TUNNEL STUDIES	
CONDITIONS AT TUNNEL STATION 61+03 ± (FT) AFTER PROPOSED NEW CONSTRUCTION - LOOKING EAST		
Richard Allen	DATE SEPT. 1982	SCALE AS SHOWN
	DEPARTMENT <i>km</i>	DRAWING NO. <i>PLATE 2</i>
PROJECT <i>903</i>	SHEET OF	REV. <i>Δ</i>