GEOCRES No:
30M3-64-1

GOVERNMENT OF ONTARIO
Ministry of Transportation
and Communications
Downsview, Ontario

THOROLD TUNNEL

INSPECTION OF ROCK SLOT
SOUTH OF WEST SERVICE BUILDING

September 1982

Acres Consulting Services Limited
Niagara Falls, Canada

TABLE OF CONTENTS

1 - INTRODUCTION

While studying a seepage problem adjacent to the west portal of the Thorold Tunnel in 1979, various areas and potential sources of water were investigated. One of these was the rock squeeze pressure relief slot which had been excavated in 1973 - 1974 on the south side of the west service building. A cursury inspection of the slot, where it is exposed in two manholes, indicated that the surface of the slot fill material (a clay/bentonite mixture) was below the bedrock surface. In Acres Consulting Services Limited (Acres) report on the seepage control works dated September 1979, it was recommended that the manholes be pumped out and the slot conditions carefully checked to ensure that the slot fill and piping barriers are performing in the manner for which they were intended. A general arrangement of the slot and manholes is shown on Plate 1.

In August 1982, the Ministry of Transportation and Communications (MTC) authorized Acres to undertake the slot inspection under Agreement No. 4242-9082-124. The terms of reference for the study were defined as follows, "Inspect the "Rock Slot" at the Thorold Tunnel, determine the condition and efficiency of the bentonite seal and prepare a report detailing findings and containing recommendations for remedial action."

An inspection of the slot was undertaken by Acres' personnel, the results of which are outlined herein together with recommendations. In addition to the work related to the slot, the rate of flow into the west sump and the condition of rock instrumentation in the vicinity of the slot were checked. The findings from this work are also included in this report.

2 - FIELD INVESTIGATION WORK AND OBSERVATIONS

The field work related to the slot inspection was undertaken primarily between August 31 and September 2, 1982 and included the following items.

2.1 - Survey Elevations

Using the main floor of the west service building as a benchmark (el 588.50 ft), elevations at and in the two manholes were determined as follows.

	East Manhole (ft)	West Manhole (ft)
Cover el	587.62	587.44
Water el	566.97	563.80
Bedrock el	563.82	563.80

By way of reference, the water level in the Welland Canal is approximately 569.0±.

2.2 - Brass Bolts (West Manhole)

In December 1976, two brass bolts were set in the bedrock surface on each side of the slot in the west manhole for the purpose of measuring rock surface movements. At the time of installation the near-faces of the bolts were 10.48 in. apart. During this inspection program the bolt faces were 10.19 in. apart indicating a relative movement of the surface rock of 0.29 in. since 1976.

2.3 - Dewatering of East Manhole

The water in the east manhole was drawn down from el 566.97 to el 564.12 in 13 minutes using a 2 in. submersible Flygt pump. This represents an average pumping rate of approximately 17 gal/min.

On completion of the slot inspection, the water level recovery was noted and it was found that the rate of inflow into the manhole was quite low and of the order of 3 gal/h.

2.4 - Inspection of Slot Fill

The probing within the slot was carried out using a metal fish wire which was pushed along the slot until an obstruction was encountered. Details of what was found in each manhole area are shown on Plate 1, Detail 1 representing the west manhole and Detail 2 the east manhole.

In the west manhole, three wooden bulkheads were encountered, one in the centre, to which instrumentation tubes had been fastened, and two others under the manhole walls. The west bulkhead prevented insertion of the fish line, however it was possible to insert the fish over the bulkhead on the east side and extend it for 13.6 ft. Clay/bentonite adhering to the fish indicated that the slot was full on the east side. Within the manhole area, the slot fill was about 1 ft below the bedrock surface in the western half and about 2 ft down in the eastern half.

In the eastern manhole, only one wooden bulkhead was found near the manhole centre and it also had instrumentation tubes attached to it. The slot is full of clay/bentonite on the west side of the bulkhead, while a triangular-shaped void about 2 ft deep and 5 ft long exists on the east side (see Detail 2, Plate 1).

2.5 - Flow in Slot

It was of significant interest to know whether any water flow exists along the slot. Visual observations of the water in the slot did not reveal any signs of flow.

To investigate this matter further, a Kent Miniflo Type 265 flow meter was inserted in the water below each manhole and no flow was detected. Finally, a dye sample consisting of 4 ounces of Rhodamine B-500 indicator dye was placed in the water in the east manhole on September 2. Twenty-one days later on September 23, the water in the slot below each manhole was checked for color. Water in the east manhole was pink while there were no traces of color in the west manhole.

2.6 - Instrumentation Tubes in Slot

The instrumentation tubing in each manhole was checked for identification markers, however none was observed.

In the east manhole, 3 pairs of tubing exit from the slot, however 2 pairs appear to have been damaged and discarded. The other pair were tied up to the top ladder rung. In the west manhole, 3 pairs of tubing extend up to the top ladder rung.

Because of the lack of identification tags and the inability to locate the readout equipment, reading of these instruments was not carried out.

2.7 - Flow into the West Sump

The maintenance staff have arranged to take readings of the time for water to rise in the west sump. They record the time required for the water to rise between depths of 8.60 ft and 4.7 ft or a height of 3.90 ft. On August 27, 1982 the time was 9 minutes and 4 seconds while the range of readings for the month of August varied between 9 minutes and 0 seconds and 9 minutes and 24 seconds. A time of 9 minutes and 39 seconds was measured on September 24, 1982.

The volume of water in the 3.90 ft depth of sump is
70.5 x 13 x 3.90 x 6.24 = 22 300 gal.
The current range of inflow rate = 2,310 to 2,480 gal/min.

The comparable range of flow rate measured in 1979 was 2,125 to 2,235 gal/min.

2.8 - Extensometers Through Tunnel Wall

A brief inspection was undertaken to assess whether any of the extensometers which had been installed through the tunnel wall and into the slot area were still in operating condition. It appeared that all of the instruments were either badly calcified or had been grouted over.

3 - CONCLUSIONS

(a) Rock movement and slot closure are taking place as evidenced by the movements of the brass bolts in the west manhole where the reduction in distance between the bolt faces has been 0.29 in. over a period of approximately 6 years.

(b) The lowering of the surface of the slot fill material appears to have occurred only locally at the two manholes as shown on Plate 1.

(c) No water flow appears to be taking place along the slot indicating that the seepage control barriers across the slot and the slot fill material are performing effectively.

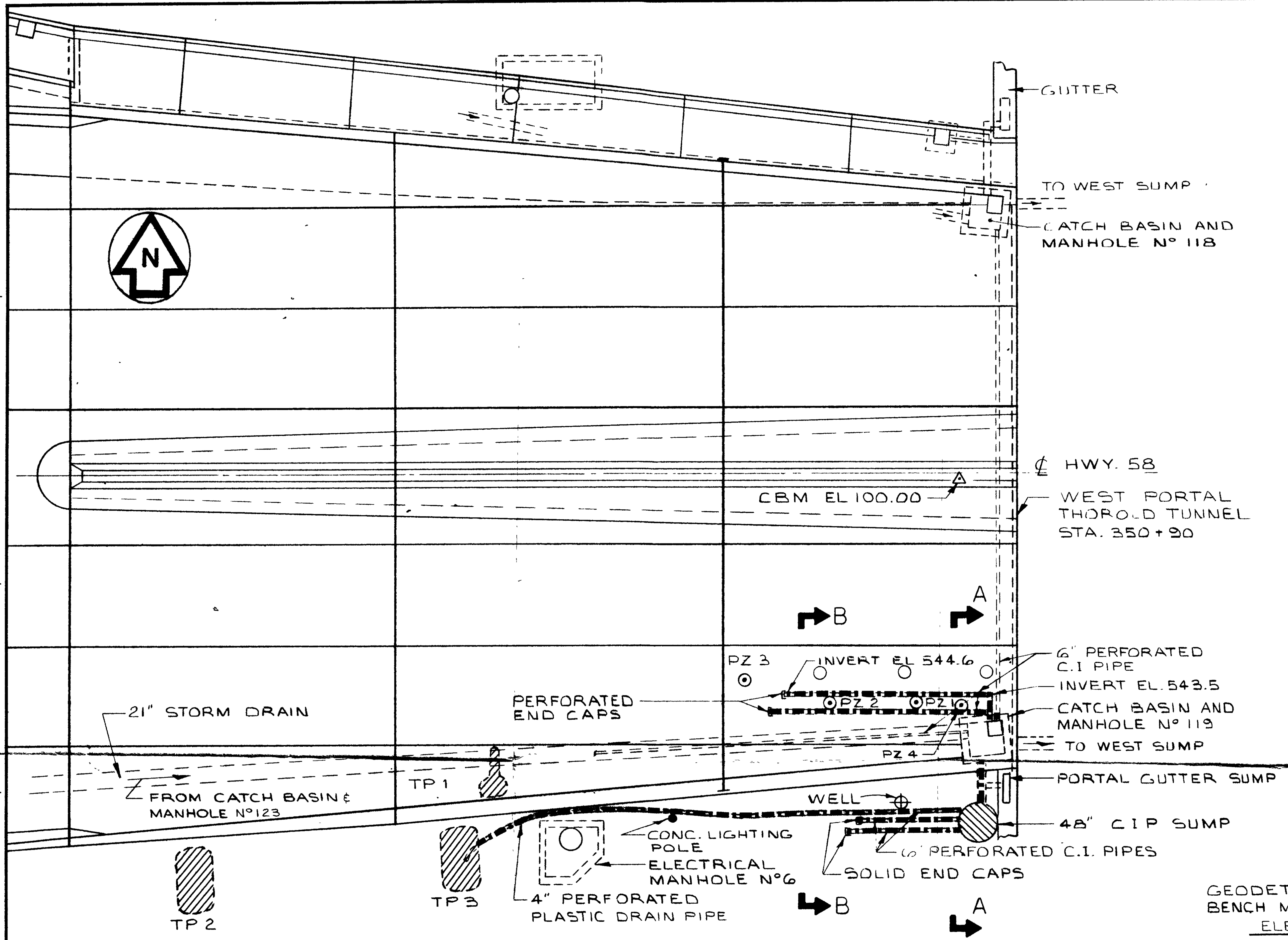
(d) Much of the existing instrumentation in and across the slot appears to be no longer serviceable. A more detailed inspection of these instruments would be required to assess which instruments are or could be made operable.

(e) The rate of flow into the west sump during August and September ranged from 2,310 to 2,480 gal/min as compared to 2,125 to 2,235 gal/min in 1979. This indicates a flow rate increase of approximately 10 percent over the 3-yr period.

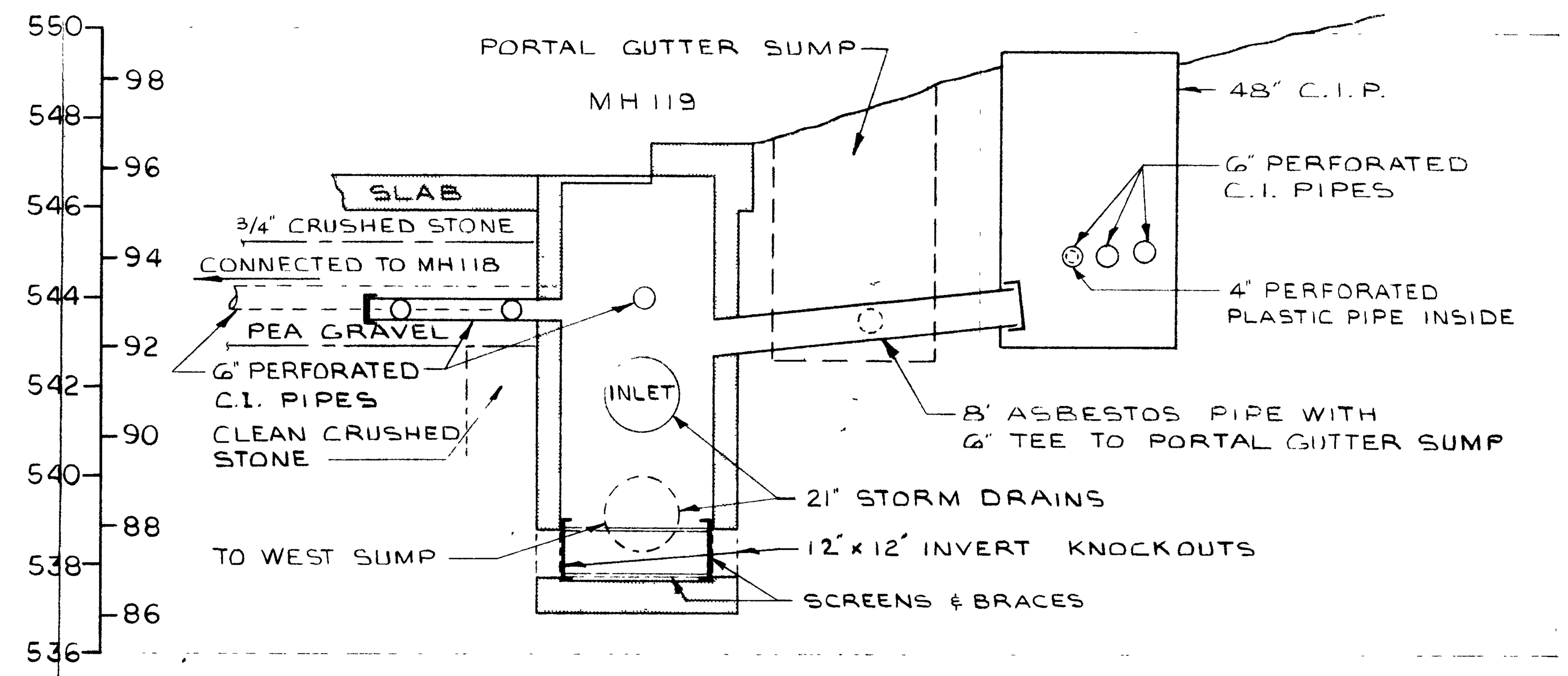
4 - RECOMMENDATIONS

Since the portion of the slot without fill material is relatively small and no flow appears to be occurring along the slot, it is not considered necessary to proceed with filling the voids at this time. It is recommended that the slot be inspected in the future, say 5 years from now, to assess whether any changes have occurred.

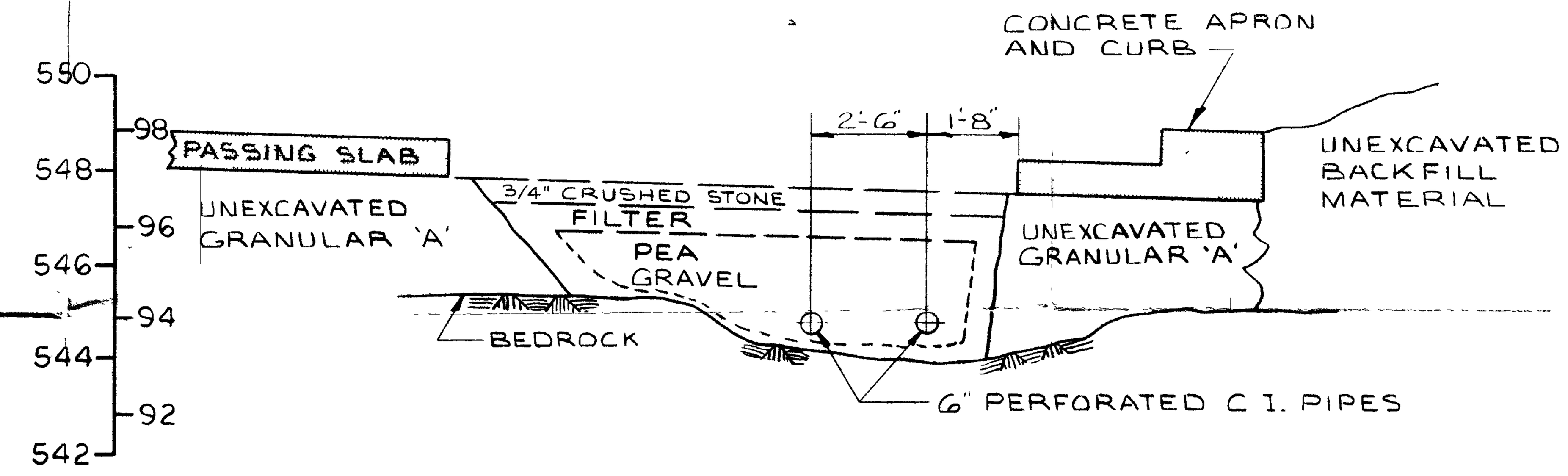
There appears to be an increase in the flow into the west sump of the order of 10 percent over the past 3 years. It is recommended that the MTC flow records be reviewed to see if this does represent a true flow increase or whether it may have been caused by changes in precipitation or variations in the methods of taking the flow measurements. It is further recommended that the flow measurements be continued on a regular basis.



PLAN
SCALE: 1" = 10'-0"



SECTION A-A



GEODETIC BENCH MARK — CONSTRUCTION BENCH MARK
ELEVATION IN FEET

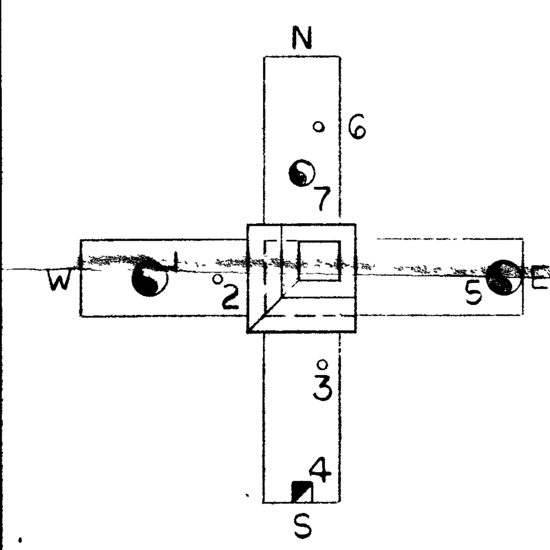
SECTION B-B
SHOWING PLACEMENT OF BACKFILL MATERIALS
SCALE 1" = 30'-0"

LEGEND

- ⊙ STANDPIPE PIEZOMETERS (PZ)
- ⊕ WELL
- ▨ TEST PIT (TP)
- △ CONSTRUCTION BENCH MARK (CBM) PLUG IN MEDIAN BARRIER
- ○ HOLE CORED THROUGH CONCRETE PAVEMENT
- ▬·▬ NEW DRAINAGE CONTROL WORKS

CATCH BASIN AND MANHOLE Nº 118
INFLOW INSPECTION (JUNE 26 1979)

OPENING Nº	DESCRIPTION	OBSERVATIONS
1	18"ø STORM SEWER	A TRICKLE OF WATER
2	6"ø PERFORATED SURFACE DRAIN	1/2" FLOW
3	SAME AS 2	SAME AS 2
4	12" x 12" INVERT KNOCK-OUT	FLOWING 1/4 FULL-CLEAR WATER
5	21" STORM DRAIN	FLOWING TO TUNNEL SUMP
6	1 1/2"ø HOLE	OPEN ONLY THROUGH WALL OF CATCH BASIN, NO CONNECTION TO OTHER PIPES, FLOWING 1/2 FULL
7	12" GUTTER SUMP AND CB189 CONNECTION	1" FLOW

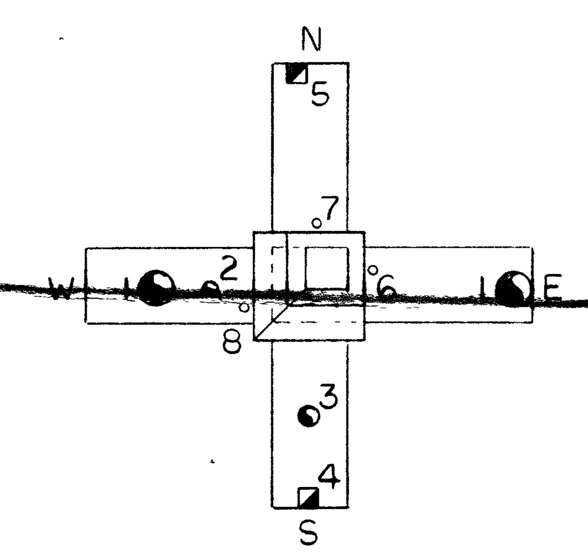


SCHEMATIC DIAGRAM
CATCH BASIN & MANHOLE Nº 118

NOTE
1 THE BOTTOM OF THE CATCH BASIN WAS COVERED WITH 3" OF SAND, GRAVEL AND ROCK RUBBLE.
2 A STRONG SULFUR/SEWER SMELL WAS NOTED.

CATCH BASIN AND MANHOLE Nº 119
INFLOW INSPECTION (JUNE 22 1979)

OPENING Nº	DESCRIPTION	OBSERVATIONS
1	21"ø STORM DRAIN FROM MH-123	A TRICKLE OF WATER FROM THE FIRST PIPE JOINT WEST OF THE MH.
2	6"ø PERFORATED SURFACE DRAIN	FLOWING 1/2 CAPACITY. OPEN FOR 55' WEST OF MANHOLE. PIPE RUNS WEST APPROX. 30' AND DOGLEGS TO THE SOUTH WEST.
3	12" GUTTER SUMP CONNECTION	A TRICKLE OF WATER-SOURCE UNKNOWN. AS SUMP IS DRY
4	12"x12 INVERT KNOCK-OUT	OPENING BLOCKED ON OUTSIDE BY SEVERAL PIECES OF COARSE ROCKFILL. FLOWING ~~1/3 TO 1/2 FULL-CLEAR~~ WATER
5	SAME AS 4	SAME AS 4
6	1 1/2"ø SURFACE DRAIN	PROBED LENGTH-3.5'. FLOWING 1/4 TO 1/3 FULL-CLEAR WATER.
7	SAME AS 6	PROBED LENGTH-3'-0". FINES SLUICED OUT FOR 2-3 MINUTES DURING PROBING. FLOW INCREASED FROM 1/4 TO 3/4 DURING PROBING.
8	SAME AS 6	PROBED LENGTH-2.5'. INCREASE IN FLOW FROM 1/4 TO 3/4.



SCHEMATIC DIAGRAM
CATCH BASIN & MANHOLE Nº 119

NOTE
1. AFTER PROBING 6, 7 & 8, THE LEVEL OF WATER AT ROAD SURFACE WAS DRAWN DOWN APPROX. 2-2 1/2" IN 15 MINUTES.
2. THE BOTTOM OF THE CATCH BASIN WAS COVERED WITH 3" OF SAND, GRAVEL AND ROCK RUBBLE.

DATE	No.	REVISIONS	CH.	APP.	APP.

ACRES
MINISTRY OF TRANSPORTATION AND COMMUNICATIONS
THOROLD TUNNEL - WEST PORTAL AREA

SEEPAGE INVESTIGATIONS AND CONTROL WORKS

DATE SEPT 1979 — SCALE AS NOTED
DEPARTMENT — DRAWING No. 5464-B-2 — REV
PROJECT — SHEET OF

PLATE 1

DRAWING No. 5464-B-2 SHEET OF REV

APPLIED MECHANICS | ARCHITECTURAL | CIVIL | CONSTRUCTION | ELECTRICAL | GEOTECHNICAL | HYDRAULIC | MECHANICAL | DESIGNED | DRAWN | CHECKED

TRANSLAR 250-3-79

GOVERNMENT OF ONTARIO
Ministry of Transportation
and Communications
Downsview, Ontario

THOROLD TUNNEL

EFFECT ON TUNNEL STRUCTURE OF CONSTRUCTING AN EXTENSION TO THE UPPER EAST APPROACH WALL, LOCK 7 WELLAND CANAL

September 1982

Acres Consulting Services Limited
Niagara Falls, Canada

ACRES

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,

for R. G. Tanner
Project Manager

TJB:mjg
Encl

ACRES CONSULTING SERVICES LIMITED
5259 Dorchester Road, P.O. Box 1001, Niagara Falls, Ontario L2E 6W1
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Cables ACRESCAN NFS
Toronto, Burlington, Calgary, Halifax, Niagara Falls, St. John's, Vancouver, Winnipeg

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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 serviceability 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 - 1974[1], 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..

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* 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 phenomenon[2]. 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 Lo[3], 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.

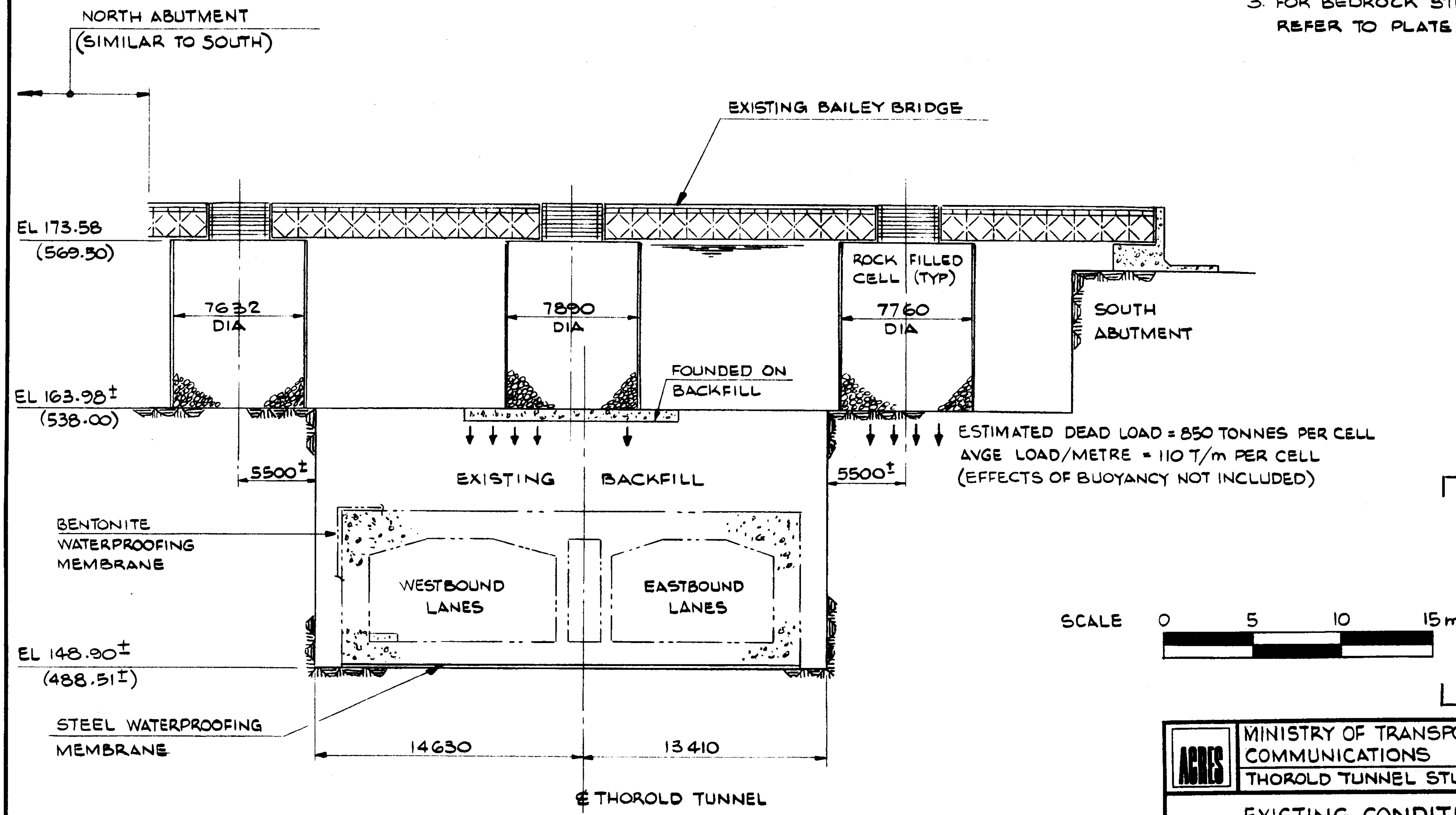
[3] C. F. Lee and K. Y. Lo. "Rock Squeeze Study of Two Deep Excavations at Niagara Falls", Proceedings of a Specialty Conference on Rock Engineering for Foundations and Slopes. University of Colorado, Boulder, August 15 - 18, 1976, New York: ASCE, 1976. Vol 1, pp 116 - 140.

[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.

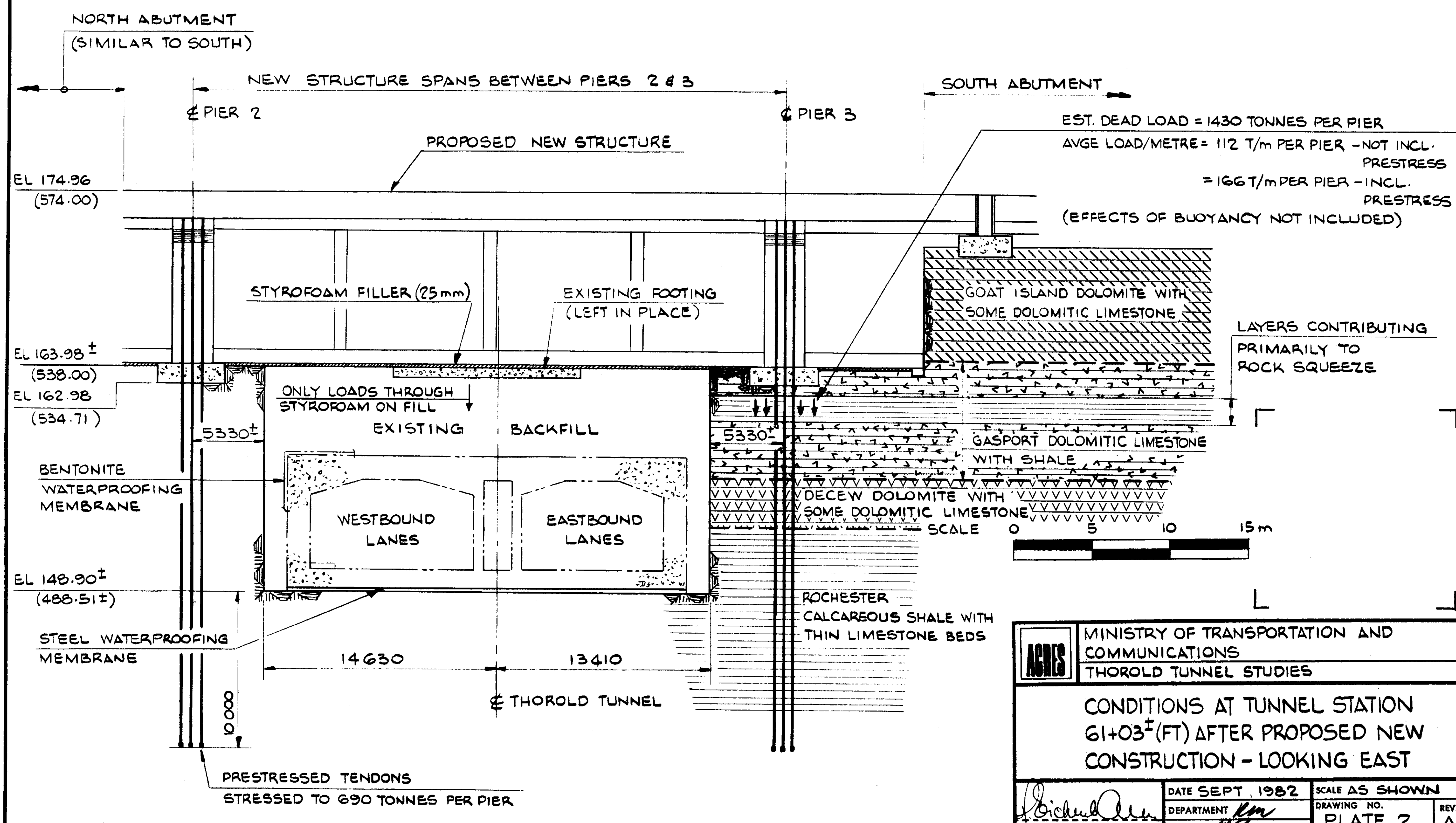


ACRES	MINISTRY OF TRANSPORTATION AND COMMUNICATIONS
	THOROLD TUNNEL STUDIES
	EXISTING CONDITIONS AT TUNNEL STATION 61+03 ± (FT) LOOKING EAST
ACRES	DATE SEPT, 1982
	DEPARTMENT
	PROJECT
SCALE AS SHOWN	
DRAWING NO. PLATE 1 SHEET OF	REV.

DRAWING No. PLATE 1 SHEET OF REV.

NOTES

1. INFORMATION ON PROPOSED CONSTRUCTION TAKEN FROM SLSA 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

ACRES	DATE SEPT. 1982	SCALE AS SHOWN	
	DEPARTMENT	DRAWING NO. PLATE 2	REV.
	PROJECT	SHEET OF	

DRAWING No. PLATE 2 SHEET OF REV.

September 14, 1979
P5464.00

Ministry of Transportation
and Communications
1182 North Shore Blvd. East
P.O. Box 5020
Burlington, Ontario
L7R 3Z9

Attention: Mr. J. F. Lougheed
Supervisor Traffic Services

Dear Mr. Lougheed:

Thorold Tunnel
Report on Remedial Works
Pavement Slab - West Portal
Eastbound Lanes

We are pleased to submit herewith three copies of our Report on Remedial Works - Pavement Slab - West Portal Eastbound Lanes. A separate copy is being sent directly to Mr. Murray Sinclair in Toronto in accordance with your instructions on August 30, 1979.

The report includes a description of the various investigation and construction activities which were undertaken in connection with the seepage problem, together with our conclusions and recommendations.

We would be pleased to meet with you at your convenience to discuss the report and its recommendations.

Yours very truly,

Original Signed by
R. G. TANNER

R. G. Tanner
Project Manager

RGT:ja
encl

cc - Mr. M. Sinclair
Regional Maintenance Engineer
3501 Dufferin Street
Toronto, Ontario
M3K 1N6
(incl 1 copy of report)

NOTE:
Meeting Burlington District
Office September 24th, 10:00 a.m.

RECEIVED
SEP 1 . 1979
Central Region Maint.
Office

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MINISTRY OF TRANSPORTATION
AND COMMUNICATIONS

REMEDIAL WORKS - PAVEMENT SLAB
WEST PORTAL - EASTBOUND LANES

September 1979

Acres Consulting Services Limited
Niagara Falls, Ontario

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1 - INTRODUCTION

Following a meeting and site inspection at the Thorold Tunnel on June 19, 1979, Acres Consulting Services Limited (Acres) was requested by the Ministry of Transportation and Communications (MTC) to provide engineering advice and technical assistance in the investigation of the water problem under the curb lane tunnel approach slab at the west portal, south tube. The work included the devising of remedial measures to lower the water levels to permit the placing of seepage control works under the pavement slab and the supervision of the placing of such works. By agreement with MTC personnel on site, Acres was not involved in the replacement of the pavement slab.

A program of field investigations was started on June 21, 1979 and from then until the completion of the seepage control work on July 26, Acres maintained a full-time representative on site. The investigation work consisted of inspection of flows into manholes and the tunnel west sump, well drilling, pumping, piezometer installations and test pitting. Remedial works comprised underdrain systems leading into the existing storm water system and the reinstatement of the subgrade. The work was performed by the following contractors

- Dicon Contracting Limited, Niagara Falls
- Ray Field, Well Driller, Vineland
- G. Hart & Sons, Well Driller, Fenelon Falls.

2 - INITIAL OBSERVATIONS AND INVESTIGATIONS

During the site inspection on June 19, 1979, it was observed that water was flowing from the joint between the eastbound concrete approach slabs and the west portal structure. When heavy trucks went over the slabs, the water actually spurted from the joint and the slabs appeared to deflect.

Initial investigation on June 21 and 22 included hand excavation behind the south curb and a detailed inspection of manhole/catch basin No. 119 by a diver in a wet suit to determine water inflow from the various drainage pipes and openings. A detailed survey of manhole No. 118 was conducted on June 26. The results of the surveys in manholes No. 118 and 119 are presented along with a site plan on drawing 5464-B-2 (Plate 1). In electrical manhole No. 6, 3.5 ft of stagnant water was observed with no perceptible flow. Manhole No. 123, located approximately 200 ft west of the portal, showed no flow in any of the pipes.

On June 26, three holes were drilled by an MTC bridge crew through the curb lane concrete in preparation for the installation of well points which were to serve as water level observation wells. The locations of these holes are shown on the plan. In the hole closest to the portal, the water level was 6 in. below the top of the 10-in. thick slab. A 1/2-in. to 5/8-in. deep void was found below the slab which extended from 10 in. to 4 ft away from the hole when checked by a probe. In the next hole further west, the water level was 1 in. below the bottom of the concrete or 10-1/2 in. below the top of the slab. No water was encountered in the most westerly hole. In the latter two holes, no voids were apparent beneath the slab.

During discussions with MTC staff, it was learned that seepage into the west sump had been greatly reduced during the winter of 1978 - 1979 while the water level in the Welland Canal had been lowered. It was also reported that a check with Regional Niagara regarding the water mains crossing the west approach had failed to indicate any leakage from these lines.

On the basis of the above information, it was considered that most of the water at the west portal probably originated from seepage of canal water around the south end of the portal. If this were so, it was likely that the water was seeping along or near the portal face. This water should be intercepted by the 6-in. perforated C.I.P. subdrain flowing into the west wall of manhole No. 119 (this pipe was observed to be flowing almost full) and possibly in the 6-in. subdrain pipe laid on the bedrock surface and exiting into manhole No. 123 approximately 200 ft west of the portal (this pipe was dry).

It appeared that the undermining of the pavement slab had been accomplished, in part, by the erosion of base course material through the three 1-1/2-in. diameter surface drain pipes, immediately below the pavement, which had been installed to facilitate catch basin repair in 1978.

3 - PROPOSED WORKS

On the basis of the previous information, a tentative outline of work was proposed by Acres in a letter to MTC on June 28, 1979. It should be noted that only limited investigations were undertaken to assess the origin of the seepage water to the extent necessary to eliminate seepage onto the pavement. MTC personnel advised that any remedial works should be carried out, if possible, while the south lane was closed for lighting modifications in the tunnel.

The outline proposed was

(a) installation of a pump well behind the south curb, intended to effect a drawdown of the water level

(b) installation of three piezometers (in the location of the previously drilled holes through the concrete) to monitor the depressed water levels upon pumping

(c) pumping of the well and recording of the water levels in the piezometers

(d) removal of the south lane eastbound slab after lowering of the water table, inspection of the north lane slab base, and some exploratory test pitting as directed

(e) installation of an underdrain system to be designed when subsurface conditions were known

(f) reinstatement of the subgrade and pavement.

4 - WELL DRILLING AND SUMP INSTALLATION

On June 28, a horizontal bench at curb level was cut back into the south slope fill adjacent to the portal to provide a platform for a well drilling machine. During this work a flow of water was intercepted within the embankment rock fill at about curb level. Shortly after, the water level at the roadway slab dropped approximately 5 in.

A well drilling contractor from Vineland, Ray Field, attempted to drill a hole through the rock fill on June 28 using a Bucyrus Erie 20W drill with a 9-in. chopping bit, however, he was unable to penetrate below a depth of 4 ft. On July 4, G. Hart & Sons from Fenelon Falls started to drill a pilot hole using a large Gardner-Danver rotary drill. By July 6, a 12-1/2-in. diameter hole had been advanced to a depth of 20 ft. The hole was backfilled with a pea gravel pack to 15.5 ft and a 12-ft section of 9-3/4-in. diameter louvered well screen and a 3.5-ft long standpipe section was installed in the hole. The gravel pack was extended to the ground surface.

A 1-1/4-in. drive type well point was placed to a depth of 16 ft between the well and the portal on July 9. The well was flushed with phosphate and air after drawdown tests showed low water yield. After flushing, there was an increase in flow but this had no effect on the water level in the adjacent well point. On July 10, a pit was excavated behind the curb to expose the south side of the well. Free water flow was encountered 2 ft below the drilling pad elevation to within 2 ft of the well, but no hydraulic connection with the well was apparent due to the relative impermeability of the overburden and rock fill. Pump tests showed the flow into the excavation to be of the order of

60 gal/min. Photo No. 1 shows the exposed well standpipe and screen. The seepage into the excavation, which was mainly at the bedrock surface, can be seen in photo No. 2.

During excavation behind the curb, two 13,800-V power cables were damaged as shown in photos No. 3a and 3d. Three cable ducts were exposed during the repair work. They extend from electrical manhole No. 6 to the curb near the portal. One of the ducts carried three power cables and the other two were empty as can be seen in photo No. 3e. The two empty conduits acted as drains for the manhole. Electrical repairs were conducted on July 11 and 12 by G.A.M.S. Ltd. who spliced the two cables (photo No. 3e). Photo No. 4 shows the complete excavation and the relative positions of the portal (to the left), well standpipe and the repaired electrical cables.

Test pit TP1 was excavated through the curb lane concrete and to a shallow depth into the granular base on July 12. The water level stabilized 4 in. below the base of the slab, or 1.4 ft above the water level at the well location. This indicated that the majority of inflow was probably further west of the portal than originally thought. Excavation along the portal wall (photos No. 2 and 4) had intercepted a small flow of water, but did not affect the water level beneath the slab. Since the well was relatively ineffective in lowering the groundwater, it was removed and a 48-in. diameter C.I.P. was placed in the excavation near the portal wall as shown in photo No. 5a to create a permanent sump. Three 6-in. perforated steel pipes were placed along the length of the excavation as shown on Plate 1 to collect the 60 gal/min flow and direct it into the 48-in. sump. The sump was connected into manhole No. 119. Photo No. 5b shows the pipe arrangement inside the sump. The three 6-in. C.I.P.'s are all flowing while an 8-in. asbestos pipe leads the water into manhole No. 119 (the 4-in. plastic pipe shown extends back to TP3). It should be noted that the original flow in the 6-in. subdrain connected to the west side of manhole No. 119 was not significantly affected by the installation of the new sump.

5 - PIEZOMETER INSTALLATION AND TEST PITTING

Four piezometers (PZ-1 to PZ-4) were placed on July 13 at locations shown on Plate 1. Piezometer 4 was later removed as it interfered with the excavation operations. Drilling of this piezometer is shown on photo No. 6 (manhole No. 119 is in the lower left corner). Piezometer installation details and water levels are presented in Table 1.

TABLE 1

PIEZOMETER DETAILS

Piezometer No.	Elev of Pavement Surface WRT C.B.M. (ft)	Depth Below Pavement to Bottom of Hole (ft)	Depth Below Pavement to Tip (ft)	Water Depth July 16 (ft)	Water Depth July 19 (ft)	Water Depth July 24* (ft)
4	95.8	13.0	12.5	7.5	6.8	9.0
1	96.3	13.0	11.0	4.9	4.3	4.8
2	96.9	16.4	16.4	3.7	3.4	3.4
3	97.5	13.4	13.0	1.3	1.8	2.7

*after completion of underdrain system

It can be seen that a significant gradient in the water levels was established. Drawdown under the pavement slab at the portal was attributed to two factors as follows

(a) interception of part of the flow by the 48-in. C.I.P. sump and its associated drain lines

(b) hydraulic connection to a lower, more permeable layer beneath the slab when the piezometers were installed.

The results also indicated that a significant portion, if not the majority of the flow, was originating from the area to the west of manhole No. 119.

Test pit 2 was excavated into the side of the south slope to a depth of about 2 ft to 3 ft below curb level while the piezometers were being placed. The water level in it was measured at 0.2 ft above that of TP1 or 1.8 ft above the water level in PZ-3, indicating the water level gradient was essentially flat west of TP1.

A significant amount of water was encountered in the hole for PZ-3. Pumping at a rate of 50 gal/min out of PZ-3 established a stable pumping level at a depth of 4.1 ft in PZ-3 and effected a drawdown of 3 in. in PZ-2, and 1 in. in PZ-1. Water was also drawn down below the bottom of test pit 1 as evidenced by a dry pit bottom.

Test pit 3 was excavated to a depth of about 3 ft below curb level on July 16 and intercepted a flow of 50 to 60 gal/min. Photo No. 7a shows the pit location with respect to the portal and electrical manhole No. 6. Upon pumping from the test pit, flow in the 6-in. pipe leading into the west side of manhole No. 119 was reduced to about half its original volume. A trench was dug south of the curb leading from the end of the pipes connected to the sump to the test pit. A 4-in. perforated plastic pipe was laid through one of the 6-in. perforated steel pipes (photo No. 5b) along the trench and into TP3 to collect the flow (photo No. 7b).

A slight reduction of flow in the 6-in. pipe leading into manhole No. 119 was noted with this arrangement, however, it was felt drainage was incomplete as the pipe was set higher than desirable due to a bedrock rise and concrete conduits encountered along the trench.

A piezometer was drilled and installed off Ormond Street on July 17 to measure water levels behind the portal structure. Photo No. 8 shows the drilling rig set up over the hole location. At a depth of 24.3 ft, the drill bit contacted steel. As the depth corresponded approximately with the elevation of the tunnel roof, and the hole location was very near the wall of the tunnel, it was considered prudent to drill no deeper. A piezometer tip was placed at the 24.3-ft depth. Water level in this piezometer was found at a depth of 22.9 ft (monitored to July 23) which corresponds to an elevation approximately 3.4 ft below the Welland Canal water level.

6 - UNDERDRAIN SYSTEM

The south lane concrete slab adjacent to the portal was broken out on July 17. Photo No. 9a is a view looking west across the slab from the tunnel portal. A string line from the portal to the pavement joint 35 ft west of the portal indicated that the passing lane slab had deflected from a straight line by as much as 1-1/16 in. measured 6 ft west of the portal. In this area of maximum deflection it was also noted that a void existed under the passing lane slab as shown in photo No. 9b. The slab flexed about 1/8 in. during the passing of transport trucks. Hairline cracks across the pavement were noted in this area.

During the exploratory excavation work, it was observed that the Granular Base Course Class "A" (GBC "A") was not sufficiently pervious to permit the free drainage of the seepage waters in the area. It was therefore proposed that pea gravel be used in any drainage zone.

Before excavation for the underdrains began, a filter material was designed to protect the GBC "A" existing beneath the slab. This was necessary to prevent the migration of fines from GBC "A" into the proposed pea gravel drainage zone when subjected to the flow of water. Any movement of fines would further undermine the passing lane slab and curb. To attain the proper gradation, the following materials were mixed at the given ratios

- 8: pea gravel, Steed and Evans pit, Fonthill
- 4: 1/4 in. washed stone, Aberfoyle pit
- 1: concrete sand, Walker Bros. Quarry, Thorold.

Approximately 25 tons of the filter material was prepared on July 20. Excavation of the subgrade began at the portal on July 23 utilizing a backhoe, with digging adjacent to the passing lane slab and the curb being done by hand. Extreme caution was required to ensure the stability of the excavation slopes and prevent any possibility of undermining the travelled road slab or the curb which contained the power cables.

Clean crushed stone was found at the 38-in. depth adjacent to manhole No. 119. Good hydraulic connection was found between this layer and the bottom knockout of the catch basin (100 percent take at 50 gal/min), so that further excavation of underlying material was deemed unnecessary. It is not known to what depth the clean crushed stone extends. Large broken rock pieces were noted at the knockout elevation from observations inside the manhole.

Elsewhere in the excavation, GBC "A" material was found to extend to bedrock. Slopes in the GBC "A" along the north and west walls of the excavation were cut flatter than 1:1 to prevent undermining of the roadway. It was possible to attain a near vertical cut along the south wall as shown in photos No. 10a and 10b. The portal step formed the eastern wall of the excavation.

Solid bedrock was encountered at a depth of approximately 30 in. over most of the excavated area (8 ft to 35 ft west of the portal). Broken rock pieces were removed along the south side of the excavation to extend the maximum depth to 45 in. This rock had been previously shattered, probably during trench construction for the adjacent 21-in. storm drain.

A flow of 25 gal/min (estimated) was encountered at the western end of the excavation flowing through channels in the broken bedrock (photo No. 10a). The water, under head, boiled into the excavation as shown in photo No. 10b.

Filter material was placed in the bottom of the excavation to a thickness of 3 in. above the bedrock. Six-inch perforated steel pipes were laid in pea gravel as shown in Section BB on Plate 1. Two pipes were laid along the south side to intercept the major inflow of water. Perforated steel caps, rather than solid caps, were placed over the ends of these pipes. Both pipes were connected to manhole No. 119 by means of a single 6-in. diameter header. An existing 6-in. pipe leading across the roadway to manhole No. 118 was connected to manhole No. 119.

Once the underdrain system had been installed, a lowering of the water table was noted, especially in PZ-3 (see Table 1). In addition, the flow in the original 6-in. subdrain leading into manhole No. 119 was significantly reduced (1/3 to 1/2 flow).

Two raw water mains west of the site were shut off for 3 hours on July 24 to ascertain whether the inflow noted at the west end of the excavation could be due to a broken line. After no effect was seen on water levels or flow rates in the 3 hours, backfilling procedures were begun. Filter material was placed for a minimum depth of 6 in. along the edges of the excavation with the center area being filled with pea gravel. A vibrating plate compactor was used for compaction during backfilling. Photo No. 11 shows the excavation with backfilling procedures underway. Filter material is being placed along the north (left) side of the excavation. Plywood sheets were used as formwork to build the filter layer along the vertical south (right) side. Six inches of filter material was also placed over the pea gravel to bring the grade to a level 6 in. below the bottom of the slab. Thus, the pea gravel was completely enveloped by the filter material, which blanketed all sides of the excavation as shown in Section BB on Plate 1.

Three-quarter inch crushed stone was placed over the filter material to bring the grade to the required bottom of pavement elevation. A minimum depth of 6 in. of this material was placed over the entire area, wetted and compacted in 2-in. layers by the vibrating plate. A Bomag vibrating roller was used for compaction once most of the material had been placed. Photo No. 12 shows manhole No. 119 during placement of the crushed stone. One of the three 1-1/2 in. surface drains leading into the catch basin can been seen. Two of these drains were removed, and the third one plugged as it could not be pulled out because of interference with the portal concrete.

Final backfilling to proper grade and compaction was completed on July 25. Photo No. 13a shows the entire area just before the final crushed stone was placed and compacted. Note the piezometer pipes extending above the grade. These were left in place to permit an ongoing monitoring of the water levels below the slab. Compaction tests using a nuclear densometer were performed by the Ministry of Transportation and Communications. Photo No. 13b shows the western edge of the backfilled area with load transfer bars extending from the adjacent slab.

7 - OTHER WATER LEVEL AND FLOW OBSERVATIONS

During the initial phases of the work, various observations were made in addition to those mentioned previously in an effort to ascertain the source and quantity of the seepage water. One area investigated was the pressure relief slot in the bedrock located on the south side of the west service building. This slot had been backfilled with a clay/bentonite mixture to the bedrock surface. Two manholes were constructed over the slot from the bedrock surface up to grade, one on the upstream (east) side and the other on the downstream (west) side of the seepage control dike.

On July 4, inspection of the manholes showed the following.

West Manhole
The water level in the manhole was at the top of the slot (bedrock surface level) and the clay/bentonite surface was 24 in. below the bedrock surface. There was no apparent water flow.

East Manhole
The water level was 3 ft above the bedrock surface (top of slot) and the top of the clay/bentonite was 4 ft below the top of slot. There was no apparent water flow.

The effectiveness of the pressure relief holes in the west portal pump sump, about 60 ft east of the west portal, was investigated by measuring the rate of flow into the sump. This was done by pumping the water level down to the lowest float level then measuring the time for the water to rise to the upper float level. The distance between the floats is 3.75 ft. The weather was dry with no inflow of storm water. By operating gates on the pumping well, three flow conditions were observed

(a) total flow into sump for north and south tubes combined

(b) flow from south tube of tunnel only

(c) flow from north tube of tunnel only.

The volumes of water in the sump for each of the three conditions are as follows

(a) 21,447 gal

(b) 11,103 gal

(c) 12,320 gal.

For flow condition (a), the time required for the water to rise 3.75 ft in the complete sump, north and south tubes combined, ranged from approximately 9.6 to 10.1 min indicating a range of inflow rates from 2,235 to 2,125 gal/min.

For flow condition (b), the south tube only, the water inflow time was 8.75 min indicating an inflow rate of approximately 1,270 gal/min.

For flow condition (c), the north tube only, the inflow time was 13.35 min indicating a flow of approximately 925 gal/min.

A review of Acres' records shows that on October 19, 1971, the flow into the south sump was approximately 1,300 to 1,400 gal/min which is slightly higher than the rates measured in this program.

In April 1974, the technique for measuring the rate of flow into the west sump was modified. It is believed that this modified method is the one that has been used to the present, that is, the time is measured for the water level to rise 3.75 ft in the sump. Mr. F. I. Hewison provided a plot of the time data for the period from April 1974 to March 1977. These data indicate that the times vary significantly from approximately 9.5 to 11.7 min, however, the longer times (lower seepage rates) are consistently obtained during the winter months. The shorter times are generally obtained during the summer and fall seasons. There is an indication of increasing flow rates (shorter sump filling times) with time between 1974 and 1975, however, there is insufficient data to be conclusive. The flow rates which were measured during June and July 1979 are generally consistent with those indicated for the same period in 1976.

8 - CONCLUSIONS AND RECOMMENDATIONS

(a) Flow Under West Approach Pavement

(i) MTC personnel advised that seepage from under the west approach slab became apparent early in June 1979. The limited investigative work carried out during this program failed to determine what might have happened to cause this seepage water to appear at this time. However, it was apparent that even though the 6-in. diameter subdrain leading from the west into manhole No. 119 was flowing to capacity, it was insufficient to cope with the volume of seepage. The similar subdrain leading into manhole No. 118 appears to have adequate capacity.

(ii) The investigations indicated that the quantity of seepage flowing along or near the face of the portal was only a minor portion of the total flow entering manhole No. 119. The major portion of seepage appeared to be flowing under the pavement towards the portal from the west, and the permeability of the base course layers and subdrains was too low to accommodate the quantity of water.

(iii) The underdrain system installed during this program has lowered the water levels beneath the pavement immediately adjacent to the portal. It is concluded that provided no major increase in flows occurs, then the new subdrain system is working effectively to intercept the seepage. If major increases of seepage occur, then it is

FILL UP TIME IN FLOW TIME	VOLUME GALLONS	IN FLOW RATE GALLONS/m	PUMP OUT TIME	TOTAL PUMP OUT VOLUME GALLONS	PUMP OUT RATE GALLONS/m
13'-57" 13.95	21488	1540	11'-31" 11.52	39233	3 Pumps 3406 1 Pump 1135
9'-50" 9.83	21488	2186	13'-03" 13.05	50015	4 Pumps 3833 1 Pump 958
11'-50" 11.83	21488	1816	14'-47" 14.78	48334	3 Pumps 3270 1 Pump 1090
10'-20" 10.33	21488	2080	15'-50" 15.83	54417	3 Pumps 3438 1 Pump 1146
11'-02" 11.03	21488	1948	16'-07" 16.12	52892	3 Pumps 3281 1 Pump 1094
9'-35" 9.58	21488	2243	11'-46" 11.77	47888	4 Pumps 4069 1 Pump 1017
9'-15" 9.25	21488	2323	12'-42" 12.70	50990	4 Pumps 4015 1 Pump 1004
10'-48" 10.80	21488	1990	11'-38" 11.63	44627	4 Pumps 3837 1 Pump 959
9'-52" 9.87	21488	2177	11'-32" 11.53	46590	4 Pumps 4041 1 Pump 1010
11'-36" 11.60	21488	1852	11'-06" 11.10	42050	4 Pumps 3788 1 Pump 947

likely water may rise to the slab surface level when both north and south subdrain systems become overloaded. The system of piezometers (PZ-1 to PZ-3) was left in place to permit the monitoring of water levels in the future.

(b) Pressure Relief Slot
(South of West Service Building)

As indicated in a previous section, it was observed that the level of the clay/bentonite had settled below the bedrock surface level by as much as 4 ft. Although no flow of water was observed, this settlement could have been caused by erosion of slot filling material and if allowed to continue it could create a flow path to carry substantial seepage to the west portal area. It is recommended that this situation be carefully checked by pumping out the manholes and slot down to the clay/bentonite surface. Probes should be made along the slot to assess whether the bitumen cutoff wall is still intact. The slot should then be filled up to the bedrock surface with additional clay/bentonite mixture.

(c) Flow Into West Sump

While it cannot be definitely stated that the rate of seepage inflow is increasing during recent years, the records do indicate that the flow has significantly increased since 1967 when measurements indicated the flows to be 740 gal/min into the south part of the sump and 126 gal/min into the north.

The quantity of flow into the south part of the sump does not appear to have increased since 1971. It could be however, that the two 6-in. diameter pressure relief pipes in the south wall of the sump are flowing at capacity and any increase in seepage has caused the water level to rise until the water is flowing over the top of the tunnel and into the north tube sump. This could lead to increased seepage at the north side of the west portal.

(d) Overall Seepage Conditions

Indications are that the groundwater level between the cutoff dike holding back the canal and the west portal is probably up to the original bedrock surface and this is a prime cause for the seepage conditions observed at the west portal. It means that the pressure relief holes in the north and south sides of the west portal pump sump are operating at capacity. Any increase in seepage flow will be immediately transferred outside the west portal.

The seepage is probably derived from the head of water in the canal, but it may be flowing by a number of possible routes. These include fissures in the original bedrock, through or around the concrete plug at the west service building, erosion passages through the clay cutoff dike or adjacent overburden, or the pressure relief slot south of the west service building. In the first two cases it may be possible to increase the pressure relief (drainage) capacity and so intercept more groundwater directly at the pump sump and thereby keep it away from the west portal. In the last two cases it would not be as simple as the increased pressure relief would steepen the hydraulic gradient and could accelerate erosion of fine material leading possibly to rapidly increasing volumes of seepage and eventually failure of the dike.

Due to the subsurface complexity at the west portal, it is not possible to assess the prime source of seepage without a substantial investigation of potential water paths by means of piezometers and flow observations. Nevertheless, it is recommended that such a program be planned and carried out as without it, it is not possible to predict future changes in seepage conditions and their effects on the tunnel operation or to plan and install any remedial works to ensure long-term control of seepage.

PHOTOGRAPHS

Well standpipe

Louvered well screen

PHOTO NO. 1

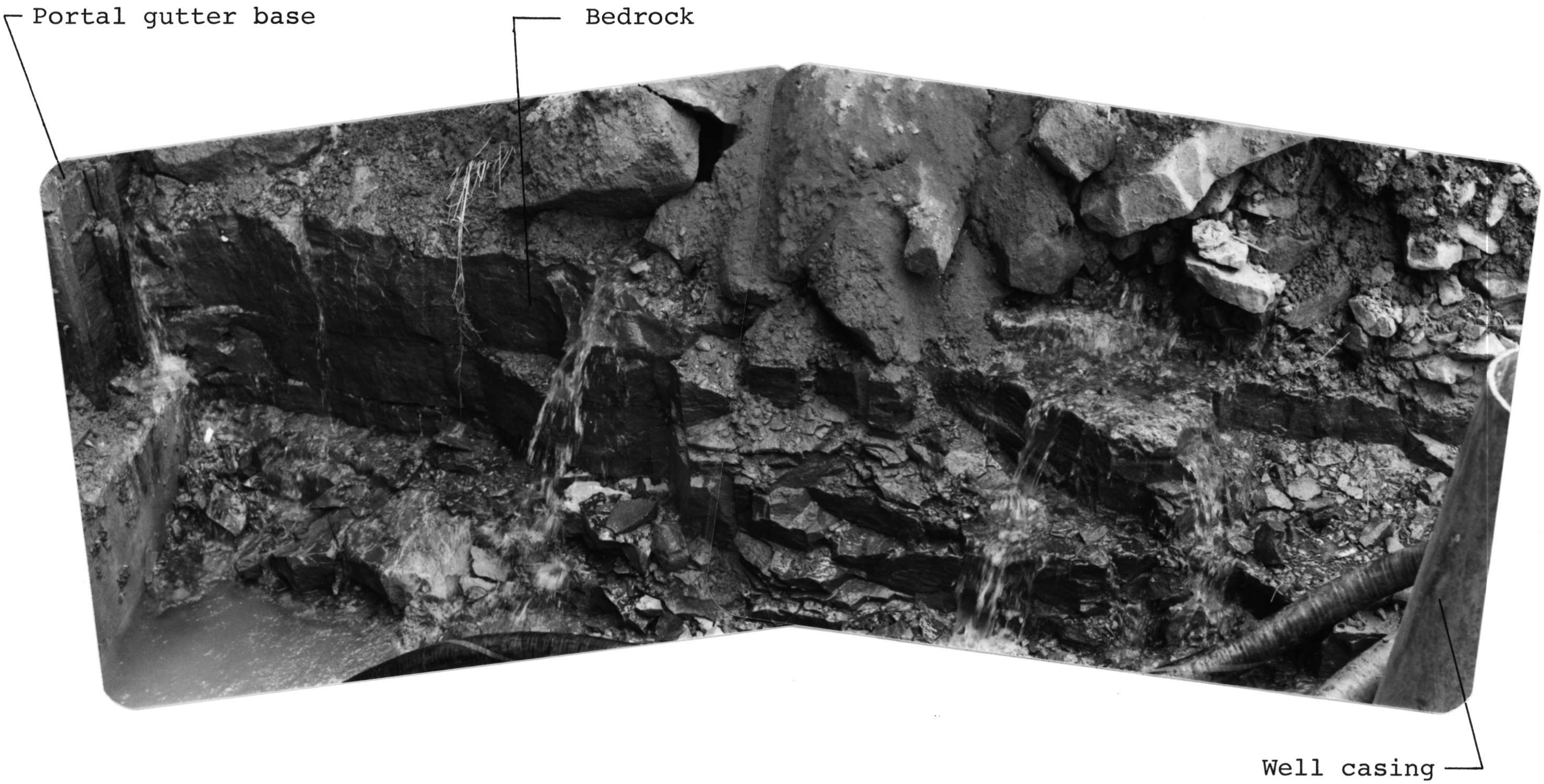


PHOTO NO. 2

Back face of curb

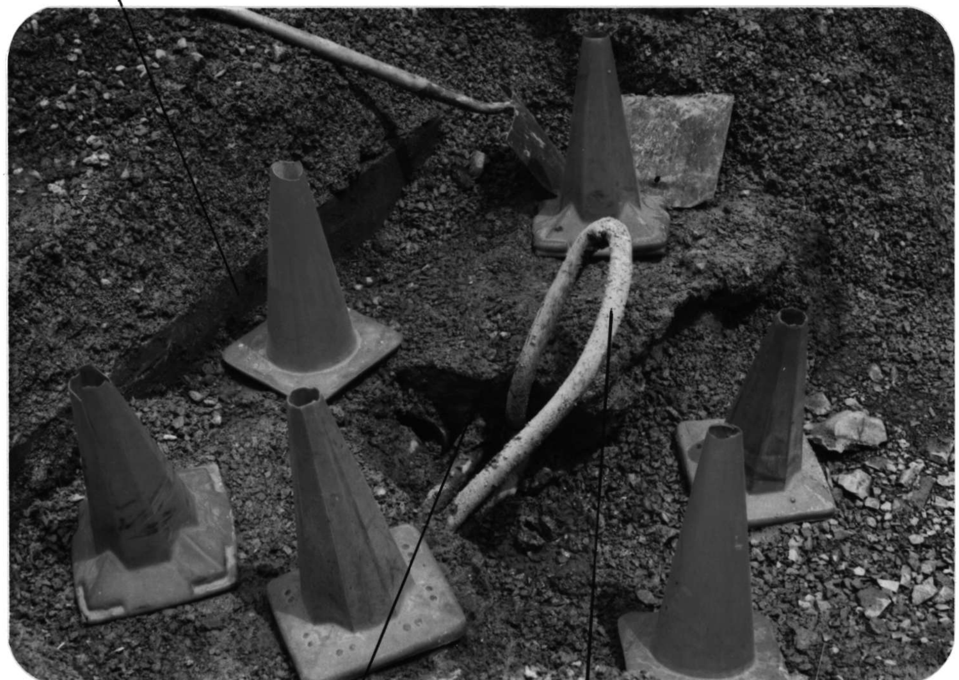


PHOTO NO. 3a

Damaged power cable

Break in concrete cover over ducts

PHOTO NO. 3b

Damaged power cable

Damaged insulation and grounding

PHOTO NO. 3c

Damaged power cable

PHOTO NO. 3d

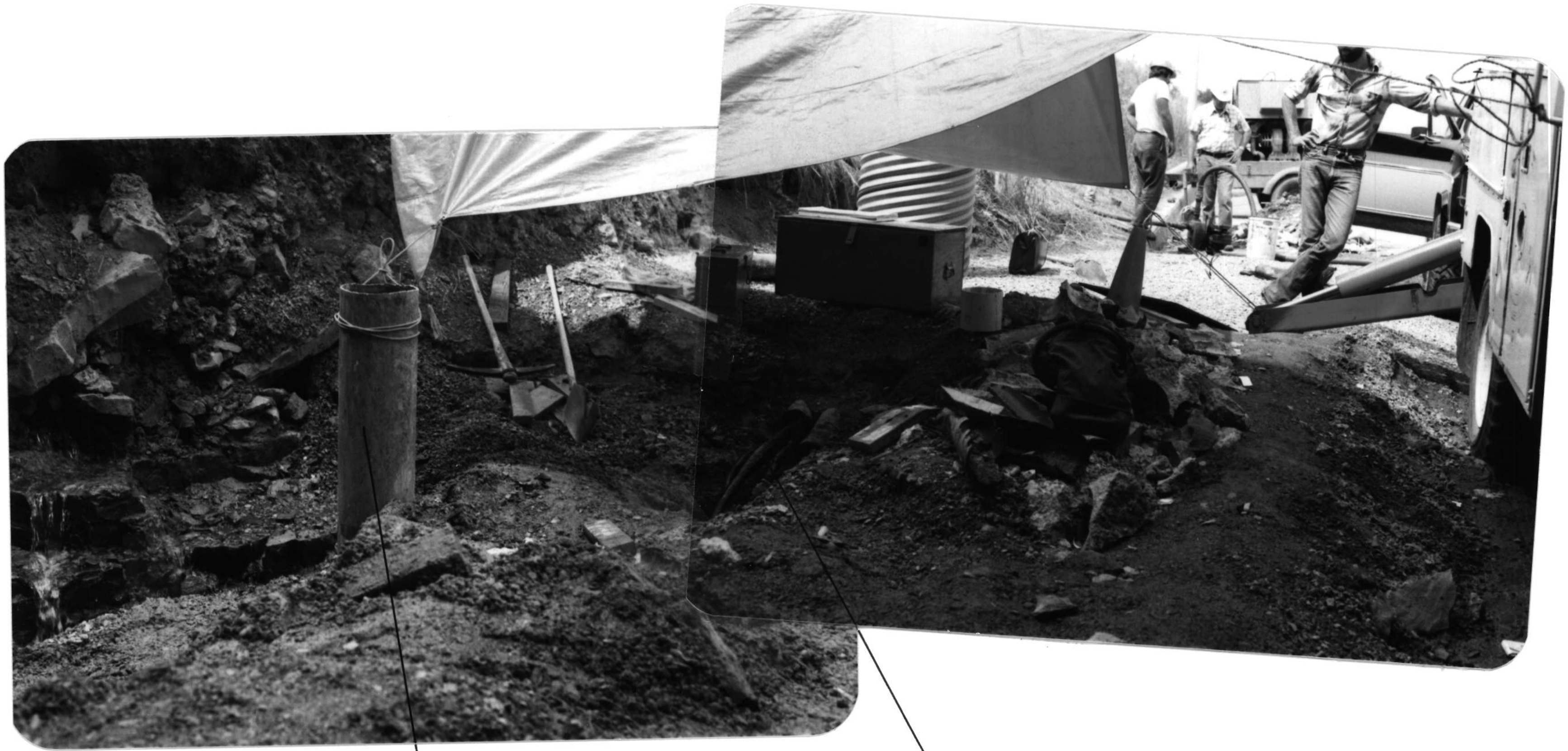
PHOTO NO. 3e

Ducts broken out

Preparing to repair damaged cables

Repaired cables

PHOTO NO. 3f



Repaired power cables

Well casing

PHOTO NO. 4

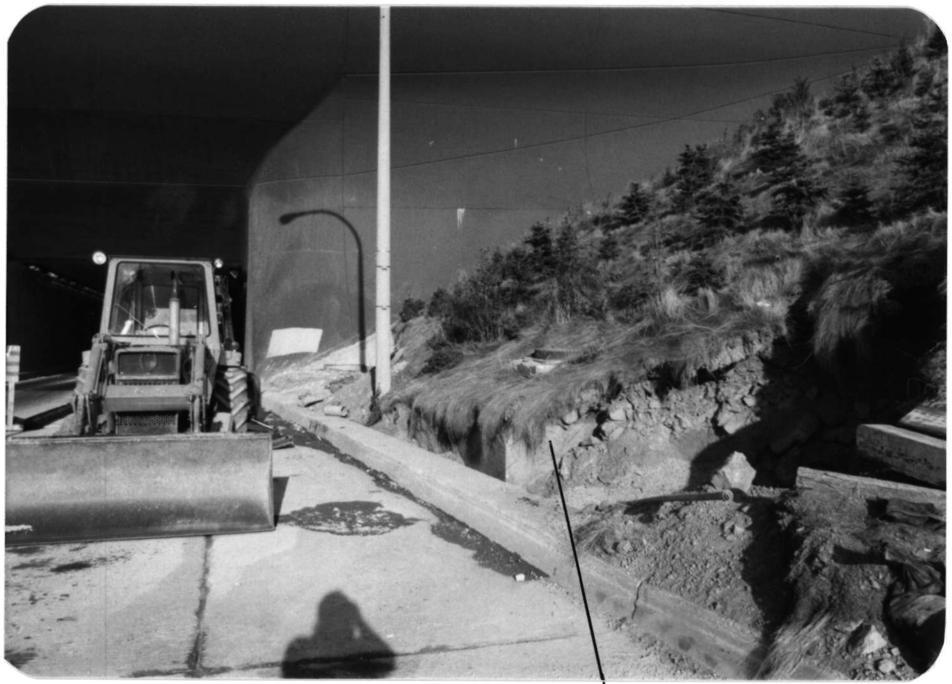
PHOTO NO. 5a

PHOTO NO. 5b

Drilling hole for PZ-4

Manhole No. 119

PHOTO NO. 6



TP-3

PHOTO NO. 7a

Electrical manhole No. 6

PHOTO NO. 7b

Perforated plastic pipe in TP-3

G. Hart & Sons well drill

PHOTO NO. 8

PHOTO NO. 9a

PHOTO NO. 9b

Void under slab

PHOTO NO. 10a

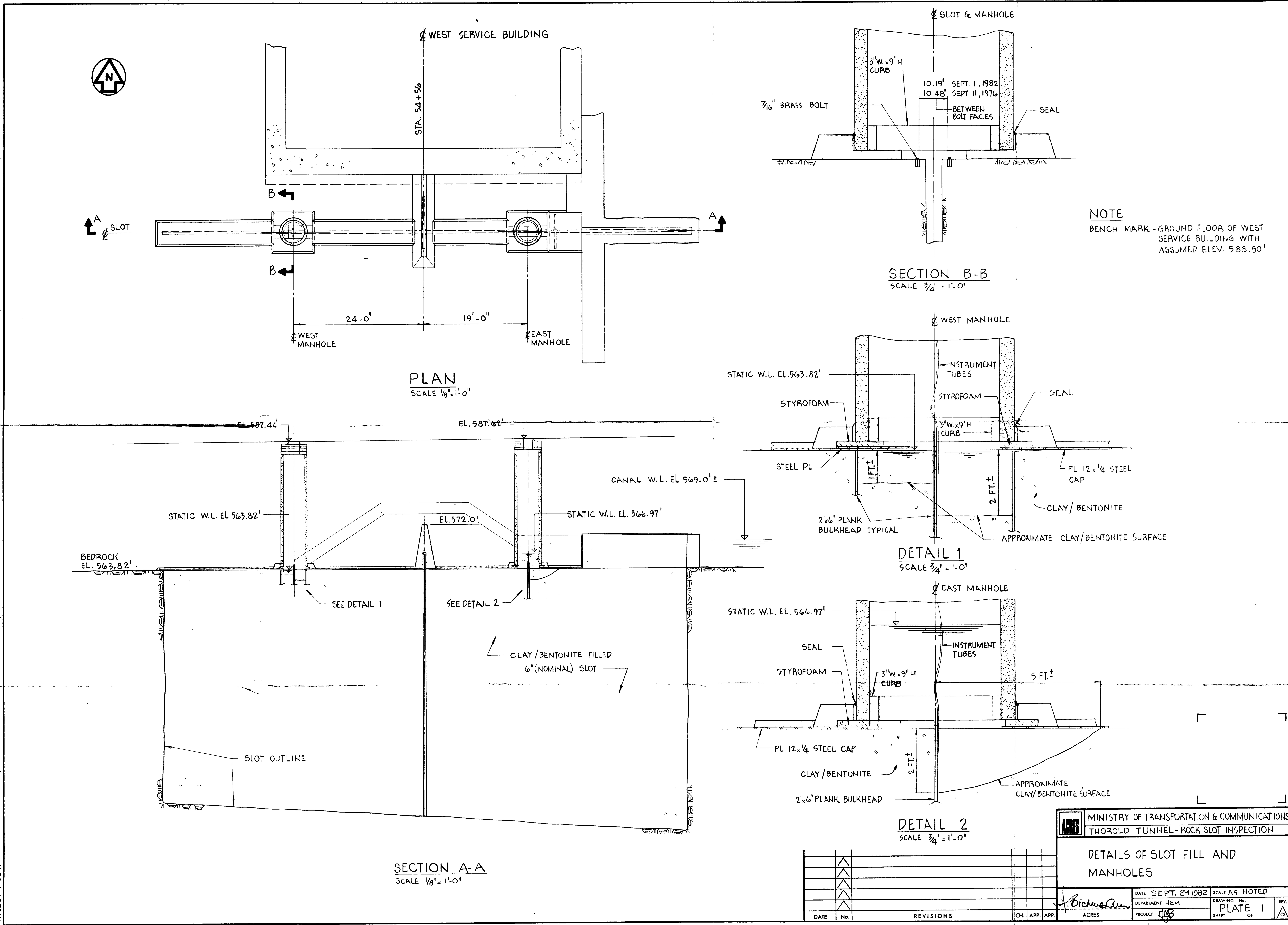
PHOTO NO. 10b

PHOTO NO. 11 — Piezometer PZ-2

PHOTO NO. 12

PHOTO NO. 13a

PHOTO NO. 13b



℄ WEST SERVICE BUILDING
STA. 54+56
B
A
℄ SLOT
A
B
24'-0"
19'-0"
℄ WEST MANHOLE
℄ EAST MANHOLE
PLAN
SCALE 1/8"=1'-0"
EL. 587.44'
EL. 587.62'
CANAL W.L. EL 569.0'±
STATIC W.L. EL 563.82'
EL. 572.0'
STATIC W.L. EL. 566.97'
BEDROCK
EL. 563.82'
SEE DETAIL 1
SEE DETAIL 2
CLAY/BENTONITE FILLED
6"(NOMINAL) SLOT
SLOT OUTLINE
SECTION A-A
SCALE 1/8"=1'-0"
℄ SLOT & MANHOLE
3"W.x9"H CURB
10.19' SEPT. 1, 1982
10.48' SEPT 11, 1976
7/16" BRASS BOLT
BETWEEN BOLT FACES
SEAL
SECTION B-B
SCALE 3/4"=1'-0"
NOTE
BENCH MARK - GROUND FLOOR OF WEST SERVICE BUILDING WITH ASSUMED ELEV. 588.50'
℄ WEST MANHOLE
STATIC W.L. EL.563.82'
INSTRUMENT TUBES
STYROFOAM
STYROFOAM
SEAL
3"W.x9"H CURB
STEEL PL
1 FT.±
2 FT.±
PL 12x1/4 STEEL CAP
CLAY/BENTONITE
2"x6" PLANK BULKHEAD TYPICAL
APPROXIMATE CLAY/BENTONITE SURFACE
DETAIL 1
SCALE 3/4"=1'-0"
℄ EAST MANHOLE
STATIC W.L. EL. 566.97'
SEAL
INSTRUMENT TUBES
STYROFOAM
3"W.x9"H CURB
5 FT.±
PL 12x1/4 STEEL CAP
2 FT.±
CLAY/BENTONITE
2"x6" PLANK BULKHEAD
APPROXIMATE CLAY/BENTONITE SURFACE
DETAIL 2
SCALE 3/4"=1'-0"
DATE
No.
REVISIONS
CH.
APP.
APP.
ACRES
MINISTRY OF TRANSPORTATION & COMMUNICATIONS
THOROLD TUNNEL - ROCK SLOT INSPECTION
DETAILS OF SLOT FILL AND MANHOLES
DATE SEPT. 24, 1982
SCALE AS NOTED
DEPARTMENT HEM
DRAWING No. PLATE 1
REV. 0
ACRES
DRAWING No. PLATE 1 REV. 0
PROJECT-P6641

COMPARE:

Both tubes 2,235 —— 2,125 galls/min.
South tube only 1270 galls/min.
North tube only 925 galls/min.

Acres records for October 19th 1971 show:
South tube only 1300 – 1400 galls/min.

(6) According to J. Loughead the pumping time for the West Sump is on the average 36 hours/day a figure which has not changed for years.

	WEST BUILDING	READINGS	DIFFERENCE
11818.8	SUPPLY FAN #1	118190	0.2
10648.0	SUPPLY FAN #2	106482	0.1
10330.6	SUPPLY FAN #3	103309	0.3
10233.7	SUPPLY FAN #4	102340	0.3
14910.4	EXHAUST FAN #1	149104	NIL
48049.3	EXHAUST FAN #2	486562	606.9
46001.7	EXHAUST FAN #3	466134	611.7
40019.1	EXHAUST FAN #4	400197	0.6
1150.7	WEST COMP.	01154.3	3.6
49729.5	WEST PUMP #1	501665	437.0
44699.0	WEST PUMP #2	451362	437.2
46676.3	WEST PUMP #3	471533	477.0
9588.6	WEST SUMP #9	09593.4	4.8
1543.0	MID PUMP #7	015448	1.8
1964.2	MID PUMP #8	1967.1	2.9
	EAST BUILDING	**READINGS**	**DIFFERENCE**
8260.4	SUPPLY FAN #5	08260.6	0.2
324.3.	SUPPLY FAN #6	00324.3	NIL
9512.2	SUPPLY FAN #7	09512.5	0.3
10484.3.	SUPPLY FAN #8	10489.5	5.2
594.2	EAST COMP	005981	3.9
37934.8.	EXHAUST FAN #5	037933.3	0.5
47659.9.	EXHAUST FAN #6	48187.5	527.6
25000.9	EXHAUST FAN #7	25000.9	NIL
48045.1	EXHAUST FAN #8	48045.1	NIL
1428.1.			
2318.3	EAST PUMP #4	01428.6	0.5
441.0	EAST PUMP #5	02344.8	26.5
	EAST PUMP #6	00441.0	NIL

Jan 31

WEST BUILDING	READINGS	DIFFERENCE
SUPPLY FAN #1	11819	—
SUPPLY FAN #2	10648	—
SUPPLY FAN #3		
SUPPLY FAN #4		
EXHAUST FAN #1	14910	—
EXHAUST FAN #2	48899	243
EXHAUST FAN #3	46876	163
EXHAUST FAN #4	40312	115
#9	9596	3
WEST PUMP #1	50528	362
WEST PUMP #2	45472	336
WEST PUMP #3	47480	327
W COMP	1157	3
MID PUMP #7	1545	3
MID PUMP #8	1268	1
EAST BUILDING	READINGS	DIFFERENCE
SUPPLY FAN #5	8260	—
SUPPLY FAN #6	324	—
SUPPLY FAN #7	9512	—
SUPPLY FAN #8	4997	10
EXHAUST FAN #5	38241	306
EXHAUST FAN #6	48436	348
EXHAUST FAN #7	25000	—
EXHAUST FAN #8	48175	130
E COMP	603	5
EAST PUMP #4	1429	—
EAST PUMP #5	3365	21
EAST PUMP #6		

1981 March 1 PB

WEST BUILDING	READINGS	DIFFERENCE
SUPPLY FAN #1	11819	0
SUPPLY FAN #2	10649	1
SUPPLY FAN #3	10331	
SUPPLY FAN #4	10234	
EXHAUST FAN #1	14910	0
EXHAUST FAN #2	48900	1
EXHAUST FAN #3	46949	73
EXHAUST FAN #4	40770	458
#9	9598	2
WEST PUMP #1	50866	338
WEST PUMP #2	45801	329
WEST PUMP #3	47808	328
WEST COMP	1161	4
MID PUMP #7	1548	3
MID PUMP #8	4970	2

EAST BUILDING	READINGS	DIFFERENCE
SUPPLY FAN #5	8261	1
SUPPLY FAN #6	324	0
SUPPLY FAN #7	9513	1
SUPPLY FAN #8	10499	0
EXHAUST FAN #5	28772	531
EXHAUST FAN #6	48437	1
EXHAUST FAN #7	25000	0
EXHAUST FAN #8	48621	456
EAST COMP	607	4
EAST PUMP #4	1428	0
EAST PUMP #5	2390	25
EAST PUMP #6	OUT-OF ORDER	

March 31 [illegible]

WEST BUILDING	READINGS	DIFFERENCE
SUPPLY FAN #1	11819.7	0
SUPPLY FAN #2	10649.0	0
SUPPLY FAN #3	10331.7	0
SUPPLY FAN #4	10234.4	0
EXHAUST FAN #1	14910.4	0
EXHAUST FAN #2	49378.1	478
EXHAUST FAN #3	47515.0	566
EXHAUST FAN #4	40771.0	1
West Compressor	1166.2	5
WEST PUMP #1	51222.8	356
WEST PUMP #2	46151.9	350
WEST PUMP #3	48158.6	350
West Pump #9	9601.0	3
MID PUMP #7	1550.0	2
MID PUMP #8	1974.4	4

EAST BUILDING	READINGS	DIFFERENCE
SUPPLY FAN #5	8261.2	0
SUPPLY FAN #6	324.3	0
SUPPLY FAN #7	9513.3	0
SUPPLY FAN #8	10499.9	0
East Compressor	611.3	4
EXHAUST FAN #5	39316.4	544
EXHAUST FAN #6	48437.4	0
EXHAUST FAN #7	25000.9	0
EXHAUST FAN #8	48631.8	0
EAST PUMP #4	1428.9	~~[illegible]~~ 0
EAST PUMP #5	2411.2	21
EAST PUMP #6	out of Service	— — —

81.05.01

	WEST BUILDING	READINGS	DIFFERENCE	
11819.7	SUPPLY FAN #1	11820.0	0.3	
10649.0	SUPPLY FAN #2	10652.4	3.4	
10331.7	SUPPLY FAN #3	10332.3	0.6	
10234.4	SUPPLY FAN #4	10234.5.	0.1	
14910.4	EXHAUST FAN #1	14910.4	NIL	
49378.1	EXHAUST FAN #2	49963.3	585.2	RECHECKED 8
47515.0	EXHAUST FAN #3	47920.5	405.5	
40771.0	EXHAUST FAN #4	40951.7	180.7.	
1166.2	West Compressor	1170.8	4.6	
51222.8.	WEST PUMP #1	51627.1	404.3	
46151.9	WEST PUMP #2	46589.0	437.1	
48158.6	WEST PUMP #3	48568.1	409.5.	
9601.0	West Pump #9	9602.8	1.8.	
1550.0	MID PUMP #7	1552.8	2.8.	
1974.4	MID PUMP #8	1976.8	2.4	
	EAST BUILDING	READINGS	DIFFERENCE	
8261.2	SUPPLY FAN #5	8261.5	0.3.	
324.3	SUPPLY FAN #6	324.3	NIL	
9513.3	SUPPLY FAN #7	9513.7	0.4	
10499.9	SUPPLY FAN #8	10500.1	0.2	
611.3	East Compressor	615.9	4.6	
39316.4	EXHAUST FAN #5	39715.7	399.3	
48437.4	EXHAUST FAN #6	48640.6	203.2.	
25000.9	EXHAUST FAN #7	25000.9	NIL	
48631.8.	EXHAUST FAN #8	48835.3	203.5	
1428.9	EAST PUMP #4	1430.1	1.2.	
2411.2	EAST PUMP #5	2434.6	23.4	
	EAST PUMP #6	Out of Service	—	

81. 06. 01. 12:10 AM To 12:30

	WEST BUILDING	READINGS	DIFFERENCE
11820. 0.	SUPPLY FAN #1	11820.1	0.1.
10652. 4	SUPPLY FAN #2	10652. 6	0.2
10332. 3.	SUPPLY FAN #3	10332. 5.	0.2
10234. 5.	SUPPLY FAN #4	10234. 7	0.2
14910. 4.	EXHAUST FAN #1	14910. 4	-
49963. 3.	EXHAUST FAN #2	50306.4	343.1
47920. 5.	EXHAUST FAN #3	47920.8	0.3.
40951. 7.	EXHAUST FAN #4	41537.0	585.3
1170. 8.	West. Compressor.	1174.6	3.8.
51627. 1.	WEST PUMP #1	51991.1	364.0
46589. 0.	WEST PUMP #2	47042.7	453.7
48568. 1.	WEST PUMP #3	49034.9	466.8.
9602.8.	West Pump #9.	9608.5	5.7
1552. 8.	MID PUMP #7	1554. 5.	1.7
1976. 8.	MID PUMP #8	1979. 4	2.6.
	EAST BUILDING	READINGS	DIFFERENCE
8261. 5.	SUPPLY FAN #5	8262.0	0.5
324. 3.	SUPPLY FAN #6	324.3	-
9513. 7.	SUPPLY FAN #7	9513. 9	
10500. 1.	SUPPLY FAN #8	10500. 6	0.5
615. 9.	East Compressor.	619.2	3.3
39715. 7.	EXHAUST FAN #5	39957.7	242.0
48640.6.	EXHAUST FAN #6	48984.5	343.9
25000. 9.	EXHAUST FAN #7	25000.9	-
48835. 3.	EXHAUST FAN #8	49420.2	584.9.
1430. 1.	EAST PUMP #4	1437.0	6.9
2434.6	EAST PUMP #5	2449.8	15.2
	EAST PUMP #6	OUT OF SERVICE	

81. 07. 01

	WEST BUILDING	READINGS	DIFFERENCE	
11820.1	SUPPLY FAN #1	11820.1	NIL	
10652.6	SUPPLY FAN #2	10652.6	NIL	
10332.5	SUPPLY FAN #3	10332.5	NIL	
10234.7	SUPPLY FAN #4	10234.7.	NIL	
14910.4	EXHAUST FAN #1	14910.4	NIL	
50306.4	EXHAUST FAN #2	50328.2	21.8	
47920.8.	EXHAUST FAN #3	47920.9	0.1	
41537.0	EXHAUST FAN #4	42103.5	566.5.	
1174.6	West Compressor	1178.7	4.1	
51991.1	WEST PUMP #1	52355.8	364.7	
47042.7	WEST PUMP #2	47482.8	440.1	
49034.9	WEST PUMP #3	49531.4	496.5	
9608.5	West Pump #9.	9613.8	5.3	
1554.5	MID PUMP #7	1558.1	3.6	
1979.4	MID PUMP #8	1984.2	4.8	
	EAST BUILDING	READINGS	DIFFERENCE	
8262.0	SUPPLY FAN #5	8263.4	1.4	
324.3	SUPPLY FAN #6	324.3	NIL	
9513.9	SUPPLY FAN #7	9513.9	NIL	
10500.6	SUPPLY FAN #8	10500.6	NIL	
619.2	East Compressor	622.2	3.0	
39957.7	EXHAUST FAN #5	40359.8	402.1.	
48984.5	EXHAUST FAN #6	49149.3	164.8	
25000.9	EXHAUST FAN #7	25000.9	NIL	
49420.2	EXHAUST FAN #8	49820.0		LOCKED OUT.
1437.0	EAST PUMP #4	1449.7	12.7	
2249.8	EAST PUMP #5	2460.4	10.6	
	EAST PUMP #6	OUT OF ORDER		

Aug 4
81

WEST BUILDING	READINGS	DIFFERENCE
SUPPLY FAN #1	11820	—
SUPPLY FAN #2	10652	—
SUPPLY FAN #3	10332	—
SUPPLY FAN #4	10234	—
EXHAUST FAN #1	14910	—
EXHAUST FAN #2	50403	75
EXHAUST FAN #3	48009	89
EXHAUST FAN #4	42658	555
W COMP	1181	3
WEST PUMP #1	52839	484
WEST PUMP #2	48111	629
WEST PUMP #3	50006	475
#9	9625	12
MID PUMP #7	1561	3
MID PUMP #8	1990	6

EAST BUILDING	READINGS	DIFFERENCE
SUPPLY FAN #5	9263	—
SUPPLY FAN #6	324	—
SUPPLY FAN #7	9513	—
SUPPLY FAN #8	10500	—
E COMP	6224	2
EXHAUST FAN #5	40451	92
EXHAUST FAN #6	49701	203
EXHAUST FAN #7	25379	367
EXHAUST FAN #8	49910	90
EAST PUMP #4	1467	18
EAST PUMP #5	2470	10
EAST PUMP #6		

Aug 31/81

WEST BUILDING	READINGS	MONTHLY DIFFERENCE	HOURS SINCE OVERHAUL
WEST PUMP # 1	53250	411	7713
PUMP # 2	48541	430	3656
PUMP # 3	50312	306	378
PUMP # 9	9627	2	25
SUPPLY FAN # 1	11820	—	
FAN # 2	10652	—	
FAN # 3	CLOCK MISSING		
FAN # 4	10234	—	MOTOR / FAN
EXHAUST FAN # 1	14910	NIL	
FAN # 2	50914	511	
FAN # 3	48519	510	
FAN # 4	42658	—	1888
COMPRESSOR	1184	3	
MID SUMP # 7	1564	3	
MID SUMP # 8	1994	4	
EAST PUMP # 4	1475	8	47
PUMP # 5	2481	11	
SUPPLY FAN # 5	8263	—	
SUPPLY FAN # 6	CLOCK MISSING		
SUPPLY FAN # 7	9513	—	
SUPPLY FAN # 8	10500	—	MOTOR / FAN
EXHAUST FAN # 5	40962	511	
FAN # 6	49701	—	
FAN # 7	25377	1	
FAN # 8	50420	510	800
COMPRESSOR	626	4	

Oct 1/81

WEST BUILDING	READINGS	MONTHLY DIFFERENCE	HOURS SINCE OVERHAUL	
WEST PUMP # 1	53687	430	8143	
PUMP # 2	49004	8463	[illegible]0	
PUMP # 3	50683	371	749	
PUMP # 9	9629	2	27	
SUPPLY FAN # 1	11820	—		
FAN # 2	10652	—		
FAN # 3	CLOCK MISSING			
FAN # 4	10234	—		
			MOTOR	FAN
EXHAUST FAN # 1	161	-14768		
FAN # 2	51338	424		
FAN # 3	48944	425		
FAN # 4	42820	162	2050	
COMPRESSOR	1187	3		
MID SUMP # 7	1567	3		
MID SUMP # 8	1997	3		
EAST PUMP # 4	1489	14	61	
PUMP # 5	2490	9		
SUPPLY FAN # 5	8264	1		
SUPPLY FAN # 6	CLOCK MISSING			
SUPPLY FAN # 7	9515	2		
SUPPLY FAN # 8	10502	2		
			MOTOR	FAN
EXHAUST FAN # 5	41384	422		
FAN # 6	49863	162		
FAN # 7	25390	13		
FAN # 8	50989	569	1269	
COMPRESSOR	629	3		

Nov. 1, 1981

	WEST BUILDING	READINGS	MONTHLY DIFFERENCE	HOURS SINCE OVER HAUL	
53687	WEST PUMP #1	#6 54102			
49004	PUMP #2	49437	433	433	
50683	PUMP #3	51009	326	283	
9629	PUMP #9	9644	15	242	
11820	SUPPLY FAN #1	11820	—		
10652	FAN #2	10652	—		
	FAN #3	—	—		
10234	FAN #4	10234	—		
				MOTOR	FAN
161	EXHAUST FAN #1	727	566		
51338	FAN #2	51338	—		
48944	FAN #3	48945	1		
42820	FAN #4	43389	569	2619	
1187	COMPRESSOR	1190	3		
1567	MID SUMP #7	1569	2		
1997	MID SUMP #8	2002	5		
1489	EAST PUMP #4	1503	14	75	
2490	PUMP #5	2499	9		
8264	SUPPLY FAN #5	8264	—		
	SUPPLY FAN #6	—	—		
9515	SUPPLY FAN #7	9515	—		
10502	SUPPLY FAN #8	10502	—		
				MOTOR	FAN
41384	EXHAUST FAN #5	41384	—		
49863	FAN #6	50432	569		
25390	FAN #7	25885	495		
50989	FAN #8	50989	—	1769	
629	COMPRESSOR	634	5		

81/11/09 PUMP #1 BACK IN SERVICE 54220.8

Dec 1, 1981.

WEST BUILDING	READINGS	MONTHLY DIFFERENCE	HOURS SINCE OVER HAUL.
WEST PUMP # 1	54501.2	280.4	280.4
PUMP # 2	49854.9	417.9	~~4964~~ 7850.9
PUMP # 3	51362.6	353.6	636.6
PUMP # 9	9646.9	2.9	44.9
SUPPLY FAN # 1	11820.4	—	
FAN # 2	10652.9	—	
FAN # 3	—	—	
FAN # 4	10235.0	1	
			MOTOR / FAN
EXHAUST FAN # 1	1298.6	571.6	
FAN # 2	51352.9	14.9	
FAN # 3	48960.8	15.8	
FAN # 4	43960.1	571.1	3190.1
COMPRESSOR	1193	3	
MID SUMP # 7	1572.5	3.5	
MID SUMP # 8	2005.8	3.8	
EAST PUMP # 4	1515.8	12.8	87.8
PUMP # 5	2511.4	12.4	
SUPPLY FAN # 5	8264.8	.8	
SUPPLY FAN # 6	—		
SUPPLY FAN # 7	9516.1	1.1	
SUPPLY FAN # 8	10502.5	.5	
			MOTOR / FAN
EXHAUST FAN # 5	41453.0	69.0	
FAN # 6	50950.2	581.2	
FAN # 7	26339.3	454.3	
FAN # 8	51045.3	56.3	1225.3
COMPRESSOR	637	3.	

DATE	SUM OF MONTHLY DIFFERENCES
81 01 02	1356.0
81 01 31	1028.0
81 03 01	997.0
81 03 31	1059.0
81 05 01	1252.7
81 06 01	1290.2
81 07 01	1306.6
81 08 04	1600.0
81 08 31	1149.0
81 10 01	1266.0
81 11 01	774.0
81 12 01	1054.8

ANNUAL SUM = 14,133.3

FOR WEST PUMPS
NUMBERS
1, 2, 3 AND 9

81-1-2

	WEST BUILDING	READINGS	DIFFERENCE
11818.8	SUPPLY FAN #1	118190	0.2
10648.0	SUPPLY FAN #2	106482	0.1
10330.6	SUPPLY FAN #3	103309	0.3
10233.7	SUPPLY FAN #4	102340	0.3
14910.4	EXHAUST FAN #1	149104	NIL
46049.3	EXHAUST FAN #2	486562	606.9
46001.7	EXHAUST FAN #3	466134	611.7
40019.1	EXHAUST FAN #4	400197	0.6
1150.7	WEST COMP	01154.3	3.6
49729.5	~~WEST PUMP #1~~	~~501665~~	~~[illegible]~~
44699.0	~~WEST PUMP #2~~	~~451362~~	~~437.2~~
46676.3	~~WEST PUMP #3~~	~~471533~~	~~477.0~~
9588.6	~~(WEST COMP A-C)~~	~~09593.4~~	~~4.8~~
1543.0	MID PUMP #7	015448	1.8
1964.2	MID PUMP #8	1967.1	2.9
	EAST BUILDING	READINGS	DIFFERENCE
8260.4	SUPPLY FAN #5	08260.6	0.2
324.3	SUPPLY FAN #6	00324.3	NIL
9512.2	SUPPLY FAN #7	09512.5	0.3
10484.3	SUPPLY FAN #8	10489.5	5.2
594.2	EAST COMP	005981	3.9
37934.8	EXHAUST FAN #5	037935.3	0.5
47659.9	EXHAUST FAN #6	48187.5	527.6
25000.9	EXHAUST FAN #7	25000.9	NIL
48045.1	EXHAUST FAN #8	48045.1	NIL
1428.1			
2318.3	EAST PUMP #4	01428.6	0.5
441.0	EAST PUMP #5	02344.8	26.5
	EAST PUMP #6	00441.0	NIL

Jan 31

WEST BUILDING	READINGS	DIFFERENCE
SUPPLY FAN #1	11311	—
SUPPLY FAN #2	10645	—
SUPPLY FAN #3		
SUPPLY FAN #4		
EXHAUST FAN #1	14910	—
EXHAUST FAN #2	48891	243
EXHAUST FAN #3	46326	163
EXHAUST FAN #4	40312	115
#9	1596	3
~~WEST PUMP #1~~	~~50522~~	~~302~~
~~WEST PUMP #2~~	~~45477~~	~~336~~
~~WEST PUMP #3~~	~~42480~~	~~337~~
W COMP	1157	3
MID PUMP #7	15455	3
MID PUMP #8	1963	1
EAST BUILDING	**READINGS**	**DIFFERENCE**
SUPPLY FAN #5	9260	—
SUPPLY FAN #6	324	—
SUPPLY FAN #7	9512	—
SUPPLY FAN #8	479	10
EXHAUST FAN #5	38241	306
EXHAUST FAN #6	49436	344
EXHAUST FAN #7	25022	—
EXHAUST FAN #8	48175	130
E COMP	603	5
EAST PUMP #4	14233	—
EAST PUMP #5	3355	21
EAST PUMP #6		

1981 March 1 P.B.

WEST BUILDING	READINGS	DIFFERENCE
SUPPLY FAN #1	11819	0
SUPPLY FAN #2	10649	1
SUPPLY FAN #3	10331	
SUPPLY FAN #4	10234	
EXHAUST FAN #1	14910	0
EXHAUST FAN #2	48900	1
EXHAUST FAN #3	46949	73
EXHAUST FAN #4	40770	458
#9	9598	2
WEST PUMP #1	50866	338
WEST PUMP #2	45801	329
WEST PUMP #3	47808	328
WEST COMP	1161	4
MID PUMP #7	1548	3
MID PUMP #8	1970	2

EAST BUILDING	READINGS	DIFFERENCE
SUPPLY FAN #5	8261	1
SUPPLY FAN #6	324	0
SUPPLY FAN #7	9513	1
SUPPLY FAN #8	10499	0
EXHAUST FAN #5	28772	531
EXHAUST FAN #6	48437	1
EXHAUST FAN #7	25000	0
EXHAUST FAN #8	48621	456
EAST COMP	607	4
EAST PUMP #4	1428	0
EAST PUMP #5	2390	25
EAST PUMP #6	OUT OF ORDER	

March 31 [illegible]

WEST BUILDING	READINGS	DIFFERENCE
SUPPLY FAN #1	11819.7	0
SUPPLY FAN #2	10649.0	0
SUPPLY FAN #3	10331.7	0
SUPPLY FAN #4	10234.4	0
EXHAUST FAN #1	14910.4	0
EXHAUST FAN #2	49378.1	478
EXHAUST FAN #3	47515.0	566
EXHAUST FAN #4	40771.0	1
West Compressor	1166.2	5
~~WEST PUMP #1~~	~~51222.8~~	~~336~~
~~WEST PUMP #2~~	~~46151.9~~	~~350~~
~~WEST PUMP #3~~	~~48138.6~~	~~350~~
~~West Pump #9~~	9601.0	3
MID PUMP #7	1550.0	2
MID PUMP #8	1974.4	4
EAST BUILDING	**READINGS**	**DIFFERENCE**
SUPPLY FAN #5	8261.2	0
SUPPLY FAN #6	324.3	0
SUPPLY FAN #7	9513.3	0
SUPPLY FAN #8	10499.9	0
East Compressor	611.3	4
EXHAUST FAN #5	39316.4	544
EXHAUST FAN #6	48437.4	0
EXHAUST FAN #7	25000.9	0
EXHAUST FAN #8	48631.8	0
EAST PUMP #4	1428.9	~~142~~ 0
EAST PUMP #5	2411.2	21
EAST PUMP #6	out of Service — — —	

81.05.01

Previous	WEST BUILDING	READINGS	DIFFERENCE	
11819.7	SUPPLY FAN #1	11820.0	0.3	
10649.0	SUPPLY FAN #2	10652.4	3.4	
10331.7	SUPPLY FAN #3	10332.3	0.6	
10234.4	SUPPLY FAN #4	10234.5	0.1	
14910.4	EXHAUST FAN #1	14910.4	NIL	
49378.1	EXHAUST FAN #2	49963.3	585.2	Rechecked?
47515.0	EXHAUST FAN #3	47920.5	405.5	
40771.0	EXHAUST FAN #4	40951.7	180.7	
1166.2	West Compressor	1170.8	4.6	
51222.8	WEST PUMP #1	51627.1	404.3	
46151.9	WEST PUMP #2	46589.0	437.1	
48158.6	WEST PUMP #3	48568.1	409.5	
9601.0	West Pump #9	9602.8	1.8	
1550.0	MID PUMP #7	1552.8	2.8	
1974.4	MID PUMP #8	1976.8	2.4	

Previous	EAST BUILDING	READINGS	DIFFERENCE
8261.2	SUPPLY FAN #5	8261.5	0.3
324.3	SUPPLY FAN #6	324.3	NIL
9513.3	SUPPLY FAN #7	9513.7	0.4
10499.9	SUPPLY FAN #8	10500.1	0.2
611.3	East Compressor	615.9	4.6
39316.4	EXHAUST FAN #5	39715.7	399.3
48437.4	EXHAUST FAN #6	48640.6	203.2
25000.9	EXHAUST FAN #7	25000.9	NIL
48631.8	EXHAUST FAN #8	48835.3	203.5
1428.9	EAST PUMP #4	1430.1	1.2
2411.2	EAST PUMP #5	2434.6	23.4
	EAST PUMP #6	Out of Service	—

81. 06. 01. 12 [illegible] To 12 [illegible]

	WEST BUILDING	READINGS	DIFFERENCE
11820. 0.	SUPPLY FAN #1	11820.1	0.1.
10652. 4	SUPPLY FAN #2	10652.6	0.2
10332. 3.	SUPPLY FAN #3	10332.5.	0.2
10234. 5.	SUPPLY FAN #4	10234.7	0.2
14910. 4.	EXHAUST FAN #1	14910.4	-
49963. 3.	EXHAUST FAN #2	50306.4	343.1
47920.5.	EXHAUST FAN #3	47920.8	0.3.
40951. 7.	EXHAUST FAN #4	41537.0	585.3
1170. 8.	West. Compressor.	1174.6	3.8.
51627. 1.	WEST PUMP #1	51991.1	364.0
46589. 0.	WEST PUMP #2	47042.7	453.7
48568.1.	WEST PUMP #3	49034.9	466.8
9602.8.	West Pump #9.	9608.5	5.7
1552.8.	MID PUMP #7	1554.5.	1.7
1976.8.	MID PUMP #8	1979.4	2.6
	EAST BUILDING	READINGS	DIFFERENCE
8261.5.	SUPPLY FAN #5	8262.0	0.5
324.3.	SUPPLY FAN #6	324.3	-
9513.7.	SUPPLY FAN #7	9513.9	
10500.1.	SUPPLY FAN #8	10500.6	0.5
615.9.	East Compressor.	619.2	3.3
39715.7.	EXHAUST FAN #5	39957.7	242.0
48640.6.	EXHAUST FAN #6	48984.5	343.9
25000.9.	EXHAUST FAN #7	25000.9	-
48835.3.	EXHAUST FAN #8	49420.2	584.9.
1430.1.	EAST PUMP #4	1437.0	6.9.
2434.6	EAST PUMP #5	2449.8	15.2.
	EAST PUMP #6	OUT OF SERVICE	

81. 07. 01

	WEST BUILDING	READINGS	DIFFERENCE	
11820.1	SUPPLY FAN #1	11820.1	NIL	
10652.6	SUPPLY FAN #2	10652.6	NIL	
10332.5	SUPPLY FAN #3	10332.5	NIL	
10234.7	SUPPLY FAN #4	10234.7.	NIL	
14910.4	EXHAUST FAN #1	14910.4	NIL	
50306.4	EXHAUST FAN #2	50328.2	21.8	
47920.8.	EXHAUST FAN #3	47920.9	0.1	
41537.0	EXHAUST FAN #4	42103.5	566.5.	
1174.6	West Compressor	1178.7	4.1	
51991.1	~~WEST PUMP #1~~	~~52355.8~~	~~364.7~~	
47042.7	WEST PUMP #2	~~47482.8~~	~~440.1~~	
49034.9	~~WEST PUMP #3~~	~~49531.4~~	~~496.5~~	
9608.5	~~West Pump #9.~~	~~9613.8~~	~~5.3~~	
1554.5	MID PUMP #7	1558.1	3.6	
1979.4	MID PUMP #8	1984.2	4.8	
	EAST BUILDING	READINGS	DIFFERENCE	
8262.0	SUPPLY FAN #5	8263.4	1.4	
324.3	SUPPLY FAN #6	324.3	NIL	
9513.9	SUPPLY FAN #7	9513.9	NIL	
10500.6	SUPPLY FAN #8	10500.6	NIL	
619.2	East Compressor	622.2	3.0	
39957.7	EXHAUST FAN #5	40359.8	402.1.	
48984.5	EXHAUST FAN #6	49149.3	164.8	
25000.9	EXHAUST FAN #7	25000.9	NIL	
49820.2	EXHAUST FAN #8	49820.0		LOCKED OUT.
1437.0	EAST PUMP #4	1449.7	12.7	
2449.8	EAST PUMP #5	2460.4	10.6	
	EAST PUMP #6	OUT OF ORDER		

Aug 4
81

WEST BUILDING	READINGS	DIFFERENCE
SUPPLY FAN #1	11820	—
SUPPLY FAN #2	10652	—
SUPPLY FAN #3	10332	—
SUPPLY FAN #4	10234	—
EXHAUST FAN #1	14910	—
EXHAUST FAN #2	50403	75
EXHAUST FAN #3	48009	89
EXHAUST FAN #4	42658	555
W COMP	1181	3
~~WEST PUMP #1~~	~~59839~~	~~484~~
~~WEST PUMP #2~~	~~48111~~	~~629~~
~~WEST PUMP #3~~	~~50006~~	~~4757~~
~~#9~~	~~9625~~	~~12~~
MID PUMP #7	1561	3
MID PUMP #8	1990	6

EAST BUILDING	READINGS	DIFFERENCE
SUPPLY FAN #5	9263	—
SUPPLY FAN #6	324	—
SUPPLY FAN #7	9513	—
SUPPLY FAN #8	10500	—
E COMP	6224	2
EXHAUST FAN #5	40451	92
EXHAUST FAN #6	49701	203
EXHAUST FAN #7	25378	367
EXHAUST FAN #8	49910	90
EAST PUMP #4	1467	18
EAST PUMP #5	2470	10
EAST PUMP #6		

Aug 31/81

WEST BUILDING	READINGS	MONTHLY DIFFERENCE	HOURS SINCE OVERHAUL	
~~WEST PUMP #1~~	~~53250~~	~~411~~	~~7713~~	
~~PUMP #2~~	~~43541~~	~~430~~	~~3656~~	
~~PUMP #3~~	~~50312~~	~~306~~	~~378~~	
~~PUMP #9~~	~~9627~~	~~2~~	~~235~~	
SUPPLY FAN #1	11820	—		
FAN #2	10652	—		
FAN #3	CLOCK MISSING			
FAN #4	10234	—		
			MOTOR	FAN
EXHAUST FAN #1	14910	NIL		
FAN #2	50914	511		
FAN #3	48519	510		
FAN #4	42658	—	1888	
COMPRESSOR	1134	3		
MID SUMP #7	1564	3		
MID SUMP #8	1994	4		
EAST PUMP #4	1475	8		47
PUMP #5	2481	11		
SUPPLY FAN #5	8263	—		
SUPPLY FAN #6	CLOCK MISSING			
SUPPLY FAN #7	9513	—		
SUPPLY FAN #8	10500	—		
			MOTOR	FAN
EXHAUST FAN #5	40962	511		
FAN #6	49701	—		
FAN #7	25377	1		
FAN #8	50420	510	600	
COMPRESSOR	626	4		

Oct 1/81

WEST BUILDING	READINGS	MONTHLY DIFFERENCE	HOURS SINCE OVERHAUL	
~~WEST PUMP #1~~	~~53687~~	~~430~~	~~8143~~	
~~PUMP #2~~	~~49004~~	~~463~~	~~0~~	
~~PUMP #3~~	~~50693~~	~~371~~	~~749~~	
~~PUMP #9~~	~~9699~~	~~2~~	~~27~~	
SUPPLY FAN #1	11920	—		
FAN #2	10652	—		
FAN #3	CLOCK MISSING			
FAN #4	10234	—		
			MOTOR	FAN
EXHAUST FAN #1	161	161		
FAN #2	51338	424		
FAN #3	48944	425		
FAN #4	42820	162	2050	
COMPRESSOR	1187	3		
MID SUMP #7	1567	3		
MID SUMP #8	1997	3		
EAST PUMP #4	1489	14	61	
PUMP #5	2490	9		
SUPPLY FAN #5	9264	1		
SUPPLY FAN #6	CLOCK MISSING			
SUPPLY FAN #7	9515	2		
SUPPLY FAN #8	10502	2		
			MOTOR	FAN
EXHAUST FAN #5	41354	422		
FAN #6	49863	162		
FAN #7	25390	13		
FAN #8	50959	569	1069	
COMPRESSOR	629	3		

Nov. 1, 1981

	WEST BUILDING	READINGS	MONTHLY DIFFERENCE	HOURS SINCE OVER HAUL	
3687	~~WEST PUMP #1~~	~~54102~~			
49004	~~PUMP #2~~	~~49437~~	~~433~~	~~433~~	
50683	~~PUMP #3~~	~~51009~~	~~326~~	~~283~~	
9629	~~PUMP #9~~	~~9644~~	~~15~~	~~42~~	
11820	SUPPLY FAN #1	11820	—		
10652	FAN #2	10652	—		
	FAN #3	—	—		
10234	FAN #4	10234	—		
				MOTOR	FAN
161	EXHAUST FAN #1	727	566		
51338	FAN #2	51338	—		
48944	FAN #3	48945	1		
42820	FAN #4	43389	569	2619	
1187	COMPRESSOR	1190	3		
1567	MID SUMP #7	1569	2		
1997	MID SUMP #8	2002	5		
1489	EAST PUMP #4	1503	14	75	
2490	PUMP #5	2499	9		
8264	SUPPLY FAN #5	8264	—		
	SUPPLY FAN #6	—	—		
9515	SUPPLY FAN #7	9515	—		
10502	SUPPLY FAN #8	10502	—		
				MOTOR	FAN
41384	EXHAUST FAN #5	41384	—		
49863	FAN #6	50432	569		
25390	FAN #7	25885	495		
50989	FAN #8	50989	—	1769	
629	COMPRESSOR	634	5		

81/11/09 Pump #1 Back in service 54220.8

Dec 1, 1981.

WEST BUILDING	READINGS	MONTHLY DIFFERENCE	HOURS SINCE OVERHAUL
WEST PUMP #1	~~54501.2~~	~~280.4~~	~~280.4~~
PUMP #2	~~49854.9~~	~~417.9~~	~~8509~~
PUMP #3	~~51362.6~~	~~353.6~~	~~636.6~~
PUMP #9	~~9646.9~~	~~2.9~~	~~44.9~~
SUPPLY FAN #1	11820.4	—	
FAN #2	10652.9	—	
FAN #3	—	—	
FAN #4	10235.0	1	
			MOTOR / FAN
EXHAUST FAN #1	1298.6	571.6	
FAN #2	51352.9	14.9	
FAN #3	48960.8	15.8	
FAN #4	43960.1	571.1	3190.1
COMPRESSOR	1193	3	
MID SUMP #7	1572.5	3.5	
MID SUMP #8	2005.8	3.8	
EAST PUMP #4	1515.8	12.8	87.8
PUMP #5	2511.4	12.4	
SUPPLY FAN #5	8264.8	.8	
SUPPLY FAN #6	—		
SUPPLY FAN #7	9516.1	1.1	
SUPPLY FAN #8	10502.5.	.5	
			MOTOR / FAN
EXHAUST FAN #5	41453.0	69.0	
FAN #6	50.950.2	581.2	
FAN #7	26339.3	454.3	
FAN #8	51045.3	56.3	1225.3
COMPRESSOR	637	3.	

1.05 Use of explosives.

advise MTC

Use of explosives is permitted as follows:

.1 General

The Contractor may use explosives for the work where it is safe and practical to do so, except where it is stated otherwise in the Specifications or on the Drawings or where he is directed otherwise by the Engineer.

The Contractor shall note that other more specific requirements related to the use of explosives may be included in another section of these specifications.

.2 Laws and Regulations

The Contractor shall be familiar with and comply with all local, provincial and Federal Laws and Regulations regarding the transportation, storage, handling and use of explosives. He shall obtain such permits as are required.

.3 Storage and Handling

The Contractor shall only store sufficient explosives for the current day's use on the site at any one time. He shall suitably mark and lock the storage facilities at all times.

The Contractor shall follow accepted methods of handling and thawing frozen explosives.

.4 Care and Precautions

The Contractor shall exercise the greatest care at all times in blasting operations. He shall take all necessary precautions required to ensure the safety of the personnel and operations. It is essential that no accidental damage is caused to structures or equipment.

.5 Powderman

The Contractor shall employ an experienced, competent powderman for the work. He shall submit proof of the powderman's qualifications, experience and license to the Engineer for approval, and the quality of the powderman's work as judged by the Engineer shall be a condition of the powderman's continued employment on this work.

.6 Induced Currents

The Contractor shall be familiar with the Institute of Makers of Explosives, Safety Library Publication No. 20, "Radio Frequency Energy". He shall take all necessary precautions against the effects of induced currents caused by radio transmitters and receivers, power lines, transformers, cables, radar beams and any other energy or wave force which might result in the premature firing of the blasting circuits.

.7 Blasting Mats

The Contractor shall have available on the site approved blasting mats. He shall use blasting mats for all blasting, ~~unless otherwise directed by the Engineer~~.

.8 Hours of Blasting

The Contractor shall note that the hours which blasting operations may be undertaken shall be subject to the approval of the Engineer and shall normally be between the hours of 0800 (8 a.m.) and 1600 hours (4 p.m.) on any working day.

1.05
Use of
explosives.
(cont,d)

.9 Blasting Requirements

The Contractor shall submit a blast design prior to the start of blasting. "As blasted" records shall be kept by the Contractor and submitted to the Engineer as requested. "As blasted" records shall provide hole diameter, depth, explosive load per hole, detonator layout, collar number of holes, time of blast, weather, etc.

.10 Responsibility

The Contractor shall be completely responsible for the blasting operations notwithstanding the fact that the methods of blasting; drill patterns; firing patterns; maximum charge per delay; powder factors, and the size, strength and quantity of explosives of one blast; the qualifications and work of the powderman, etc., have to be submitted by the Contractor to the Engineer for approval.

.11 No Deviation

The Contractor shall not deviate from the approved blasting procedures unless such deviation is specifically approved by the Engineer.

.12 Monitoring

All blasts shall be monitored for blast vibrations and blast overpressure out of doors and for blast vibrations only in doors. Records of all blast monitoring shall be submitted as required along with blast data as specified in .9 above.

.13 Monitoring Equipment

The Contractor shall use seismographs for monitoring which are capable of providing a film record of the horizontal, vertical and transverse waveforms as well as a blast overpressure record. The Contractor shall deliver the firm record to the Engineer as soon as it is available.

Frequencies less than fifteen hertz (15 Hz) are not acceptable at the Thorold Tunnel.

.14 Blasting Consultant

The Contractor shall, at no additional cost to the Authority, retain the services of a qualified blasting consultant who is a member of the Association of Professional Engineers of Ontario and is a designated specialist in explosives and blasting to establish blasting procedures and to monitor the blasting vibrations and the blast overpressure.

The Contractor shall arrange a meeting between his Blasting consultant and the Engineer to review the Authority's concerns re the safety of the operations. The Contractor shall submit the blasting consultant's preliminary recommendations to the Engineer for approval subsequent to the meeting, and before any drilling is commenced.

The blasting consultant shall monitor the initial series of blasts through seismographs located in positions selected by the Engineer so that he may establish initial blasting procedures on the basis of these initial measurements. All blasts shall be monitored and changes in blasting procedures shall be submitted to the Engineer for approval.

The Contractor shall submit in writing and on drawings the blasting consultant's subsequent recommendations regarding the drill patterns; firing patterns; maximum charge per delay; powder factors, and the size, strength, and quantity of explosives of one blast and all other pertinent information to the Engineer for approval.

.15 Hazards

The Contractor shall note the Thorold Tunnel is a possible problem area with regard to blasting operations.

J.	F.	M	A	M	J	July	A	S	O	N	D	J
441	384	245	308	366	382	400	493	535	495	512	459	441
393	373	372	202	8	5	0	72	337	432	538	356	393
406	370	396	375	365	378	403	523	525	412	444	479	406
3	—	14	2	1	1	1	2	13	6	36	9	3
1243	1127	1027	887	740	766	804	1090	1410	1345	1530	1302	1243
1979			1238		1250	1320			1363.	3271		84

WEST PUMPS

Pump # 1

Pump # 2

Pump # 3

Pump # 9

664 5333

89 227-5516

GEORGE GREEN

① 45800

1st Feb. 45537

1st Jan 45153

384

1st Nov 49270

1st Dec 49729

459

44712

1979 1st Dec 45153.

441

② 42378

42005

373

44343

44699

356

41612

42005

393

③ 42365

41995

370

46198

46676

478

41589

41995

406

⑨ 9504

9504

9579

9588

07

9501

9504

3

WT 13' × 34'3" 445.25.

248 32 82

ST 13' × 30' 390.00

13 × 6'6" 84.50 Floats (3'-9")

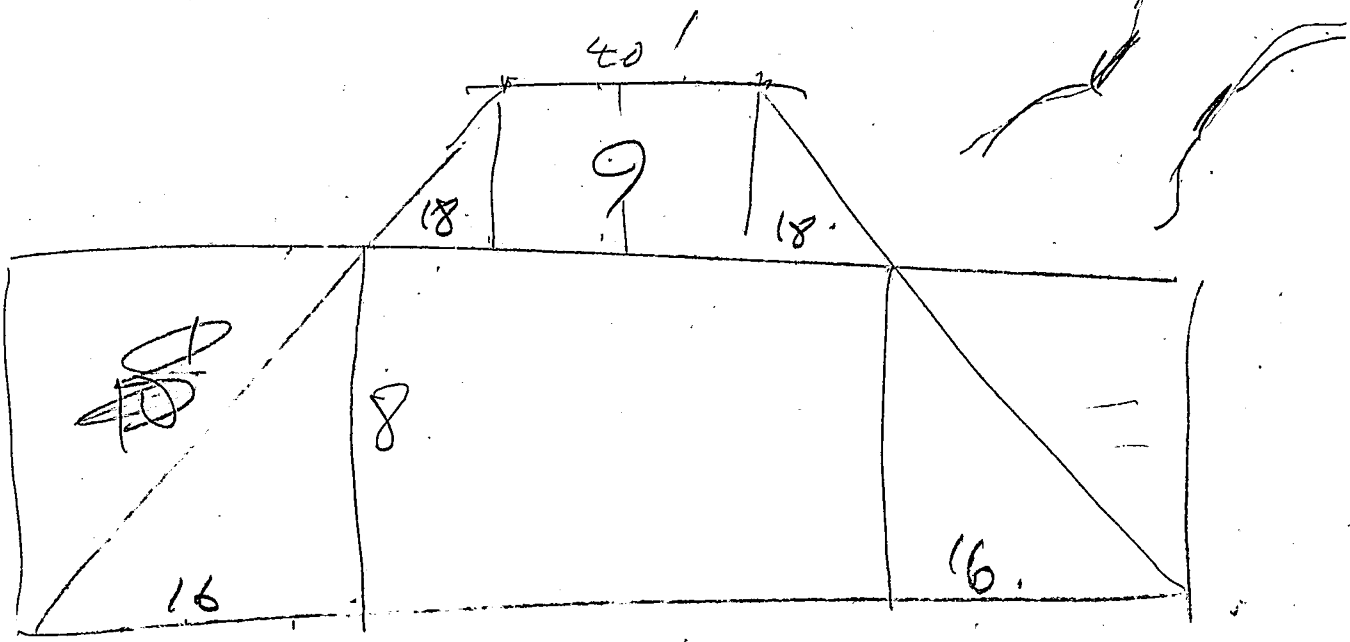
18" 18"

④ pumps Centre T.

1st Oct. ① 48758 ② 43805 ③ 45754 ⑨ 9543

3449.0625 cubic ft

= 21,556 galls



$4 \times 27 \times 8 \times 100$

27

32,000

40
36
32
108

64,000

20,000

36:35:89

13271

13,278
87

6
5087 ③
3087 ②
5017 ①

8000 litres/m

2100 g.p.m.

① Fill up time	② Volume	③ Inflow Rate	④ Pump out time	⑤ Pumpout rate
Inflow time	21,556 gallons	2192 g.p.m.	13.05′	50,260 / 13.05
9′ 50″ (9.83)		1822 g.p.m.	14.47	4 pumps 3851 /min
				1 pump 963 /min
				3 pumps 3311
11.83′	26366	47922		1 pump 1104 /min

1969	7137	+ 1200 = 8337
70	9864	
71	9387	
72	10797	
73	12632	
74	13357	
75	13532	
76	14178	
77	13783	
78	13925	
79	12705	+ 1200 = 13905.
80		

90 H.P. = 67.14 KW

$$\frac{3 \times 70 \times 347}{1000} = 72.87 \text{ KW.}$$

$$= 1.7489 \approx 1.75$$

M.N.A.

0.25

In conclusion therefore it is my opinion that the material which I

Dec	1968	876	28.3 hrs/day
JAN	1969	142	4
FEB	1969	287	4
MAR	1969	427	4

31
28
31
90

12

9.5 hrs/day.

DEC	1978	787
JAN	1979	340
FEB	1979	352
MAR	1979	451

$\frac{1143}{90} = 12.7$

JAN	1973	1081 (POSSIBILITY OF ERROR)
F		765
M		1121
A		1526
M		665
J		1123
J		1103
A		1098
S		1066
O		1227
N		1217
D		1075
JAN	1974	964
F		1005
M		1143
A		1655
M		1035
J		1068

$\frac{14000}{365} = 38$

1243

CLOSED JAN

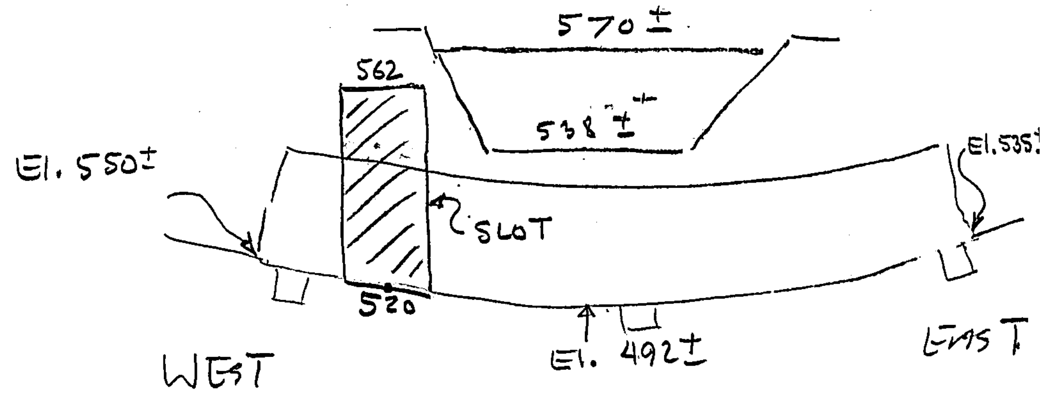
	1979	1978	1977	1976	1975	1974
Feb.	352 (~~1187~~)	1162	926	1008	1013	1005.
April.	1238	1326	1052	1107	1203	1655.
June.	1250	1141	1106	1187	1113	1068
July.	1320	1245	1327	1347	1671	1076
Oct.	1363	1168	1309	1243	1094	1115.
Nov.	1374	1134	1214	1150	1156	1063
	1288	1196	1155	1173	1208	1163
12705	~~12349~~ ~~1243~~ ~~13572~~	13925	13783	14178	13532	13357

	1973	1972	1971	1970	1969
Feb.	765	549	731	718	287
Apr.	1526	890	746	816	562
June	1123	951	822	731	718
July	1103	1040	787	786	798
Oct	1227	1062	1058	909	882
Nov.	1217	1139	923	870	814
	1160	938	844	805	678
	12632	10797	9387	9864	7137

BOB Poe Seaway 684657/
EXT. 253

Jan 1969
Lowered to 23 ft. 547 from 570
Jan 3 — Jan 19th Time ½ day to lower.
(16 days)

Jan 1979
Lowered to 21 ft. 549 from 570
Jan. 15th to March 6th.



339