41J05SE0007 2.15538 LEFROY 010

41J05SE0007 2.15538 LEFROY 010C

TABLE of CONTENTS

APPENDIX

NAME and ADDRESS of CLAIM HOLDER:

THE WARREN PAVING & MATERIALS GROUP
(Central Canada Division)

72 Ashwarren Road
Downsview, Ontario
Canada
M3J - 1Z6

Telephone (416) 633-9670
Facsimile (416) 633-4959

Company President
J.G. McLarty
51 Chalmers Road
Richmond Hill, Ontario
L4B - 1S8

CLAIM NUMBER:

792863

CLAIM LOCATION:

The west half of the northeast quarter section of lot number ***26***, Lefroy Township.

ACCESS TO CLAIM:

Access to *claim #SSM 792863* is off Highway 17 in Lefroy Township north of the village of Nestorville. The claim is on the west half of the northeast quadrant of section 26 of Lefroy Township. Directions for access to the claim are as follows.

a) turn north off Highway 17 four miles west of Thessalon onto Trunk Rd.

b) at the junction of Trunk Rd., Nestorville Rd., the CPR crossing and Scheuerman Highway turn east onto Scheuerman Highway. Scheuerman Highway bisects *claim #SSM 792863* diagonally from the southeast corner to the northwest corner.

Visual Analysis of Samples:

The sampled rock was dense, dark blue/grey with a medium to fine grain pattern, consistent to the properties of *diabase material.*

General Description of the Minerology: (local)

The property has a massive outcropping of *diabase* with some *quartzite* and *basaltic* material. The overburden is low $CaCO_3$ sand with some loam from the decomposition of the hardwood forest. The overburden is shallow to nonexistent.

Typical Geology of the Region:

The geology of the region is transitional from the loamy low lands of the Great Lakes Basin to large glacial sand ridges and massive out croppings of Nipising Diabase that are known to have traces of Cu, Zn, Ur, Au, Ag, and Fe.(ONTARIO GEOLOGICAL SURVEY MAP #2419 and testing by Clifton and Associates)

Author of the Report:

Raymond T. Hickerson
Marketing Research and Development
SMELTER BAY AGGREGATES INCORPORATED

P.O. Box 222 Thessalon, ON P0R 1L0
Ph.(705)842-2597 wk.
(705)842-2066 hm.

Qualifications;
12 years mining and prospecting, including exploration drilling and sampling
5 years marketing of stone and aggregate products

RAYMOND T. HICKERSON

DATE: July 29/94

Supervisor of Work:

Reg Gardiner
DISTRICT MANAGER
SMELTER BAY AGGREGATES INCORPORATED

P.O. Box 642 Thessalon, ON P0R 1L0

Ph.(705)842-2597 wk.
Ph.(705)842-5488 hm.

Workers/Contractors:

Drilling and Blasting,

Consbec Inc.

Contact:Richard Walker Owner/President

P.O. Box 520
2725 Belisle Dr.
Val Caron, ON P0M 3A0

Ph.(705)897-4971

Crushing and Sampling,

Gilbertson Enterprises

Contact:Don Gilbertson Manager

R.R.#1
Richard's Landing, ON P0R 1J0

Ph.(705)246-2076

Stripping of Overburden,

LeRoy Construction

Contact:Dan Roy Owner

P.O. Box 1444
300 Leacock St. Blind River, ON P0R 1B0

Equipment List:(DIRECT COSTS)

Stripping:
EXCAVATOR
LC-220 Komatsu w/1.5 cu. yd bucket

Drilling and Blasting:
DRILL
Hydraulic BV Gardner-Denver
4"x 30' holes @ 10'x 11' grid

POWDER
Austin-Austinite 15 (anfo)
Hydromite 620 (3"x16")

PRIMERS
Green cap (1/3 lb.)
Black cap (3/4 lb.)

Detonators
Nonelectric EZ-DETS
Primer nonelectric delays

Crushing
LOADER
988 Caterpillar

PRIMARY CRUSHER
30"x42" Jaw

SECONDARY CRUSHER
66" Cone

TERTARY CRUSHER
42"x42" Triple Roll

Sampling

SEIVES (fine)	SEIVES (coarse)
9.5mm	16mm
4.75mm	13.2mm
1.18mm	9.5mm
600um	4.75mm
300um	
150um	

Mechanical shaker (make n/a)
electronic scale (make n/a)

Contractor and Equipment List: INDIRECT COSTS

SHIPLOADING FACILITY
Smelter Bay Aggregates Incorporated
P.O. Box 400, THESSALON ON POR 1L0

Contact:
Reg Gardiner

Ph.(705)842-2597

LOADERS

Komatsu WA-500 (3)

SHIPLOADER

Stationary system; 2 hopper bins
1 ground conveyor
1 shiploading conveyor
1 hydraulic deflector hood

SELF-UNLOADING FREIGHTER
Southwestern Sales Corporation Ltd.
100 Lesperance Rd. TECUMSEH ON N8N 1W1

Contact:
Jack Frye President

Ph. (519)735-9822

Vessel, Algorail(ACR)

RECEIVING DOCK
Reid Aggregates Inc.
1777 St. Clair Parkway R.R.#4
Sarnia, ON N7T 7H5

Contact:
David Sheldon President

Ph.(519)337-6087

Bulk Handling, Storage, Reloading and Weighing

TRUCKING
Laidlaw Carriers Inc.

Contact:
Scott Talbot

Ph.(519)539-0471

P.O.Box 776 WOODSTOCK ON N4S 8 [illegible] 5

PROPOSED USES of DIABASE:

The extreme hardness of diabase (#6 on the Moh's scale) makes it an excellent product for industrial applications where high wear resistance and/or high strength are requirements. Examples of such applications that **SMELTER BAY AGGREGATES INCORPORATED** have investigated are:

* rail road ballast
* rock wool insulation
* wear course (asphalt)
* dense friction course (asphalt)
* microsurfacing (asphalt)
* HL-1 (asphalt)
* high strength concrete

The chemical stability of this material makes it a better product than some of those in current use. The increasing awareness of environmental concerns and new environmental legislation has increased the interest in our quarried products.

Many of the proposed markets are a great distance from the raw material source. **SMELTER BAY AGGREGATES INCORPORATED** has and will continue to ship *diabase* from our Seaway depth dock by self-unloading lake freighters to U.S. as well as Canadian markets throughout the Great Lakes Basin. The large quantities shipped,(boat loads vary depending on the vessel size, 20,000 to 30,000 tons), and the recognized quality of the material, have provided us with a growing market share. We depend on product development and large reserves to offset the very high costs of extraction, marketing, and closure,(in accordance with the Mining Act). **SMELTER BAY AGGREGATES INCORPORATED** has undertaken the acquisition and development of the necessary reserves by staking and working *claim #SSM 782863* as an integral part of our long range quarry operational plan.

DIMENSIONS and RESERVES in the DEPOSIT :(on *claim # SSM 762863*)

* approximately 360 m x 850 m x 20 m
* approximate reserves, 5.8 x10^6 m^3

SPECIFICATIONS and CRITERIA:

Please see the attached reports and specification listings, included you will find:

* results of extensive testing of the **SMELTER BAY AGGREGATES NESTORVILLE QUARRY**,(petrographic,chemical,and physical),both general and specific to rail road ballast requirements.(CLIFTON ASSOCIATES LTD.) *Please note that the Clifton Report is for your data base information only and will not be included as an expense toward our assessment work on claim #SSM 782963.*

* the criteria and results of the Ministry of Transportation Ontario(MTO) DENSE FRICTION COURSE (DFC) test strip.

* results of Ashwarren Engineering Services physical testing of samples taken from the indicated site on claim #SSM 782863 for suitability in hot mix asphalt production.

MARKET DEVELOPMENT and RESULTS:

Canadian National Railways Geotechnical Engineering Department has been working with the **SMELTER BAY AGGREGATES** marketing department to establish product suitability and the transportation logistics for supply and delivery to construction,upgrade and repair sites in the southern Ontario region. CNR geological engineers have determined that the product currently in use as railroad ballast has a life expectancy of 700,000,000 gross tons of traffic. They determined the *diabase* found in our quarry, including claim #SSM 782863 to have a life expectancy of 900,000,000 gross tons, a factor of 22% longer life for the *diabase*. Another recent development that will effect the market in our favour is the environmental concerns regarding leachates in the current product. Environmental legislation is expected that will set criteria and limit the use of that product.

Our vigorous pursuit of the asphalt markets through qualification for the provincial government's (MTO) Designated Sources list and the growing awareness of road builders and contractors of our products and unique delivery capabilities has given us early success in this market. Products included in this category are: DFC, fine and coarse; HL-1; and other aggregate according to individual engineered design mixes. (95% of the ingredients of most asphalt design mixes are aggregate products: see, Search for Skid Resistant Aggregates in Ontario; Chris Rogers, Engineering Materials Office, MTO Ontario,1983; published in "19th Forum on the Geology of Industrial Minerals Proceedings" Ontario Geological Survey Miscellaneous Paper 114, 216 p., 1983.)

HOT MIX ASPHALT AGGREGATE TESTING: Traprock

Stripping, trenching, blasting and sample extraction were carried out at the site identified within the report,(see Sample Location A). A sample was shipped to ASHWARREN ENGINEERING SERVICES for a battery of aggregate testing to determine its suitability for Hot Mix highway surfacing. The ASHWARREN ENGINEERING SERVICES REPORT is attached.

DFC TEST STRIP (MTO):

* 1 Km long
* starts 1.5 Km west of interchange 186 on highway 401
* 2 west bound lanes only

Interim approval has been granted from MTO officials based on tests and inspections to date. Attached you will find copies of MTO criteria, test methods, comments and approvals. I have included for your convenience a paper published by MTO prior to the opening of the Nestorville quarry.I have taken the liberty of highlighting some passages of interest.

note:since the original draft of this report ***SMELTER BAY AGGREGATES INCORPORATED*** has received final approval as a Designated Source for the Nestorville quarry (including claim #SSM 782863) for the production and supply of DFC, coarse and fine. Documentation of DFC approval as well as the Designated Sources approval granted in 1993 for HL-1 From the Nestorville quarry are included in the attached information.

STOCKPILES:

SMELTER BAY AGGREGATES INCORPORATED has built stockpiles of *diabase* products in excess of 18,000 tons of various gradations and specifications in anticipation of further testing and marketing needs. The costs incurred producing these stockpiles have not been submitted for consideration in the assessment work on claim #SSM 762863 in whole or in part.

SAMPLE LOCATION A:

The starting point to establish the sample location is the junction of Trunk Road, Nestorville Road, Scheuerman Highway and the CPR crossing.(See claim access)
Approximately <u>700</u> yards were paced off in a westerly direction along the CPR tracks to the *<u>#3</u> post* of *claim #SSM 782863*, a <u>180</u> degree turn was made and <u>200</u> yards were paced off. A compass bearing was shot to magnetic north, <u>70</u> yards were paced off on the established bearing to the sample location. A compass bearing was shot to magnetic west and <u>200</u> yards were paced off to the *<u>#3</u> post* of *claim #782863*. The prospector returned to the sample source and paced <u>520</u> yards on an easterly course along Scheuerman Highway to the starting above mentioned starting point. (SEE THE ATTACHED MAP #<u>2</u>)

DISCRIPTION of WORK and DATES: (DIRECT COSTS SAMPLE A)

STRIPPING: 936.25

JULY 21 & 22, 1992

LeRoy Construction
P.O. Box 1444
300 Leacock St. Blind River, Ontario
POR 1BO

DRILL and BLAST: 2037.50

JUNE 22, 1993

Consbec Inc.
P.O. Box 520
2725 Belisle Dr. Val Caron, Ontario
POM 3AO

EXTRACTION of SAMPLE: 355.77

MAY 11, 1994

Gilbertson Enterprises
RR#1
Richard's Landing, Ontario
POR 1JO

SAMPLE TESTING: 1856.00

JUNE 6, 1994

Ashwarren Engineering Services
2283 Argentia Rd. Unit 15
Mississauga, Ontario
L5N 5Z2

PROSPECTING:	150.00

MAY 12, 1994

SMELTER BAY AGGREGATES INCORPORATED
P.O. Box 400
Thessalon, Ontario
POR 1L0

SUPERVISION:	750.00

JULY 1992 -JUNE 1994

SMELTER BAY AGGREGATES INCORPORATED
P.O. Box 400
Thessalon, Ontario
POR 1L0

TOTAL 6085.52

SAMPLE LOCATION B:(DEEDED PROPERTY ADJOINING *CLAIM #SSM 782863*;for Dense Friction Course, DFC, test strip)

The total bulk sample extracted and prepared for this test exceeded 6000 tons. The sample was extracted from a portion of the deposit located on land deeded to WARREN PAVING and MATERIALS GROUP LTD. The deeded property abuts *claim #SSM 782763* from the number 3 post to the number 4 post. *Claim #SSM 782863* is held by WARREN PAVING and MATERIALS LTD. The sample was extracted at a location 285 yards SSW of *the #4 post of claim #SSM 782863* and *75 yards due west of the west boundary of the claim.*

DISCRIPTION of WORK and DATES: Direct costs, Sample B

Stripping: 2656.50

MAY 22,25,26, 1992

LeRoy Construction
P.O. Box 1444
300 Leacock St. Blind River, Ontario
POR 1BO

Drilling and Blasting: 37544.95

SEPT.28, 1992 and JUNE 23, 1993

Consbec Inc.
P.O. Box 520
2725 Belisle Dr.
Val Caron, Ontario
POM 3A0

Crushing: 20,379.34

OCT.26, 1992 and AUGUST 15, 1993

Gilbertson Enterprises
R.R. #1
Richard's Landing, Ontario
POR 1J0

Supervision: 1,284.00

MAY,1992; SEPT.,1992; OCT.,1992;
JUNE,1993; AUGUST,1993

SMELTER BAY AGGREGATES INCORPORATED
P.O. Box 400
Thessalon, Ontario
POR 1LO

TOTAL **61,865.29**

Boat Loading: 5,883.66

SEPT.4, 1993

SMELTER BAY AGGREGATES INCORPORATED
P.O. Box 400
Thessalon, Ontario
POR 1LO

Boat (self-unloading freighter): 6,549.74

SEPT.4, 1993

Southwestern Sales Corp. Ltd.
100 Lesprerance Rd.
Tecumseh, Ontario
N8N 1W1

Receiving, Handling, and Weighing: 2,997.35

SEPT.15, 1993

Reid Aggregates Ltd.
1777 St. Clair Parkway RR #4
Sarnia, Ontario
N7T 7H5

Trucking: 10,079.94

SEPT.15 - OCT.3, 1993

Laidlaw Carriers Inc.
P.O. Box 776
Woodstock, Ontario
N4S 8A2

	20% of Direct Cost =	12,373
	SUB TOTAL	25,510.69
INDIRECT	~~7 .20~~	~~5,102.14~~
DIRECT		61,865.29
TOTAL EXPENCES SAMPLE 3		~~66,927.43~~ 74239

TABLE 1
Whole Rock and Trace Element Analysis

Parameter	Units %	Sample No. L4889	Quebec Contaminated Site Guidelines* (Level C)
Major Oxides			
SiO_2	%	53.48	
Al_2O_3	%	14.16	
Fe_2O_3	%	11.67	
CaO	%	9.42	
MgO	%	6.42	
K_2O	%	0.60	
Na_2O	%	2.35	
P_2O_5	%	0.06	
MnO	%	0.17	
TiO_2	%	0.76	
LOI	%	0.90	
Trace Elements			
Pb	ppm	2	600
Mo	ppm	5	40
Zn	ppm	77	1500
Cd	ppm	3	20
Co	ppm	46	300
Cr	ppm	52	800
V	ppm	243	-
Be	ppm	1.7	-
Cu	ppm	150	500
Zr	ppm	55	-
Y	ppm	14	-
La	ppm	14	-
Th	ppm	3	-
Sr	ppm	195	-
Ba	ppm	116	2000
Ni	ppm	78	500
PBD_2	ppm	2	

* Quebec remediation guidelines were used, as Ontario guidelines have not yet been legislated.

TABLE 2

Acid Base Accounts

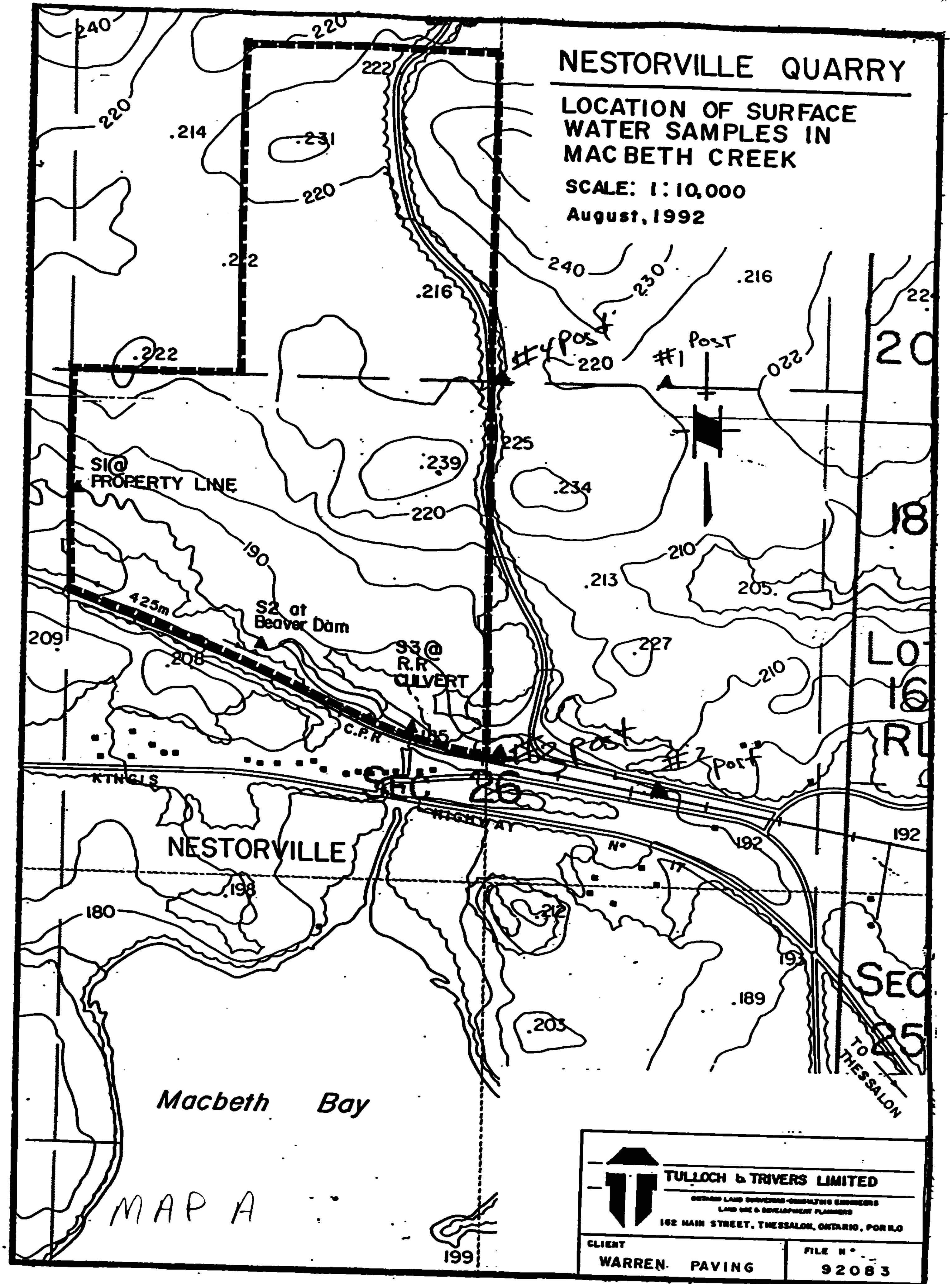
Sample	Paste Ph	%S_t	%S_{SO4}	NP*	AP*	NET NP*
L4889	9.23	0.09	0.04	6.0	1.56	4.4

* NP, AP AND NET NP are expressed in kg $CaCO_3$/tonne

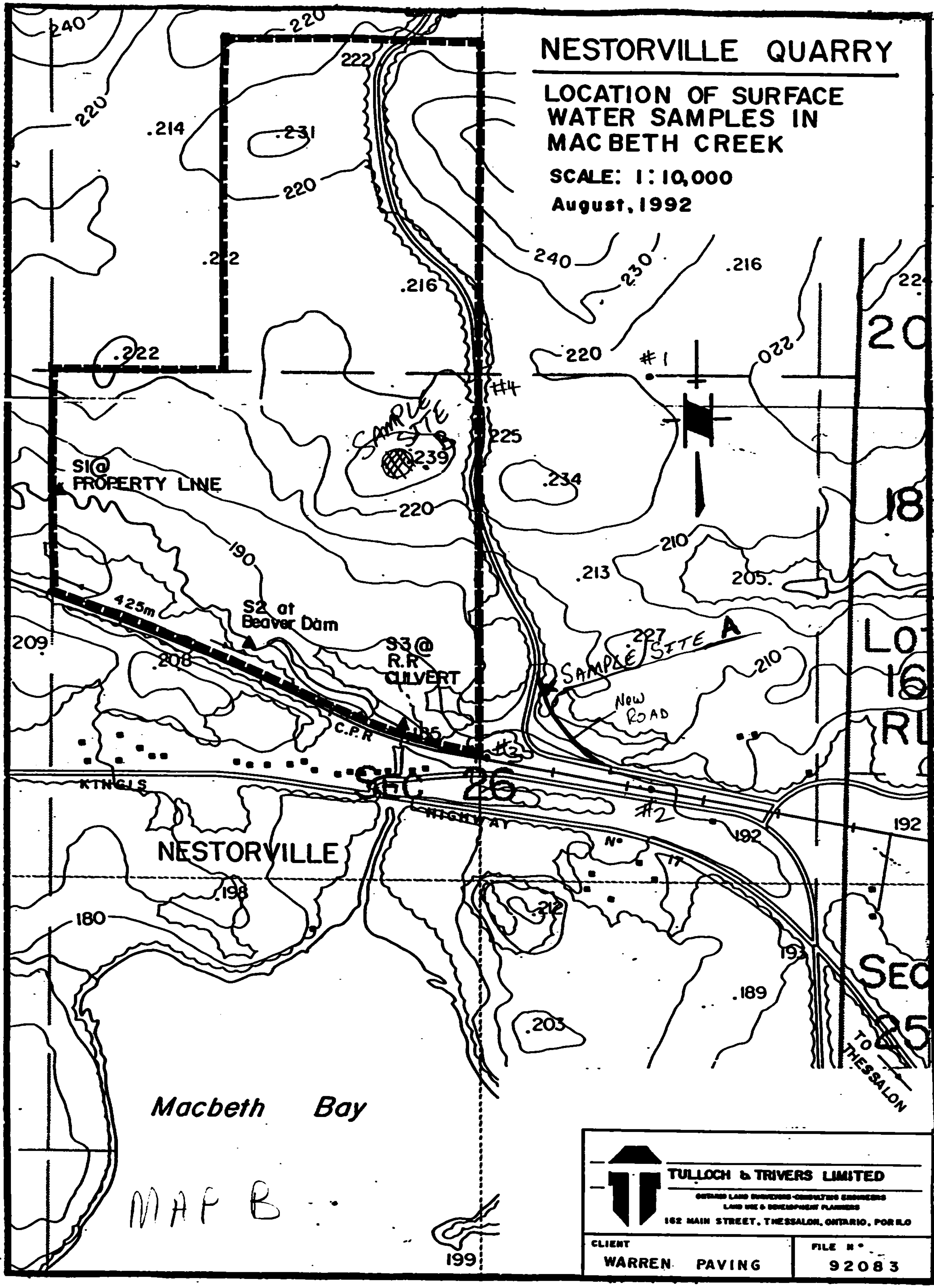
TABLE 3

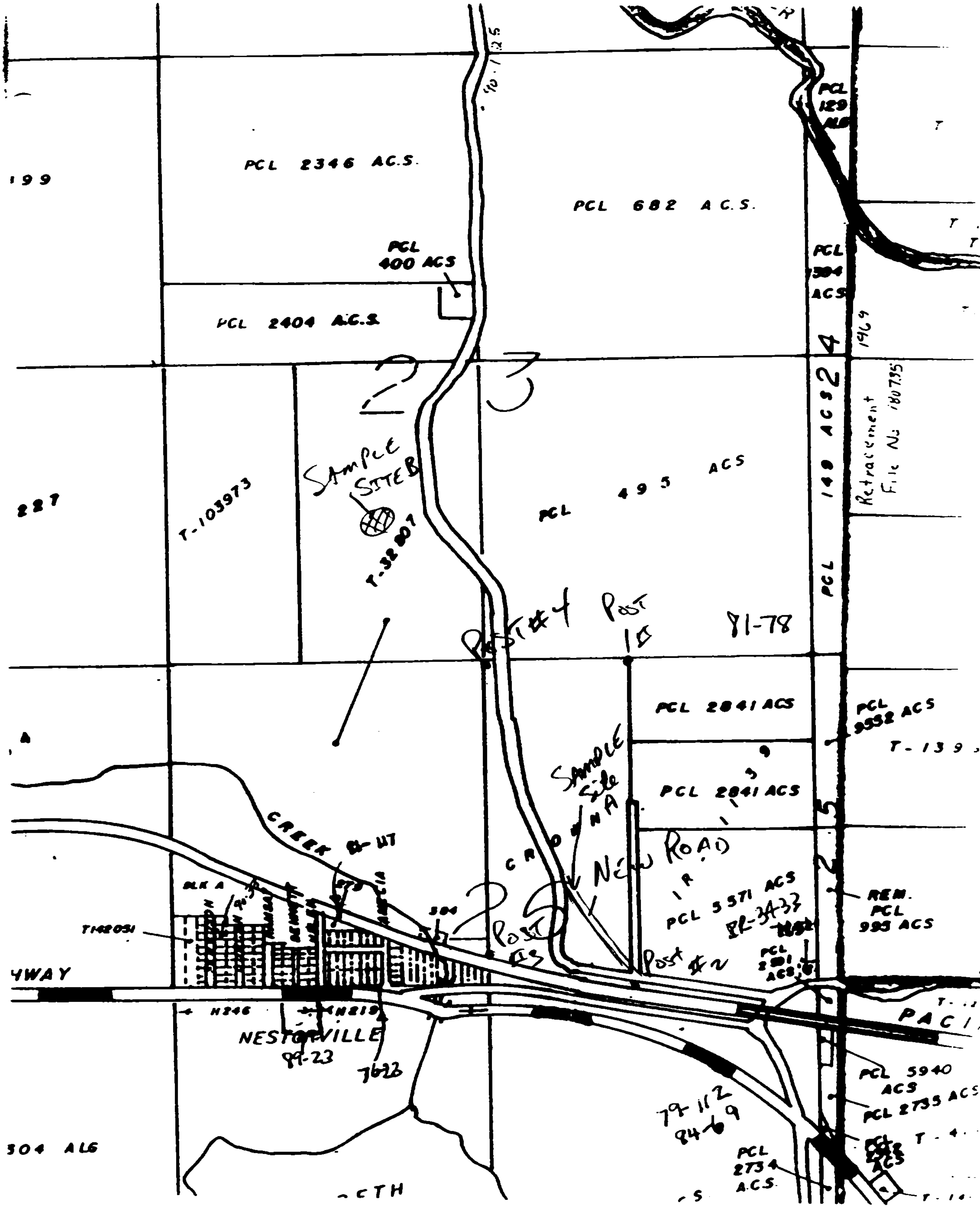
Leachate Extract Analysis

Element	Units	L4889	Leachate Quality Criteria (Ontario Reg. 309)
B	mg/L	<0.05	5.0
P	mg/L	<0.02	-
Ag	mg/L	<0.005	0.08
Al	mg/L	<0.073	-
As	mg/L	<0.0005	0.05
Ba	mg/L	0.006	1.0
Be	mg/L	<0.005	-
Ca	mg/L	6.3	-
Cd	mg/L	<0.005	0.005
Co	mg/L	0.005	-
Cr	mg/L	0.005	0.05
Cu	mg/L	<0.051	-
Fe	mg/L	0.26	-
Hg	mg/L	<0.00005	0.001
K	mg/L	1.5	-
Mg	mg/L	1.1	-
Mn	mg/L	0.048	-
Mo	mg/L	<0.02	-
Na	mg/L	1.0	-
Ni	mg/L	0.008	-
Pb	mg/L	<0.02	0.05
Si(soluble)	mg/L	0.9	-
Ti	mg/L	<0.005	-
V	mg/L	<0.05	-
W	mg/L	<0.02	-
Zn	mg/L	0.070	-



NESTORVILLE QUARRY
LOCATION OF SURFACE WATER SAMPLES IN MACBETH CREEK
SCALE: 1:10,000
August, 1992
S1@ PROPERTY LINE
S2 at Beaver Dam
S3@ R.R CULVERT
425m
C.P.R
KINGS
HIGHWAY
No 17
NESTORVILLE
Macbeth Bay
TO THESSALON
#4 post
#1 Post
#2 post
#3 post
MAP A
TULLOCH & TRIVERS LIMITED
162 MAIN STREET, THESSALON, ONTARIO, P0R 1L0
CLIENT
WARREN PAVING
FILE No
92083


NESTORVILLE QUARRY
LOCATION OF SURFACE WATER SAMPLES IN MACBETH CREEK
SCALE: 1:10,000
August, 1992
S1@ PROPERTY LINE
S2 at Beaver Dam
S3@ R.R CULVERT
425m
C.P.R
SAMPLE SITE A
SAMPLE SITE B
New ROAD
#1
#2
#3
#4
NESTORVILLE
KINGS HIGHWAY No 17
SEC 26
Macbeth Bay
TO THESSALON
MAP B
TULLOCH & TRIVERS LIMITED
162 MAIN STREET, THESSALON, ONTARIO, POR 1L0
CLIENT
WARREN PAVING
FILE No
92083



PCL 2346 AC.S.
PCL 682 A.C.S.
199
PCL 400 ACS
PCL 2404 AC.S.
PCL 129 ALS
PCL 394 ACS
1969
Retracement File No 180735
PCL 140 ACS
287
T-103973
SAMPLE SITE B
T-32807
PCL 495 ACS
Post #4
Post 1
81-78
PCL 2841 ACS
PCL 9552 ACS
T-139
SAMPLE Site #A
PCL 2841 ACS
CREEK
NEW ROAD
PCL 5571 ACS
82-3433
REM. PCL 995 ACS
BLK A
T142051
Post #5
Post #2
HWAY
H246
H219
NESTORVILLE
89-23
7623
PAC
PCL 5940 ACS
PCL 2735 ACS
79 112
84-69
PCL 2734 ACS
304 ALG
ETH

MAP C.

Ontario

Ministry of Transportation

Ministère des Transports

Soils and Aggregates Section
Engineering Materials Office
1201 Wilson Avenue
Central Building, Room 311
Downsview, Ontario M3M 1J8

Tele: (416) 235-3734
Fax: (416) 235-4101

May 19, 1994

File No.: 3162-2-0-1

Reginald C. Gardiner, Manager
Smelter Bay Aggregates Incorporated
P.O. Box 400, Boundary Road
Industrial Park
Thessalon, Ontario.
P0R 1L0

Dear Mr. Gardiner:

Re: **Approval of Your Quarry in Lefroy Township for Dense Friction Course (DFC) Coarse and Fine Aggregates, MTO MAIDB No. B22-076**

We are pleased to advise you that the above-mentioned quarry is now approved as a source of DFC coarse and fine aggregates on a contract-by-contract basis for ministry contracts. Bidders on our contracts are being advised by Addenda and special provisions on applicable contracts in our Southwestern and Central Regions.

The approval is based on the performance of the trial section placed with your aggregates on the westbound lanes of Hwy. 401 between Wellington Road and Hwy. 402, Contract No. 93-35. The trial section was inspected on April 27, 1994 by Geoff Leach, of Southwestern Region, Zoltan Katona, and myself. It was found to perform well compared to other established trap rock sources having been in place for one winter.

If you require further information, please contact our office.

Chris Rogers

Chris A. Rogers, Manager,
Soils and Aggregates Section.

pc: M.D. Billings, W.J. Peck, C.M. Bond, P.R. Bryar, P.J. Bound, R.G. Gorman, M.D. MacLean, B.L. Peltier, J.K. Robinson, K.K. Tam

CAR/SIS/jlp

Ontario

Soils and Aggregates Section
Engineering Materials Office
1201 Wilson Avenue
Central Building, Room 311
Downsview, Ontario M3M 1J8

Ministry of Transportation | Ministère des Transports

Tele: (416) 235-3739
Fax: (416) 235-4101

June 7, 1994

File No.: 3162-2-0-1
3162-2-4-6.2

Reginald C. Gardiner, Manager
Smelter Bay Aggregates Incorporated
P.O. Box 400, Boundary Road
Industrial Park
Thessalon, Ontario P0R 1L0

Dear Mr. Gardiner:

Re **Laboratory Test Results of Samples from Your Sand and Gravel Operation, (Maple Ridge, SW 1/4, Sec. 29 and NW 1/4, Sec. 32, Twp. of Thessalon East, MAIDB No. I08-004) and Traprock from Your Quarry (SW 1/4, Sec. 23, Lefroy Twp., MAIDB No. B22-76)**

As per your request, we are forwarding the test results of five samples taken on November 09, 1993 by Z. Katona and D. Williams. Results from laboratory sample numbers 93-B-9124 and 9130 meet the OPSS quality requirements for HL1/DFC coarse aggregate. Please note that loss by washing for sample number 93-B-9130 is outside OPSS requirements for HL1 and DFC, but meets the requirements for HL3, HL4, and HL8 (max. 2.0%).

Results for laboratory sample number 93-B-9129 also meet the OPSS requirements for concrete sand. Natural fine aggregate produced from your sand and gravel operation (MAIDB No. I08-004) has been listed on our Central, Southwestern, and Northwestern Regional Structural Concrete Aggregate Sources Lists as Approved since the early 1990's. It should be noted that no more than 5% material larger than the 4.75 mm sieve is permitted in the concrete sand. For some time now, we have been subjecting your concrete sand from the sand and gravel operation (MAIDB No. I08-004) to alkali-aggregate reactivity testing to identify whether your sand is potentially deleteriously reactive. We have been utilizing the Accelerated Mortar Bar Test according to a draft CSA test method (CSA A 23.2-25A). This test method is similar to a recently-approved ASTM test method (ASTM C 1260). Over the years, the expansion results for your concrete sand have consistently been below 0.20% and 0.33% expansion at 14 and 28 days, respectively. At present, there are no standards for this test, but I consider aggregates giving less than 0.33% expansion at 28 days unlikely to be deleteriously reactive. We will continue to test your concrete sand for alkali-aggregate reactivity in the future.

Best Wishes,

Chris A. Rogers Manager,
Soils and Aggregates Section.

pc: N.J. Bell
K.C. Carter
R.G. Gorman

CAR/RGG/jlp/Attachments

Ministry of Transportation | Ministère des Transports
Ontario

ADDENDUM NO. 1

CONTRACT NO. 94-07

GRADING, DRAINAGE, GRANULAR BASE AND HOT MIX PAVING AT HWY. 401 - From 2.2 km west of Interchange 194, easterly to Interchange 208.

16.6 km LONDON DISTRICT

The following will now form part of the Special Provisions of the contract and amends the applicable information contained in the original contract tendering documents.

SPECIAL PROVISIONS (NEW)

NOTICE TO CONTRACTORS

The Contractor is advised that the Smelter Bay Aggregates Inc. quarry, Inv. No. B22-076 shown on the Designated Sources List for Materials, Asphaltic Pavement, Coarse Aggregate for HL 1 and DFC as acceptable for HL 1, is also acceptable for DFC coarse and fine aggregates for this contract.

for J.A. Bordowitz
J.E. Charpentier
Head
Contract Preparation and
Control Section

Table 1

Laboratory Test Data
Samples of HL1 and DFC Aggregates
Smelter Bay Aggregates Incorporated
MTO MAIDB No. B22-076

					Specification Limits	
Lab. Sample No.	**93-B-9123**	**93-B-9124**	**93-B-9130**	**93-B-9131**	**Coarse Aggregate**	**Fine Aggregate**
Field Sample No.	**93-VM-1063**	**93-VM-1064**	**93-VM-1023**	**93-VM-1024**		
Date Sampled	**93 11 09**	**93 11 09**	**93 11 09**	**93 11 09**		
Type of Material	DFC FA	HL1/DFC CA	DFC CA	DFC FA		
Granular P.N.		100.0	104.4		N.A.	
H.L. & Conc. P.N.		100.5	106.3		120 (max.)	
$MgSO_4$ Soundness, %		2.0	2.0	8.0	5.0 (max.)	N.A.
Los Angeles Abrasion, %		15.0	17.0		N.A.	
Absorption, %	1.521	0.587	0.469		1.0 (max.)	
Bulk Relative Density	2.833	2.912	2.919		N.A.	
Loss by Washing, %		0.60	**1.79**		1.0 (max.)	
Crushed, %		100.0	100.0		N.A.	
Flat & Elongated, %		6.0	13.0		20 (max.)	
Micro-Deval Abrasion, %	11.9	6.5	7.8	11.0	N.A.	20 (max.)
Polished Stone Value		pending	pending			
Aggregate Abrasion Value		pending	pending			
Gradation, % Passing						
16.0 mm			100.0		100	
13.2 mm		100.0	99.4		96-100	
9.5 mm	100.0	58.5	61.6	100.0	50-73	100
4.75 mm	98.6	3.2	8.6	95.4	0-10	85-100
2.36 mm	74.6		3.7	75.7		50-80
1.18 mm	50.2		3.1	51.9		25-60
600 µm	33.4		2.7	34.8		15-40
300 µm	22.3		2.2	23.4		10-25
150 µm	15.0		1.7	15.1		50-20
75 µm	10.5		1.2	10.0		2-15

CAR/RGG/Jlp/June 7, 1994/3162-2-0-1/3162-2-4-6.2

Table 1

Laboratory Test Data

	92-9062	Specification Limits H.L.1
Petrographic Number (H.L.)	100	120 (max.)
Petrographic Number (Gran.)	100	-
Magnesium Sulphate Soundness, %	2	5 (max.)
Los Angeles Abrasion, %	15	-
Absorption, %	0.57	1.0 (max.)
Relative Density	2.905	-
Polished Stone Value	50	-
Aggregate Abrasion Value	3.2	-
Petrographic Rock Type Description	diabase/trap	
Flat and Elongated Particles, %	11	20 (max.)
Wash Pass 75 μm, %	1.8	1.0 (max.)
Gradation (% passing)		
16.0 mm	100	100
13.2 mm	99.7	96-100
9.5 mm	74.7	50-73
4.75 mm	9.9	0-10

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Ontario

Ministry of Transportation

Ministère des Transports

Soils and Aggregates Section
Engineering Materials Office
1201 Wilson Avenue
Central Building, Room 311
Downsview, Ontario M3M 1J8

Tele: (416) 235-3739
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July 7, 1994

File No.: 3162-2-0-1
3162-2-4-6.2

Reginald C. Gardiner, Manager
Smelter Bay Aggregates Incorporated
P.O. Box 400, Boundary Road
Industrial Park
Thessalon, Ontario
P0R 1L0

Dear Mr. Gardiner:

Re **Approval of Your Quarry in Lefroy Township for Dense Friction Course (DFC) Coarse and Fine Aggregates, MTO MAIDB No. B22-076**

We are pleased to advise you that the above-mentioned quarry is now approved as a source of DFC coarse and fine aggregates. Accordingly, your quarry will be added to the ministry's Designated Sources for Materials List (D.S.M.) 3.05.25. While approval is effective on the date of this letter, it will take several weeks to place your quarry on the D.S.M. list. Meanwhile, bidders on our contracts are being advised by Addenda and special provisions on applicable contracts in Southwestern and Central Regions.

The approval is based on the performance of the trial section placed with your aggregates on westbound lanes of Hwy. 401 between Wellington Road and Hwy. 402, Contract No. 93-35. The trial section was inspected on April 27, 1994 by Geoff Leach, of Southwestern Region, Zoltan Katona, and myself. It was found to perform well compared to other established trap rock sources after having been in place for one winter.

It would normally take two winters of DFC test section evaluation before a decision is made on whether your source should be placed on the D.S.M. Since the results of the test section inspection were favourable after having your trap rock in place for one winter, we have decided to place your material on the D.S.M. list on a provisional basis. After the second winter, we will again inspect the DFC trial section to ensure that it is still performing as well. If performance is unsatisfactory, then your quarry will be removed from the D.S.M. list.

If you require further information, please contact our office.

Best Wishes

Chris A. Rogers, Manager,
Soils and Aggregates Section.

pc: M.D. Billings
C.M. Bond
P.R. Bryar
R.G. Gorman
M.D. MacLean
W.J. Peck
J.K. Robinson
K.K. Tam

CAR/RGG/jlp

recd Nov. 23/??

Search for Skid Resistant Aggregates in Ontario

Chris Rogers[1]

[1]Engineering Materials Office
Ontario Ministry of Transportation and Communications
Downsview, Ontario

ABSTRACT

Aggregates make up about 95% of the surface of asphaltic concrete pavements. As a result, the physical properties of the aggregates have a great influence on the skid resistance or frictional properties of the pavement. Aggregates with excellent frictional properties are required on highways with high volumes of traffic.

The frictional properties of wet pavements depend on a correct asphaltic concrete mix design and the use of satisfactory aggregates. A stable, high stone content mix design is required to give initial macrotexture. Macrotexture is the projection of coarse aggregate particles above the matrix, and is important at high vehicle speeds. The particles break the water film, and provide bulk drainage, reducing the chance of hydroplaning. The property that determines the ability of the pavement to retain this macrotexture is the aggregates' resistance to abrasion. A laboratory test to measure resistance to abrasion is the Aggregate Abrasion Value test. A good microtexture or a rough sandpaper-like feel to the aggregate particle surface is needed at all vehicle speeds to penetrate the thin water film and come in contact with the tire. A laboratory test to measure the ability of an aggregate to retain or develop microtexture is the Polished Stone Value test. Good resistance to freezing and thawing is also required. This property is measured by routine durability tests such as the Magnesium Sulphate Soundness test and Absorption test. Petrographic examination, often including the use of thin sections, is also performed.

Recent work in Ontario has involved the search for new sources of skid resistant aggregate. The techniques and procedures have included field exploration and diamond drilling of likely prospects. This is followed by laboratory testing. If results are encouraging, test sections of the aggregate are placed on the highway. Long term durability is evaluated, and actual frictional values are then measured using a skid trailer prior to approval of new sources.

The following types of rock are currently used or being evaluated for use as skid resistant aggregate: hard, angular rocks such as trap (metavolcanic), quartzite, granite and igneous gravel; hard, vesicular materials such as steel and blast furnace slags; hard, gritty rocks such as sandy carbonates and sandstones.

INTRODUCTION

Until the early 1970s, major highways in southern Ontario were normally paved with asphalt, using trap rock aggregate, or with Portland cement concrete, using locally available carbonate aggregates. With increased traffic, there has been a greater awareness of the influence of the frictional properties of pavement on safety. Since the late 1960s, major efforts have been made in Ontario to measure and improve the frictional properties of these pavements. This has included the selection and use of new types of asphalt mix, and the search for, and the selection of, new aggregate sources with improved frictional characteristics.

It has been demonstrated, in a number of studies, that an improvement in frictional properties or skid-resistance will reduce accidents caused by skidding in emergency braking, sliding in curves, or during emergency manoeuvres (in Ontario, Kamel and Gartshore 1982; in the USA, Harwood *et al.* 1976; Burchett and Rizenbergs 1982; and, in the United Kingdom, Giles *et al.* 1964). It should be noted that accident rate is also related to such factors as the geometry of the highway, the amount of traffic, sight distance, and visibility (water spray, lighting).

Direct methods of measuring frictional properties of pavement surfaces include: distance skidded by an automobile with locked wheels (ASTM E 445-76), side force friction using a mu-meter (ASTM E 670-79), or the brake force skid trailer (ASTM E 274-79). The actual friction measured varies, depending upon the technique used (Hegmon 1982), the time of year (Giles *et al.* 1964; Dahir and Henry 1979), and the weather conditions (Hill and Henry 1981). In Ontario, the brake force trailer (ASTM E 274-79) technique has been chosen.

There are also indirect measures of frictional properties. These involve measurements of the kind and amount of surface texture. Developments up until 1972 were summarized by Rose *et al.* (1972). Volumetric methods can be used for measuring the projection of coarse aggregate above the surface, or the macrotexture. The sand patch, silicone putty, or grease specimen techniques have been reviewed by Yager and Buhlmann (1982). Direct contact measurements, using stylus techniques (Orchard *et al.* 1970) have also been investigated. A remote sensing technique using stereophotography was employed in the

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United Kingdom by Sabey and Lupton (1967). In general, satisfactory correlations with skid-resistance have not been obtained with these indirect techniques. Using these techniques, only one or two textural components are measured, whereas frictional properties are determined by all the textural features of the surface.

In Ontario, a remote sensing technique has been developed, using stereo-photography, which has an excellent correlation with skid-resistance at high speeds ($r = 0.93$, $n = 195$) by Schonfeld (1970). This technique has been adopted by ASTM (ASTM E 770-80). A number of surface properties, such as angularity and amount of coarse aggregate, projection of coarse aggregate above the surface, microtexture of the coarse aggregate, and matrix are recognized and measured (Schonfeld 1974; Holt and Musgrove 1977). Subsequent work on this technique has been directed toward automation of the collection of data (Howerter and Rudd 1976; Holt and Musgrove 1982).

The use of indirect measurement techniques allows the recognition of those properties that improve friction, and, subsequently, enable design modifications of the asphaltic concrete, or a change in aggregate type, to improve friction. As a result of work using indirect measurements, it has been recognized that there are two basic properties, macrotexture and microtexture, required to give a pavement satisfactory friction. Macrotexture, or projection of coarse aggregate above the surface, provides bulk water drainage and reduces the tendency of tires to hydroplane on wet surfaces at high speeds. Good microtexture, or the "sandpaper-like feel" of the surface, is important at all speeds in penetrating the remaining thin water film and coming in contact with the tire. Aggregates make up about 95% of asphaltic concrete, thus the nature and properties of the aggregate determine the subsequent frictional performance of asphalt pavements.

ONTARIO ASPHALT PAVEMENT TYPES

On secondary highways, with generally less than 2,500 AADT/lane (Annual Average Daily Traffic), the types of asphaltic concrete used for the surface course are designated as HL3 (hot-laid) or HL4 (Table 1). The coarse aggregate physical test requirements are shown in Table 2. HL3 aggregates have a maximum size of 13.2 mm, allowing a minimum mat thickness of about 25 mm, but normally 38 mm. HL4 aggregates have a maximum size of 16.0 mm, allowing a minimum mat thickness of about 30 mm, but normally 44 mm. There is, except in parts of northern Ontario, no requirement as to the frictional properties of the aggregates.

In northern Ontario, most locally available aggregates are of igneous or metamorphic origin, with hard wear-resistant minerals. These aggregates generally give good frictional properties in contrast to pavements made with carbonates of low wear-resistance. Drivers become used to the good friction supplied by the local aggregates. When carbonate aggregates of relatively poor frictional properties are used for paving, the frictional properties, compared to granitic pavements, have been poorer, yet driver behaviour, used to the better friction, has not been modified. The result has been an increase in complaints about the friction of the road surface in these locations. The level of friction required in any area depends, to a large extent, on driver behaviour and expectations, as much as on road geometry and traffic volumes. As a result, in many parts of northern Ontario, where granitic aggregates are commonly used, the use of aggregate containing carbonate rocks is prohibited.

TABLE 1. PRINCIPAL TYPES OF SURFACE COURSE ASPHALT MIX USED IN ONTARIO

MIX TYPE	MAXIMUM STONE SIZE	NORMAL STONE CONTENT PERCENT	FINE AGGREGATE TYPE	AADT*
HL4	16.0 mm	40 – 50	natural sand	<2500
HL3	13.2 mm	40 – 50	natural sand	<2500
HL1	13.2 mm	40 – 55	natural sand	>2500 <5000
D.F.C.	13.2 mm	45 – 55	angular screenings	>5000
O.F.C.	9.5 mm	65 – 70	angular screenings	>5000 Urban

* Annual Average Daily Traffic

TABLE 2.
PHYSICAL REQUIREMENTS FOR COARSE AGGREGATE FOR PRINCIPAL ASPHALT SURFACE COURSE MIXES

PHYSICAL TEST	ASPHALT MIX TYPE HL1	HL3	HL4
Los Angeles Abrasion & Impact Test, % Max. Loss	15	35	35
Magnesium Sulphate Soundness Test, % Max. Loss	5	12	12
Absorption by Weight, % Max.	1.0	1.75	2.0
Petrographic Number, Max.	100	135	160
Loss by Washing Pass 75 μm Sieve, % Max.	1	1.3*	1.3*
Flat and Elongated Particles, % Max.	20	20	20
Crushed Particles, % Min.	100	60	60

* When Quarried Rock is Used, a Maximum of 2% is permitted

On highways carrying more than 2,500 AADT/lane, the types of asphalt used are designated as HL1, DFC (dense friction course), or OFC (open friction course) (see Table 1). HL1 asphalt has the same gradation as HL3, only the nature of the stone is different. DFC has angular fine aggregates to increase stability, and to prevent the embedment of the stone into the mat. OFC is an open graded mix, allowing internal drainage through the matrix rather than over the pavement surface. This prevents a buildup of water on the pavement surface, which reduces the likelihood of hydroplaning at high speeds, reduces water spray, and also reduces tire noise. It is used on very high volume, urban highways.

The selection of the coarse aggregate for HL1, DFC, and OFC pavements is based on actual performance of the aggregate in test sections. At present, the following aggregate types are used: trap rock (metavolcanic), steel slag, blast furnace slag, dolomitic sandstone, and some igneous gravels from the north shore of Lake Huron.

SEARCH FOR NEW AGGREGATE SOURCES

In the years 1979, 1980, and 1981, an annual average of 250,000 tonnes of HL1, DFC, and OFC aggregates were used in Ontario. The Ministry of Transportation and Communications (MTC) uses about 15 million tonnes of aggregates every year for highway construction. Thus, the supply of skid resistant aggregates is a small specialized market. Producers have not found it worthwhile to open a deposit devoted exclusively to the supply of these specialized aggregates. These aggregates are usually the waste by-products of mining and smelting operations; Trap rock from iron mining or roofing granule operations, and slags from iron or steel production. As a result, supply is controlled by economic considerations unrelated to the needs of highway construction. Thus, cutbacks in the steel industry or closing of an iron mine have had an adverse effect on the supply of these aggregates. In recognition of these problems of supply, alternative sources were investigated.

Three criteria were established for selecting new sources: (1) the source should be an open deposit, preferably with production facilities; (2) the sources should be closer to the area of use than those currently available to reduce haulage, an ever-increasing component of the cost of aggregate, and (3) the sources should have frictional properties as good as, or better than, those currently available.

A literature review was conducted (Truax-Harrison 1979). The purpose was to recognize the properties and nature of potential aggregate sources, and to find those test methods most suitable for measuring frictional properties of aggregates.

WEAR-RESISTANCE (MACROTEXTURE)

Macrotexture is determined by the wear-resistance of the aggregate, and also by the mix design of the asphaltic concrete. On heavily used pavements, a high stone content, in a mix of high stability, is required to resist the embedment of the coarse aggregate into the mat by the repeated impact of tires (Ryell *et al.* 1979; Clark 1980). The high stability is achieved by using an angular fine aggregate, such as crusher screenings or manufactured sand. Rounded sand from gravel deposits does not normally give high stability, due to its lack of angularity and its rather smooth or polished surfaces.

The ability of rock to resist abrasion is determined by the hardness of the constituent mineral grains and the strength of the bond between them. A quartz sandstone of Moh hardness 7 has excellent resistance to natural abrasives found on the pavement, but only if the individual grains are well-bonded together (usually with calcite or dolomite cement). Poorly cemented, friable sandstones have low resistance to abrasion, and are unsuitable, despite the hardness of the individual grains.

Figure 1 shows the typical Moh hardness of various minerals, rock types, and abrasive agents found in Ontario. MTC uses about 1 million tonnes of ice control sand annually. This sand usually contains significant amounts of quartz and other hard materials. These minerals are a potent abrasive, especially on the carbonate rocks commonly used for HL3 and HL4 paving in Southern Ontario. Tire studs with a Moh hardness of 9 also have considerable abrasive power, even on igneous rocks. It was this factor which led to their prohibition in Ontario (Smith and Schonfeld 1972).

The test selected as the most suitable for measuring wear-resistance was the Aggregate Abrasion Value (AAV) test (BS 812, 1975). This is a modern development of the old Dorry abrasion test (Knight and Knight 1948). Two test specimens are made. Each specimen consists of at least 24 cubical particles, passing the 13.2 mm, and retained on the 9.5 mm sieve, held in an epoxy binder. These specimens are laid aggregate face down on a 600 mm diameter steel lap (Figures 2, 3). Each specimen is held down with a 2 kg weight. The lap is rotated for 500 revolutions at a speed of 30 revolutions/min. A coarse sand is fed onto the lap at a rate of 800 g/min in front of each specimen. The abrasive used in Ontario is Ottawa silica sand (ASTM C 109). The mass loss of each specimen in the test is recorded. The result reported is expressed as the percentage loss (in mass) of an assumed 33 ml volume of the aggregate. The lower the value obtained in the test, the more resistant the aggregate is to abrasion.

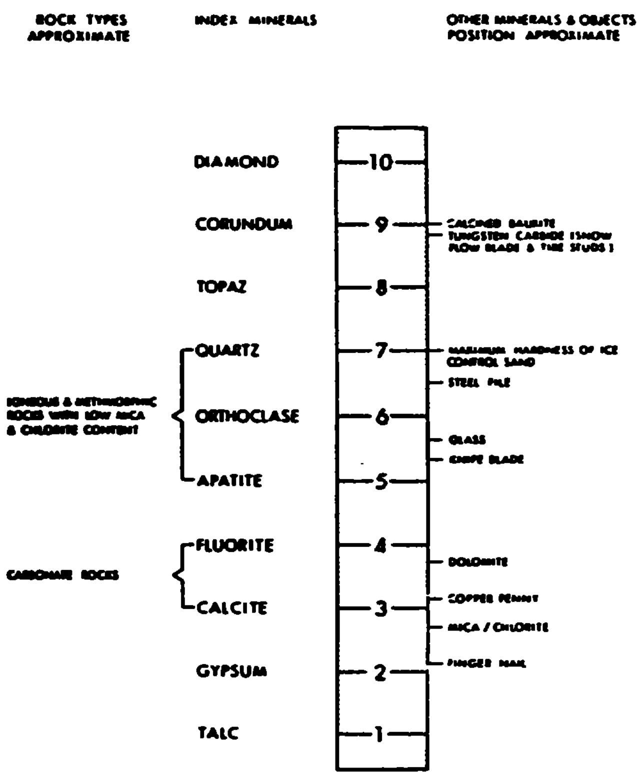

Figure 1. Mohs scale of hardness.

Figure 2. Aggregate abrasion value machine.

In the United Kingdom, the standard abrasive used in this test is Leighton Buzzard sand. A short study was done on the correlation between results obtained using the Leighton Buzzard sand and Ottawa sand. Twenty different aggregates were selected and tested using both sands. The rate of flow of the sand was regulated to 800 ± 10 g/min. The results are shown in Table 3 and Figure 4. It can be seen that there is an excellent correlation between the results obtained using the two different abrasives.

The Aggregate Abrasion Value (AAV) test is a more realistic measure of the resistance of aggregate to surface abrasion than other so-called abrasion tests, such as the Los Angeles Abrasion and Impact Test. The mechanism employed in the test and the abrasive used reflect, to some degree, the actual conditions found on pavement surfaces: abrasion caused by tires, ice control sand and other debris. In the United Kingdom, Hosking (1973) found that one unit of AAV was equivalent to a difference of 0.05 mm in texture depth after nine years of heavy traffic.

POLISH RESISTANCE (MICROTEXTURE)

Polish resistance is much harder to measure and predict than wear-resistance. Microtexture is the fine scale (less than 0.5 mm) texture possessed or developed by the individual aggregate particles. It may be thought of as the "sandpaper-like feel" of the particle. Most materials, when freshly crushed, have a good microtexture. Desirable aggregates are those that either resist loss of this texture or behave in such a manner as to regenerate this texture. These are generally termed "polish-resistant aggregates".

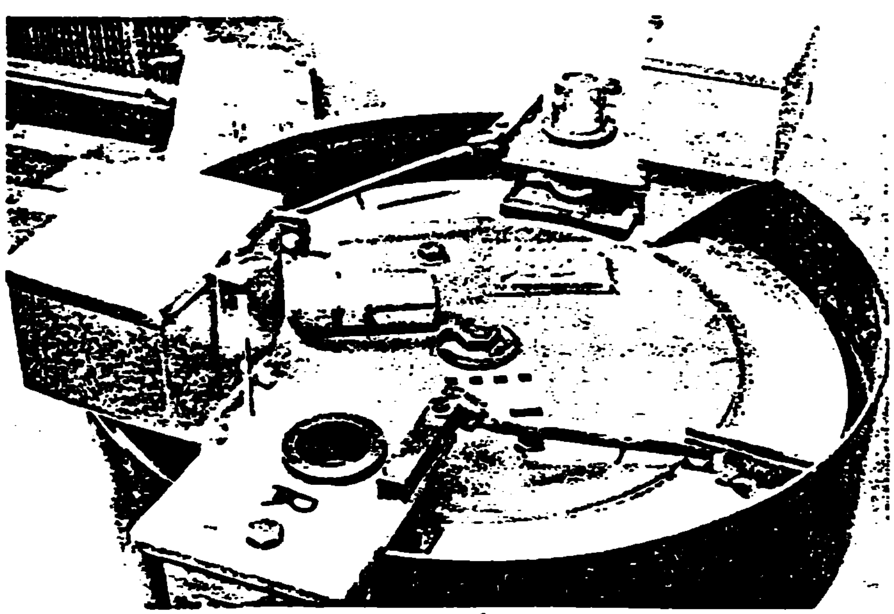

Figure 3. Aggregate abrasion value machine showing the steel lap, abrasive sand feeders and aggregate test sample.

TABLE 3. AGGREGATE ABRASION VALUES USING LEIGHTON BUZZARD AND OTTAWA SILICA SAND ABRASIVES

AGGREGATE TYPE	LABORATORY TEST			
	AGGREGATE ABRASION VALUE		POLISHED STONE VALUE	RELATIVE DENSITY
	LEIGHTON BUZZARD	OTTAWA C 109		
Blast furnace slag	19.1	18.0	54	2.24
Trap rock	2.2	2.5	44	3.03
Trap Rock	2.5	2.7	45	2.95
Dolomitic sandstone	4.2	4.0	62	2.64
Sandstone	9.3	9.8	68	2.50
Blast furnace slag	16.1	15.2	52	2.19
Sandy limestone	47.6	38.5	72	2.43
Quartzite	2.0	2.1	40	2.64
Dolostone	10.1	10.4	36	2.81
Gabbro	3.0	2.7	46	2.88
Gravel, granite	2.1	2.0	45	2.73
Granite	4.5	4.4	52	2.62
Granite gneiss	7.3	6.1	58	2.81
Sandstone	14.4	15.0	67	2.38
Gabbro	3.0	3.3	45	3.01
Steel slag (B.O.F.)	2.9	3.2	58	3.33
Blast furnace slag	16.2	14.5	51	2.09
Steel Slag (B.O.F.)	3.6	5.1	59	2.97
Limestone	24.7	22.9	51	2.50
Synopal	3.1	3.9	48	2.02

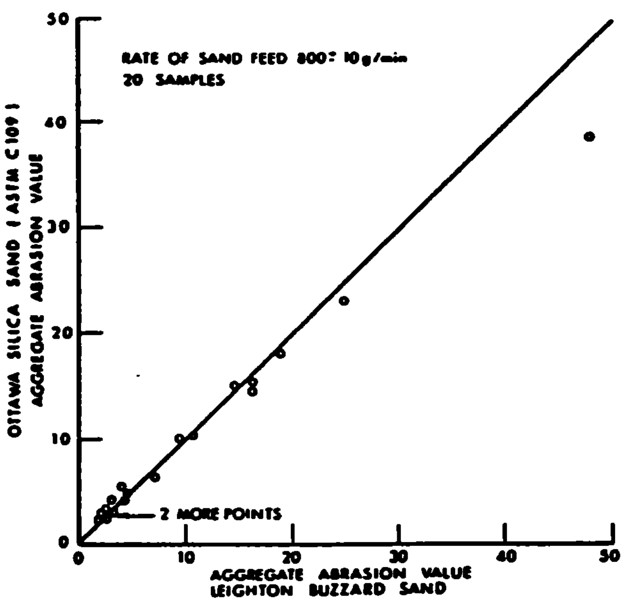

Figure 4. Aggregate abrasion value with Ottawa silica sand plotted against Leighton Buzzard sand.

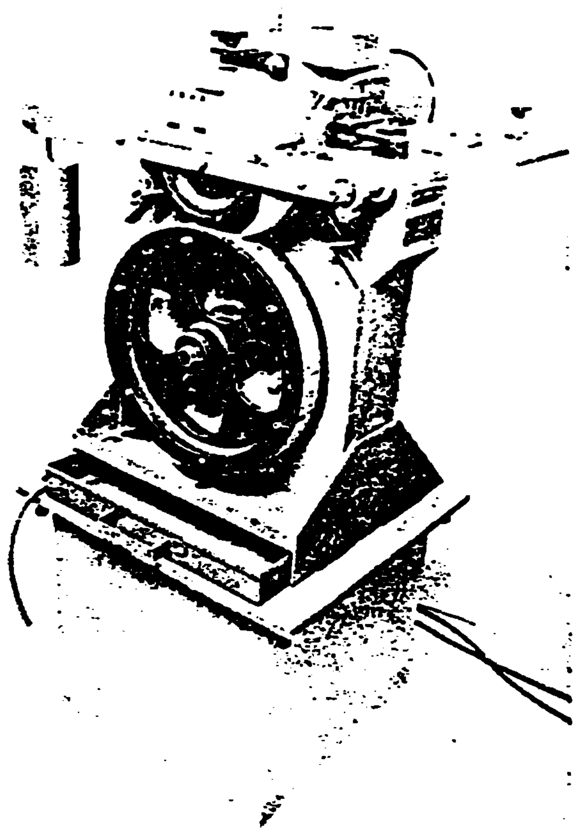

Figure 5. Polished stone value machine.

The microtexture developed by an aggregate is not only a function of the physical nature of the material, but is also a function of the environment in which it is used. The amount of traffic, the nature and availability of abrasives and climatic conditions all determine the degree to which an aggregate will polish, and the microtexture that will be developed. Response of the aggregate to these environmental conditions is determined by such attributes as mineralogy, grain size and grain size distribution, and the porosity and pore size distribution of the individual particles.

The test selected as being the most suitable for evaluating microtexture was the Polished Stone Value (PSV) test (BS 812, 1975). This accelerated polishing technique was developed in the United Kingdom (Maclean and Shergold 1959), using a sliding pendulum to measure the frictional properties of the aggregate after three hours of abrasion with coarse emery, and three hours of polishing with a fine emery powder (Figures 5, 6, 7). This test has been extensively investigated, both in the United Kingdom (Hosking 1968), and in the USA (Underwood *et al.* 1971). The higher the PSV obtained in the test, the better the frictional properties of the aggregate.

A major drawback of the PSV test is that the final polish with the fine abrasive does not always create the polish experienced in the field. The emery powder used for the final three hours of the test may continue to abrade softer aggregate particles, rather than polishing them to the same degree as is experienced under field conditions. This sometimes results in a PSV higher than warranted by the field performance. The softer, porous carbonate rocks are susceptible to this problem. Quartzites and blast furnace slag may also give misleading results. Hosking (1973) showed that frictional properties of pavements made with these two aggregate types were equivalent to those made with aggregates which were 3 PSV units higher. In other words, the PSV test underestimates the frictional properties of quartzites and blast furnace slag by 3 units. The field performance and AAV of aggregates must be considered together with PSV before selection for use in asphaltic concrete.

Despite these anomalies, it has been shown by Maclean and Shergold (1959), and Szatkowski and Hosking (1972) that the PSV is the most important aggregate characteristic affecting skidding resistance of asphalt pavements. Studies in Ontario have confirmed the significance of PSV of aggregates in determining frictional properties of pavements (Heaton *et al.* 1978; Kamel *et al.* 1982).

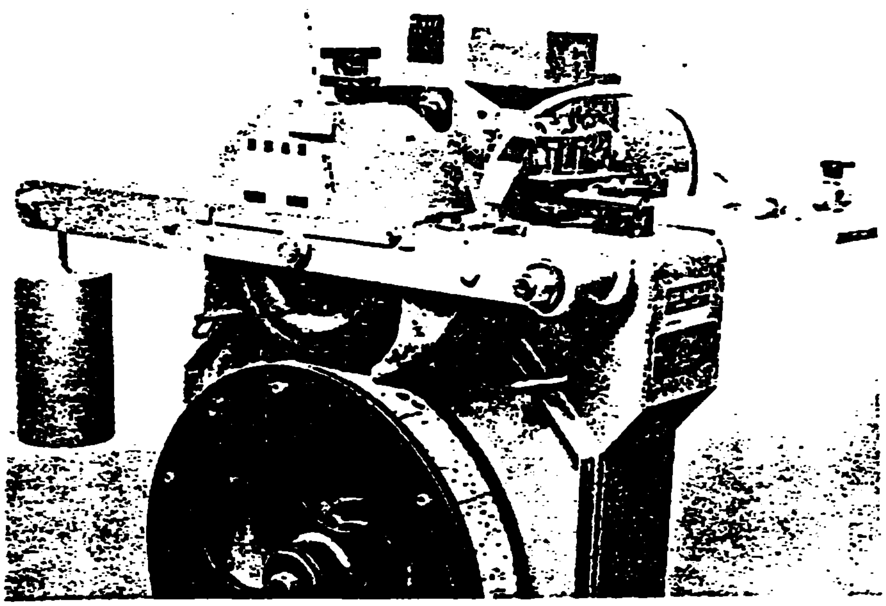

Figure 6. Polished stone value machine showing road wheel with aggregate samples.

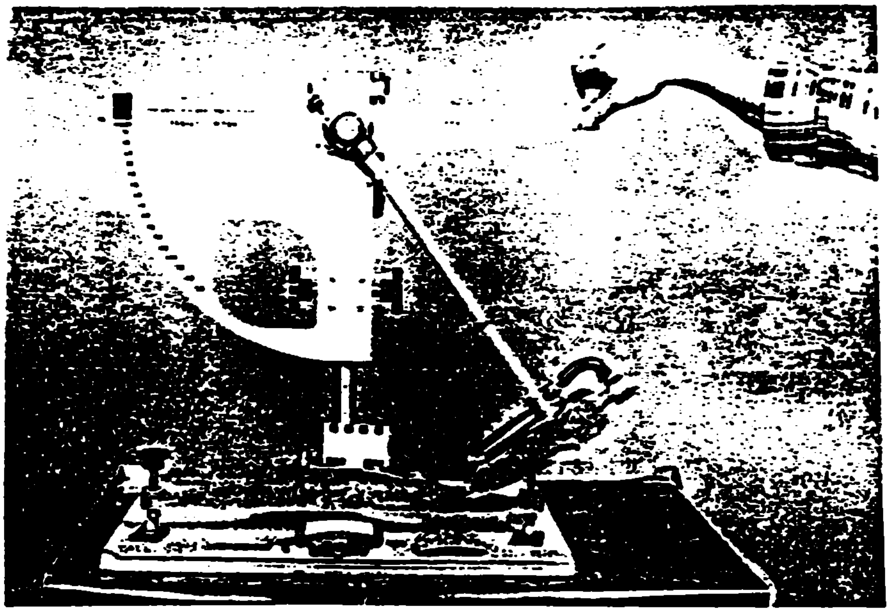

Figure 7. Portable skid resistance tester used for evaluating frictional properties of aggregate following the polishing test. Rubber pad on base of swinging arm strikes aggregate sample. The frictional value is recorded by pointer on the scale.

FIELD WORK

Following the literature review, and a review of the performance of some existing pavements, a number of rock types were identified as targets for exploration and evaluation. These were: basaltic rocks such as diabase and gabbro, granites, calcareous sandstones and slags. Study of existing geological maps and reports led to the identification of likely deposits. These deposits were visited, and samples taken. In unexposed or undeveloped deposits, diamond drilling was conducted (Rogers 1980). Generally, only those deposits were studied where subsequent commercial production was viable. In addition, a general survey of the frictional properties of Ontario aggregates was also conducted. The location of the deposits tested are shown in Figure 8.

LABORATORY TESTING

Samples were subjected to normal aggregate durability tests such as: Magnesium Sulphate Soundness (MTC-LS-606), Los Angeles Abrasion and Impact (MTC-LS-603), Absorption and Bulk Relative Density (MTC-LS-604), Petrographic Examination (MTC-LS-609), and Polished Stone and Aggregate Abrasion Value tests (BS-812, 1975). In the case of calcareous sandstones, sandy carbonates, and carbonate gravels, an insoluble residue test (MTC-LS-613) was conducted. Detailed petrographic examination involving the study of thin sections was also carried out. The results of testing are shown in Table 4.

CRITERIA FOR SELECTION

For further investigation, the criteria in Table 5 had to be met or exceeded. The owner or operator of the deposit also had to be interested in subsequent commercial production. Note that the values given in this table are limiting values, and not necessarily the most desirable values. For instance, in the case of PSV, the higher the value, the better. Note that the Los Angeles Abrasion and Impact Test was not used. Many excellent materials, such as blast furnace slag, granites, and granite gneiss, gave values that exceeded the 35% maximum loss normally allowed in Ontario.

IMPLEMENTATION

Following the identification of likely sources, the economics were considered. If the use of a new source would lead to immediate savings in cost compared to currently available sources, a decision was made to authorize immediate use, with test sections being placed on the first contract. Alternatively, a decision was made to construct a trial test section to evaluate long-term durability and frictional performance before further use was considered. Not all test sections have been constructed to evaluate the aggregates alone; they are also used to evaluate the effectiveness of various types of asphalt mix design (Ryell *et al.* 1979; Kamel *et al.* 1982).

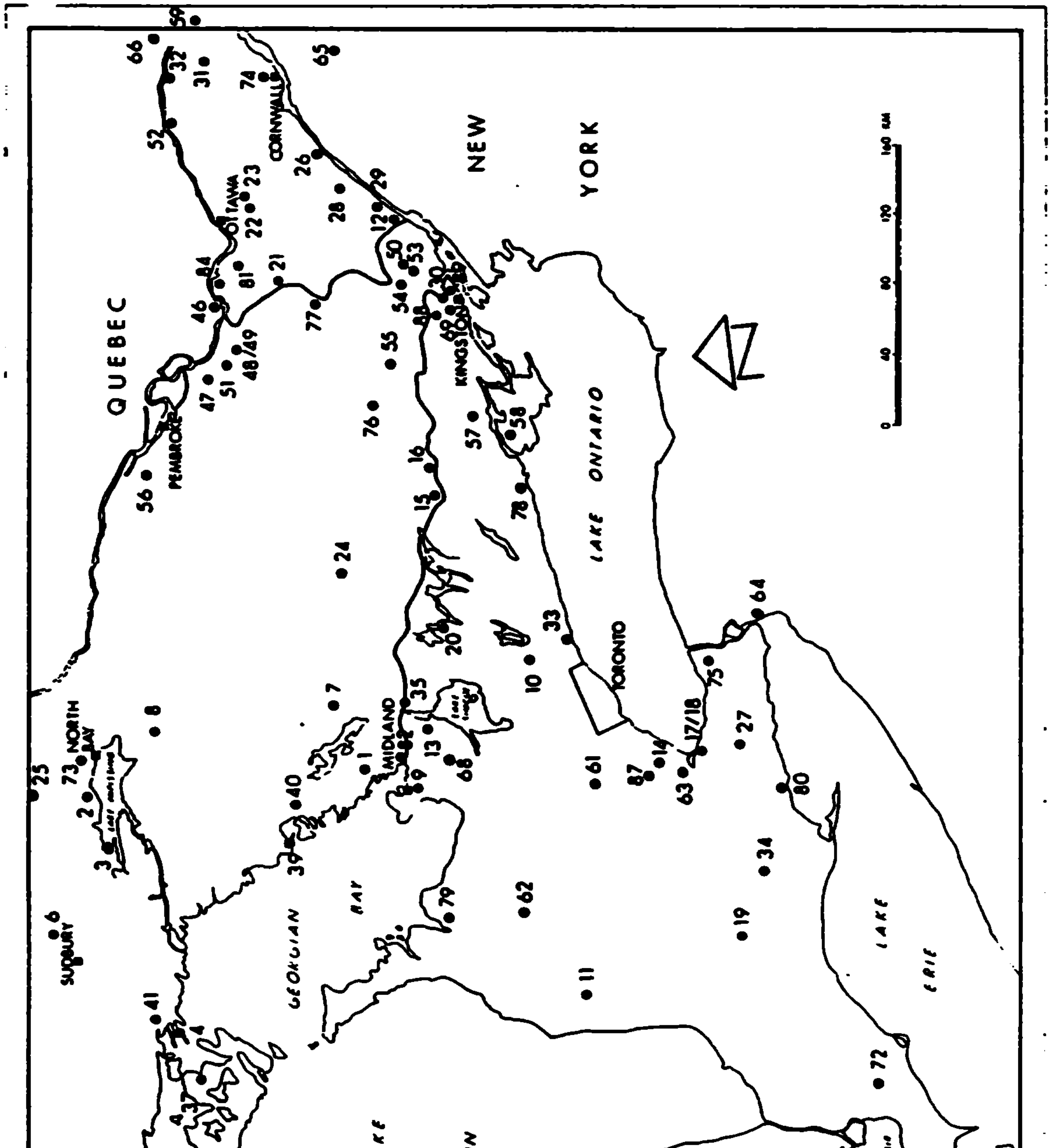

Figure 8. Aggregate sample locations. Results of laboratory tests are given in Table 4.

TABLE 4. LABORATORY TEST DATA FOR AGGREGATE SAMPLES FROM ONTARIO. SAMPLE LOCATIONS ARE GIVEN IN FIGURE 8.

SOURCE DATA							LABORATORY TEST DATA							
LOC NO.	SOURCE NAME	Q	G	NTS MAP NAME	GRID REF.	AGGREGATE TYPE	PSV	AAV	$MgSO_4$ % loss	L.A. ABR % loss	ABS* %	RELATIVE DENSITY	PETRO. NO.	INSOL. RES %
1	M.T.C.	X		Penetanguishene	962790	Granite gneiss	47	–	0	30	0.35	2.77	104	–
2	Bourassa	X		Sturgeon Falls	953385	Granite gneiss	47	–	1	33	0.53	2.64	119	–
3	Perrault	X		Verner	635296	Granite gneiss	47	–	0	39	0.50	2.65	104	–
4	Indusmin	X		Little Current	545900	Quartzite	42	2.1	0	22	0.30	2.64	100	–
4	Indusmin	X		Little Current	545900	Diabase	46	4.0	2	14	0.62	2.97	118	–
5	M.T.C.		X	Iron Bridge	127274	Granite, volcanic, greywacke	46	1.5	1	13	0.40	2.75	100	–
6	Pioneer		X	Capreol	150615	Greywacke & granite	45	–	0	14	0.47	2.71	102	–
7	Fowler		X	Bracebridge	345935	Granite gneiss	45	–	4	43	0.60	2.68	141	–
8	Ciglen		X	South River	276924	Gneiss & granite	49	5.4	4	47	0.73	2.67	115	–
9	Cedarhurst		X	Elmvale	888527	Carbonate & gneiss	45	–	4	27	0.92	2.67	120	37
10	Miller		X	Newmarket	523808	Carbonate	41	–	3	23	0.70	2.66	121	<20
11	Whitechurch		X	Wingham	648619	Carbonate	41	–	6	23	2.16	2.58	131	13
12	Henderson	X		Brockville	370295	Sandy dolostone (March)	59	4.2	5	15	0.85	2.65	110	53
13	Uhthoff	X		Orillia	195495	Limestone (Gull River)	42	–	7	20	0.91	2.68	101	1
14	Nelson	X		Hamilton	905060	Dolostone (Amabel)	45	–	2	28	1.54	2.69	102	0.1
15	3M	X		Campbellford	755245	Trap (Metavolcanic)	46	3.5	0	14	0.37	2.90	112	–
16	Armbro	X		Campbellford	890270	Trap (Metavolcanic)	45	2.0	2	13	0.40	3.02	105	–
17	National Slag	–	–	Hamilton	993903	Blast Furnace slag (Air cooled)	52	15	2	44	4.32	2.09	–	–
18	Dofasco Red-D-Mix	–	–	Grimsby	021876	Steel slag (BOF)	58	3.2	1	17	2.05	3.33	–	–
19	Warren		X	Lucan	873689	Carbonate	43	–	2	24	1.27	2.64	128	<20
20	Royal		X	Lindsay	751278	Carbonate	43	–	3	27	0.97	2.65	117	<20
21	Duffy	X		Carleton Place	105015	Dolostone (Oxford)	47	6.7	1	–	0.75	2.74	117	12
21	Duffy	X		Carleton Place	105015	Dolomitic sandstone (March)	57	5.0	1	18	0.58	2.61	111	79
22	Armbro	X		Ottawa	545165	Dolomitic sandstone (March)	58	5.1	5	27	0.67	2.64	127	60
22	Armbro	X		Ottawa	545165	Dolostone (Oxford)	47	8.2	2	19	0.70	2.75	108	
23	Drummond	X		Ottawa	566160	Dolomitic sandstone (March)	60	5.1	6	45	0.57	2.63	136	67
24	Friar		X	Wilberforce	030907	Granite & gneiss	50	6.4	3	43	0.57	2.67	158	–
25	M.T.C.		X	Ingall Lake	917818	Granite & greywacke	45	3.0	1	14	0.60	2.74	104	–
26	Fetterly	X		Morrisburg	733635	Weathered dolostone (Oxford)	58	20.4	41	24	3.55	2.57	198	–
27	Oneida	X		Dunnville	860560	Calcitic sandstone (Oriskany)	64	6.1	2	29	1.26	2.55	107	53
28	M.N.R.	X		Merrickville	573590	Quartzite	47	3.2	1	33	0.40	2.63	100	–
29	Permanent	X		Brockville	475395	Dolomitic sandstone (March)	60	6.0	17	38	0.90	2.62	149	59
30	Hughes	X		Gananoque	900116	Sandstone (Potsdam)	68	9.8	32	81	1.58	2.50	337	96
31	Kennedy	–	–	Alexandria	233303	Sandstone (Rockcliffe)	63	–	12	–	1.92	2.55	122	85
32	I.M.S.	–	–	Hawkesbury	295510	Steel slag (Electric arc)	53	3.6	2	21	2.07	3.18	–	–
33	I.M.S.	–	–	Oshawa	679575	Steel slag (Electric arc)	53	3.1	0	23	2.25	3.15	–	–
34	Stelco	X		Woodstock	124690	Sandy limestone (Columbus)	72	39	24	59	3.72	2.42	224	24
35	Rama	X		Orillia	317532	Granite/Meta-arkose	53	4.4	7	42	0.50	2.64	115	–
36	Rankin	X		Sault Ste. Marie	054609	Sandstone (Root River, Jacobsville)	65	–	5	29	2.20	2.44	113	–

TABLE 4. CONTINUED

SOURCE DATA LOC NO.	SOURCE NAME	Q	G	NTS MAP NAME	GRID REF.	AGGREGATE TYPE	LABORATORY TEST DATA PSV	AAV	$MgSO_4$ % loss	L.A. ABR % loss	ABS* %	RELATIVE DENSITY	PETRO. NO.	INSOL. RES %
37	Rolston	X		Little Current	295835	Quartzite	42	–	1	26	0.30	2.63	100	–
38	Maple Ridge		X	Iron Bridge	129283	Granite, volcanic, greywacke	45	2.0	1	12	0.50	2.73	102	–
39	M.N.R.	X		Parry Sound	599238	Granite/meta-arkose	50	–	3	60	0.43	2.60	117	–
40	Macklaim	X		Sequin Falls	800225	Gneiss & diorite	48	4.0	3	35	0.50	2.85	135	–
41	Lawson	X		Whitefish Falls	435075	Quartzite	41	2.4	1	–	0.38	2.64	100	–
42	Beamish		X	Algoma	505189	Arkosic sst. & granite	50	2.2	1	–	0.43	2.69	110	–
43	J. Heidgen	X		Bruce Mines	868305	Diabase/gabbro	46	2.7	1	13	0.43	2.73	100	–
44	Bar River	X		Lake George	302472	Quartzite	41	1.9	1	–	0.23	2.63	100	–
45	McLean		X	Sault Ste. Marie	978606	Granite, gneiss & volcanic	47	2.0	2	13	0.53	2.77	100	–
46	Hilton Mines	X		Arnprior	955387	Granite & gneiss	47	3.3	4	22	0.73	2.66	135	–
47	Rock Cut	–	–	Cobden	600430	Gabbro	47	3.4	2	15	0.40	3.05	100	–
48	Rock Cut	–	–	Renfrew	810330	Gneiss	58	6.1	5	40	0.64	2.81	105	–
49	Rock Cut	–	–	Arnprior	8332	Calcareous gneiss	49	3.3	2	24	0.50	2.66	113	92
50	Wiesener	X		Gananoque	080265	Sandstone (Potsdam)	67	15.0	16	55	2.57	2.38	171	96
51	Jamieson		X	Renfrew	720360	Granite, marble, gneiss	46	3.1	3	22	0.74	2.70	108	–
52	Rock Cut	–	–	Hawkesbury	052535	Gneiss	63	8.2	3	22	0.97	2.73	170	–
53	Rock Cut	–	–	Gananoque	047227	Granite	48	4.1	1	30	0.53	2.62	104	–
54	Brown	X		Westport	295045	Coarse grained granite	44	2.9	1	29	0.47	2.66	100	–
55	Mountain Grove	X		Tichborne	5455	Gabbro	45	3.3	1	–	0.33	3.01	100	–
56	Hoffman		X	Pembroke	203837	Gneiss & granite	51	5.0	5	29	0.80	2.63	111	–
57	McGrogan	–	–	Belleville	193968	Limestone (Bobcaygeon)	51	23	–	32	2.37	2.50	100	0.3
58	Rock Cut	X		Belleville	075844	Granite	47	1.9	–	23	0.50	2.64	100	–
59	Mont Rigaud		X	Vaudreuil	5430	Granite	49	2.9	2	26	0.84	2.60	113	–
60	Manitoulin Dol	X		Meldrum Bay	277863	Dolostone (Amabel)	36	10.4	3	25	0.40	2.81	100	0
61	Caledon		X	Bolton	816556	Carbonate, sandy, granite	46	8.2	10	26	1.37	2.62	135	<40
62	Durham		X	Durham	157907	Carbonate	44	–	3	26	1.44	2.68	116	<10
63	Steetley (Stelco)	–	–	Hamilton	935820	Steel slag (BOF)	59	5.1	4	22	1.84	2.97	–	–
64	Bethlehem	–	–	Lackawana, N.Y.		Steel slag (BOF)	60	3.5	2	22	2.24	3.19	–	–
65	Hannawa	X		Potsdam, N.Y.		Sandstone (Potsdam)	67	9.9	59	61	2.90	2.44	172	–
66	Whissell	X		La Chute	545625	Gneiss	47	2.8	3	21	0.47	2.72	100	–
67	E.C. Levy	–	–	Detroit	–	Steel slag (BOF)	57	3.3	2	20	1.47	3.44	–	–
67	E.C. Levy	–	–	Detroit	–	Blast furnace slag (air cooled)	54	13.1	4	42	3.91	2.34	–	–
68	Beamish		X	Elmvale	010360	Limestone & granite	50	5.5	5	26	0.66	2.67	124	39
69	Glen Lawrence	X		Gananoque	804045	Limestone (Gull River)	42	9.5	7	24	0.44	2.70	135	<5
70	Presquile	X		Michigan	–	Carbonate (Devonian)	48	11.4	1	26	1.38	2.57	108	1
71	Calcite (U.S. Steel)	X		Michigan	–	Carbonate (Devonian)	49	18.7	3	–	1.84	2.49	127	0.5
72	Huron		X	Chatham	150973	Carbonate & granite	42	5.2	2	21	0.84	2.68	134	30
73	Standard		X	North Bay	160433	Gneiss & granite	51	3.8	1	28	0.43	2.68	109	–
74	MacLeod	X		Cornwall	200915	Limestone (Gull River)	44	9.3	5	21	0.37	2.70	109	5
75	Walker Bros	X		Niagara	485770	Dolostone (Lockport & Decew)	52	11.2	17	24	1.54	2.67	113	–
76	W.L. Wise		X	Mazinaw Lake	277624	Gneiss & granite	51	5.2	4	37	0.80	2.61	144	–
77	Lanark S & G		X	Carleton Place	945887	Marble, gneiss & granite	49	6.9	8	37	0.97	2.69	123	
78	Trent Valley		X	Trenton	745785	Limestone	40	6.7	2	21	0.60	2.68	115	
79	Sydenham	X		Owen Sound	110350	Dolostone (Amabel)	48	13.5	2	31	1.47	2.64	101	

TABLE 4. CONTINUED

SOURCE DATA LOC NO.	SOURCE NAME	Q	G	NTS MAP NAME	GRID REF.	AGGREGATE TYPE	LABORATORY TEST DATA PSV	AAV	$MgSO_4$ % loss	L.A. ABR % loss	ABS[n] %	RELATIVE DENSITY	PETRO. NO.	INSOL RES %
80	Stelco	–	–	Simcoe	760400 (APPROX)	Steel slag (BOF)	58	3.9	1	15	2.21	3.19	–	–
81	Smith	–	–	Ottawa	258245	Sandstone (Nepean)	54	4.5	9	44	1.63	2.50	131	>80
82	Cook	X		Penetanguishene	065584	Limestone (Gull River)	50	8.4	7	17	1.49	2.65	113	<10
83	Fowler		X	Bracebridge	345920	Gneiss & granite	48	5.6	4	41	0.53	2.66	114	–
84	Kennedy	X		Arnprior	217320	Calcite Siltstone	58	10.7	32	25	1.81	2.62	158	84
85	Allied Chem	X		Amherstburg	340694	Carbonate	46	15.4	2	28	1.07	2.63	103	<10
86	Smith	X		Amherstburg	276626	Carbonate	57	18.6	16	34	4.72	2.41	125	<10
87	Longstar		X	Hamilton	813143	Carbonate & Sandstone	53	10.2	17	21	1.61	2.61	156	–
88	Elginburgh	X		Sydenham	756078	Limestone (Gull River)	41	11.8	6	25	0.33	2.70	114	<10
89	Pittsburgh	X		Gananoque	835020	Limestone (Gull River)	44	8.1	12	18	0.84	2.70	111	<10
						NORTHERN ONTARIO & SPECIAL MATERIALS								
	Zysko	X		Thunder Bay	401730	Diabase	49	3.6	–	16	0.93	2.95	100	–
	Hamilton	X		Jarvis River	169316	Diabase	51	4.2	–	–	–	2.92	100	–
	M.T.C.		X	Temagami	863256	Greywacke & granite	46	2.4	–	–	0.57	2.74	106	–
	Pearl Lake	X		Loon	788923	Granite	45	–	0	27	0.40	2.61	100	–
	------	–	–	------	---	Synopal	48	3.9	1	19	1.77	2.02	–	–
	------	–	–	------	---	Expanded shale	65	29	–	–	7.66	1.51	–	–
	M.T.C.		X	Nassau Lake	940125	Carbonate & greywacke	45	3.8	4	20	2.11	2.55	185	–
	Marblehead	X		Ohio	–	Limestone	52	16.7	12	31	2.64	2.56	109	–
	M.T.C.		X	Pickerel Lake	158004	Granite & volcanic	47	2.7	1	14	0.53	2.71	113	–
	Grann		X	Loon	760901	Granite & sandstone	53	3.8	12	25	1.04	2.61	115	–

Q = Quarry Source, G = Gravel source, PSV = Polished Stone Value, AAV = Aggregate Abrasion Value, $MgSO_4$ = Magnesium Sulphate Soundness Test, L.A. ABR = Los Angeles Abrasion and Impact Test, ABS[n] = Absorption, PETRO NO. = Petrographic Number, INSOL RES = Insoluble residue +75µm

TABLE 5. LIMITING TEST VALUES USED TO SELECT SOURCES FOR SUBSEQUENT INVESTIGATION

TEST METHOD	LIMITING VALUE
Magnesium Sulphate Soundness, Max. %	12
Absorption (natural aggregates), Max. %	2
Polished Stone Value (PSV) Min.	50
Aggregate Abrasion Value (AAV), Max.	6
Petrographic Number, Max.	145
Insoluble Residue Retained on 75 μm sieve (sandy carbonates only), Min. %	45

The frictional properties of these test sections are normally measured using a brake force skid trailer (ASTM E 274-79). Remote sensing (Holt and Musgrove 1977) and the mu-meter (ASTM E 670-79) techniques have also been used.

Long term durability has been evaluated by field inspection and remote sensing, to observe ravelling and aggregate surface loss due to freezing and thawing or asphalt stripping, and by Benkleman Beam to evaluate wear leading to wheel track rutting. Samples of the pavement were also taken to check for compaction, voids, correct mix proportions, and Marshall stability.

RESULTS

Available Sources

In 1970, two sources of trap rock (metavolcanic) were authorized for use on HL1 pavements. In 1983, one blast furnace slag, three steel slags, three dolomitic sandstones, and one igneous gravel source, in addition to the original two trap rock sources, were being or had been used for HL1 paving. In addition, other sources of aggregates, such as granite, diabase, quartzite, and other sources of steel slag, and blast furnace slag, were being evaluated in test sections.

Cost

Figure 9 shows the per-tonne cost for HL1, DFC, and OFC mixes placed in the years 1979, 1980, and 1981. Cost includes cost of aggregates, haulage, placing and compaction, but excludes the cost of liquid asphalt cement. It can be seen that dolomitic sandstone, a locally available and recently developed source for use in the Ottawa area, gave the lowest cost per tonne. It is also worth noting that, as the quantity of asphaltic concrete required on a contract increases, the unit cost is generally reduced.

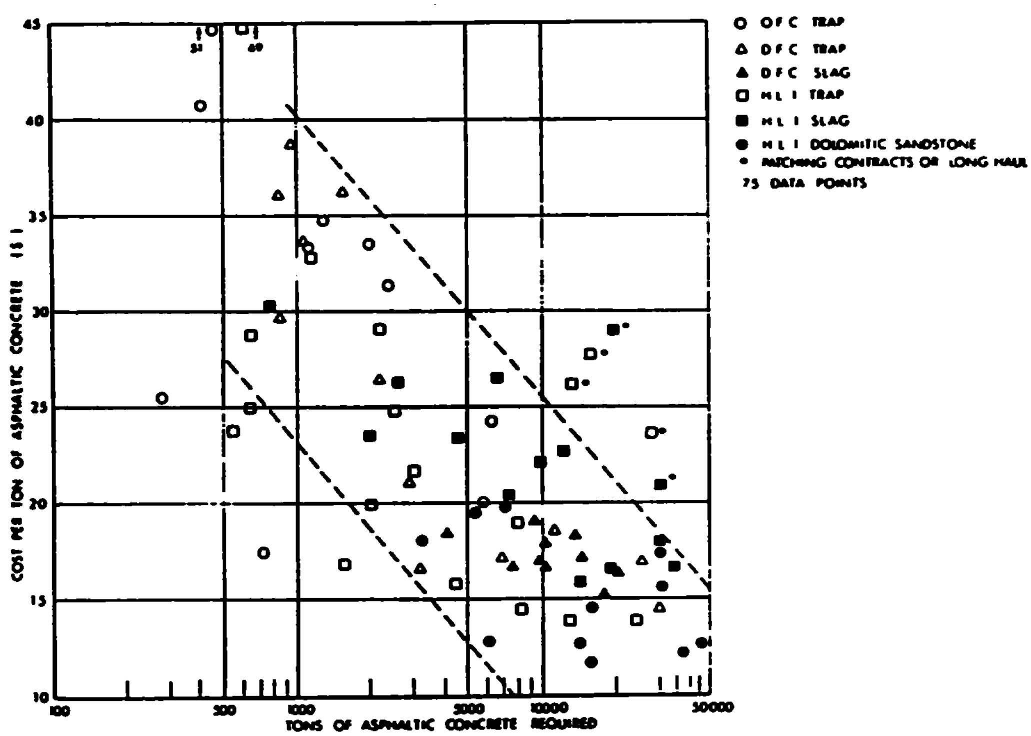

Figure 9. Cost per ton of mix plotted against quantity for 1979-1981 contracts.

Frictional Performance

The frictional properties of pavement are notoriously difficult to measure and compare. Properties of the aggregate are but one factor in determining the friction. Age, amount and type of traffic, mix design and time of year all play an important part in determining the friction obtained.

In the following examples, all variations in environment and pavement properties, other than the coarse aggregate properties, have been eliminated. This has been achieved by using two different coarse aggregates on the same highway, paved at the same time, using similar or identical fine aggregates in similar asphalt mix designs. Figures 10, 11, 12, 13, 14, and 15 all show that, with increasing PSV, the SN (skid number) also increases. This does not necessarily mean that the use of an aggregate with high PSV will ensure a high SN. Choice of the correct asphalt mix design will also play an essential role as can be seen in Figure 15.

DISCUSSION

Studies to predict skid resistance of asphalt surfaces have often been hampered by the failure to use an adequate measure of resistance of aggregate to abrasion. In North America and Australia, the Los Angeles Abrasion and Impact Test has been used without much success. Figure 16 shows a plot of Aggregate Abrasion Value against Los Angeles Abrasion and Impact Test Value. It can be seen that an aggregate with a low (less than 15% loss) Los Angeles Abrasion and Impact loss will always have good resistance to abrasion as measured by AAV. The converse

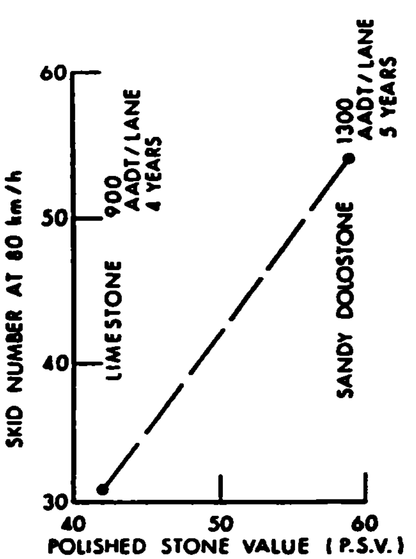

Figure 10. Skid number plotted against polished stone value (PSV) for HL4 after 4 and 5 years, 1000 Island Parkway.

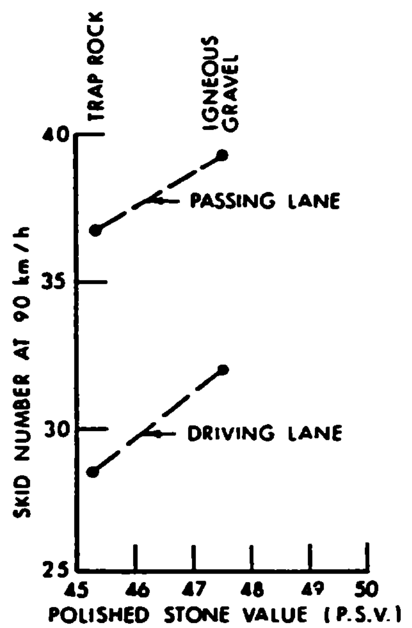

Figure 11. Skid number plotted against polished stone value (PSV) for HL1 after 4 years, Highway 11 near Orillia, 3125 AADT/lane.

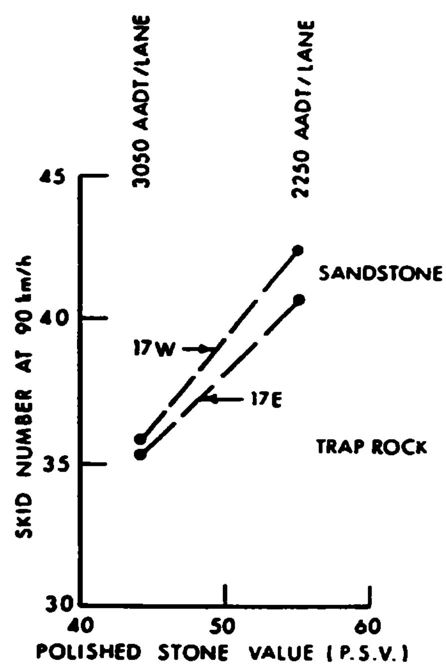

Figure 12. Skid number plotted against polished stone value (PSV) for HL1 after 2 years, Highway 17 near Amprior.

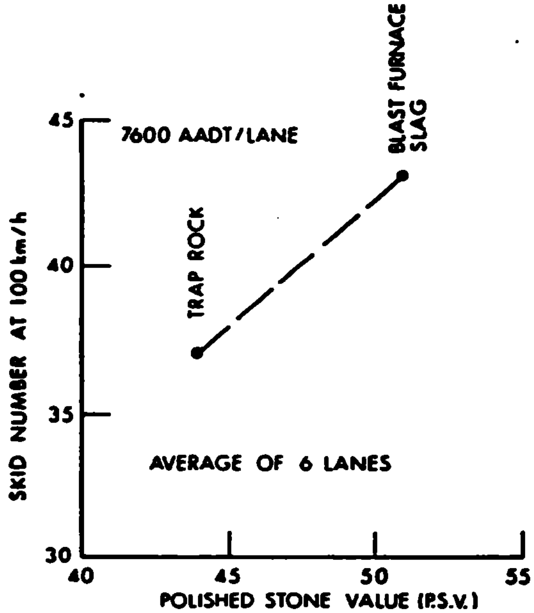

Figure 13. Skid number plotted against polished stone value (PSV) for open friction course on Highway 400 north of Highway 401 after 1 year.

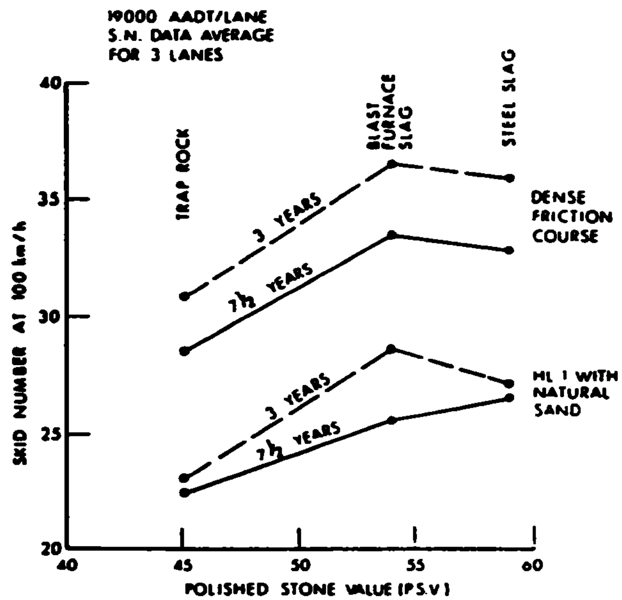

Figure 15. Skid number plotted against polished stone value (PSV) Highway 401. Skid number data at 3 years from Ryell et al. (1979). PSV data from Heaton et al. (1978).

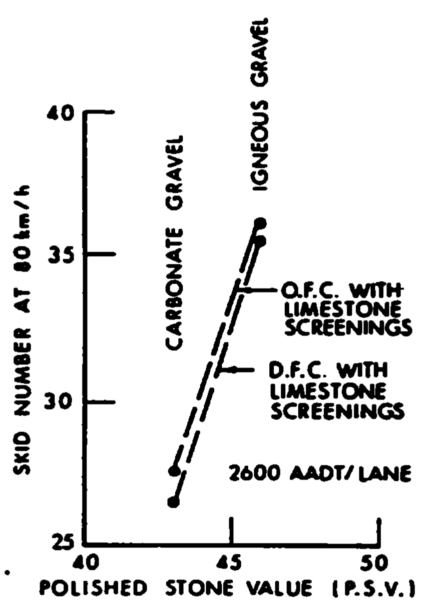

Figure 14. Skid number plotted against polished stone value (PSV) after 4 years for open friction and dense friction courses on Highway 7 near Lindsay, see Kamel et al. (1982).

is not always true; aggregates with high Los Angeles Abrasion and Impact losses may also have good resistance to abrasion. The carbonate rocks show some linear correlation between AAV and Los Angeles Abrasion and Impact loss. The other rock types do not. The Los Angeles Abrasion and Impact Test is not a reliable predictor of the resistance of aggregates to abrasion measured by the Aggregate Abrasion Value Test.

Aggregates commonly found in Ontario can be divided into a number of broad types based on their microtexture development.

1. Moderately hard rocks consisting of approximately equal amounts of relatively hard and soft minerals. The difference in hardness between the minerals should ideally be 2 Moh divisions or greater. A typical example is dolomitic sandstone (Figures 17, 18). The relatively soft dolomite wears away, leaving rounded quartz sand grains protruding above the dolomitic matrix. This gives a natural sandpaper-like texture. Dolomitic sandstones found in eastern Ontario typically give PSV's between 55 and 60, low AAV's and have excellent durability. They are the best, naturally occurring skid-resistant aggregates used in Ontario as determined by the PSV test.

The occurrence of this type of texture was first recognized by Maclean and Shergold (1959) and Knill (1961). Subsequent work has been summarized by Dahir (1979), who found that optimum microtexture is developed when 50 to 70% hard particles are embedded in a soft matrix. Hosking (1976) reported that the optimum size for the hard mineral was about 0.2 mm. It was in recognition of this phenomenon that the insoluble residue test was

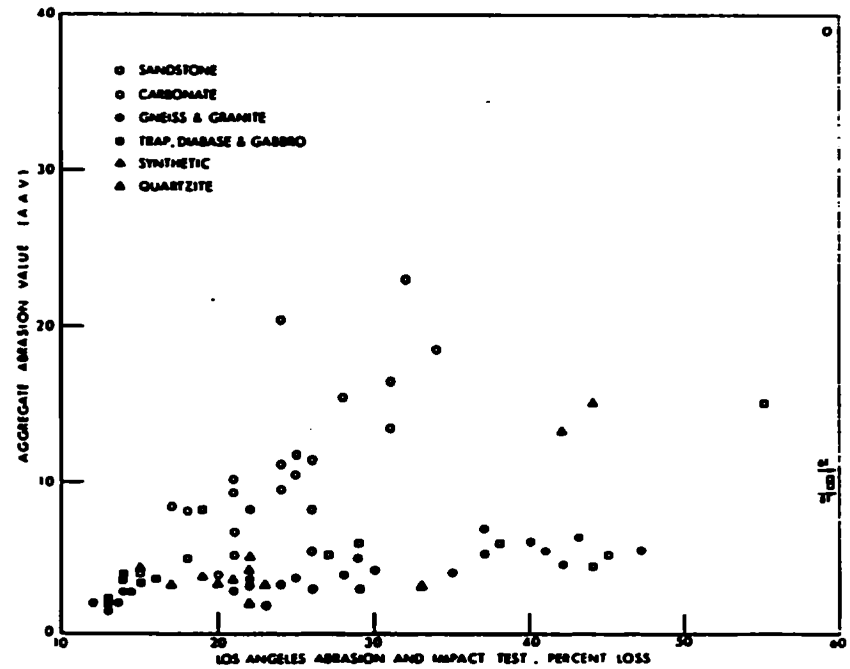

Figure 16. Aggregate abrasion value plotted against Los Angeles abrasion and impact loss.

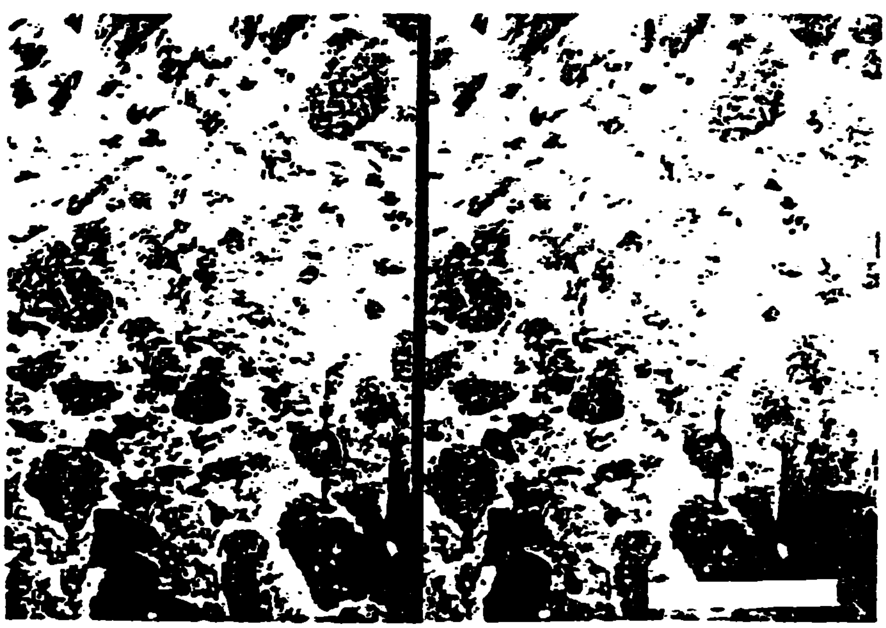

Figure 17. Scanning electron microscope stereopair of the surface of a dolomitic sandstone after exposure to abrasion and polishing. The softer dolostone has worn away leaving the quartz sand grains protruding above the matrix, giving a rough microtexture. Length of scale bar = 0.5 mm.

Figure 18. Photomicrograph under plane light of the dolomitic sandstone shown in Figure 17. Rounded quartz grains surrounded by a dolomite cement. Length of scale bar = 0.2 mm.

developed (ASTM D 3042). A carbonate rock is dissolved in acid, and the proportion of insoluble material retained on the 0.075 mm sieve is determined. Insoluble minerals in carbonate rocks are principally quartz, which has a Moh hardness of 7 compared to the Moh hardness of carbonate rocks of between 3 and 3½. This is, however, a special case of the general principal of hard particles in a soft matrix. The same phenomenon can be observed in biotite-rich gneisses (20% biotite) which gave PSV's of 58 and 63. The biotite preferentially wears away, leaving quartz grains protruding above the matrix. Quartzite and granite (see Table 4, No. 28 and 53) containing even small amounts of mica (5%) have an improved texture, due to wearing away of the biotite, leaving holes in the surface. Orthoquartzitic sandstone with a micaceous matrix also develops this texture (Figures 19, 20).

2. Angular, extremely hard rocks or minerals that resist abrasion, preserving their sharp angular edges. Quartzite is a typical example. Unlike sandstones, quartzites fracture through, rather than around, the grains, giving a relatively smooth flat surface. This results in low PSV's (Figure 21). Hosking (1973) found that the PSV's of quartzites underestimated their true frictional performance by 3 PSV units. Despite their low PSV, these rocks retain their sharp angular edges. Unfortunately, the action of compacting asphaltic concrete tends to embed the sharp aggregate edges downward with the flat surfaces exposed to the traffic.

3. Vesicular, porous, synthetic materials, such as air-cooled blast furnace slag and steel slag. The constituent minerals are relatively hard (Moh 6-7), and resist wear. The large pores with relatively thin walls provide excellent microtexture. Hosking (1976) found that the optimum pore size for blast furnace slags was about 0.15 to 0.3 mm. As porosity increased, so did PSV with optimum results being obtained with materials with a porosity of between 25 and 35%.

The steel and blast furnace slags tested in this study gave PSV's between 53 and 60, the highest values being given by BOF (Basic Oxygen Furnace) steel slags. Blast furnace slag is more porous and generally has thinner pore walls compared to steel slag, which promotes the slow attrition by breakage of the friable pore walls. This has the advantage of continual exposure of fresh, angular mineral grains throughout the life of the pavement. This may account for the better frictional performance of blast furnace slag pavements than predicted by their PSV alone, as reported by Hosking (1973). Evidence to support this was also found in this investigation. Figure 15 shows PSV against skid number for three aggregates used on Highway 401 (Ryell *et al.* 1979). It can be seen that the blast furnace slag generally gave the highest skid number, despite its intermediate PSV. Observation of cores of the blast furnace slag pavement under the microscope showed significant amounts of freshly broken, unpolished crystals after 6 years of exposure to very heavy traffic.

Unfortunately, the slow attrition of the blast furnace slag results in a loss of macrotexture and a reduction in the ability to prevent hydroplaning. Generally, as porosity or

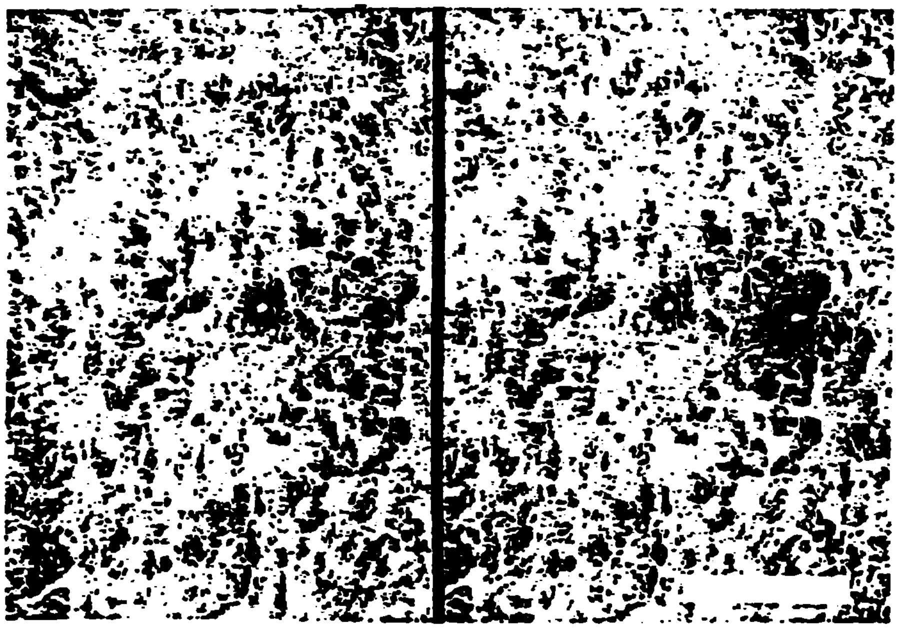

Figure 19. Scanning electron microscope stereopair of the surface of a micaceous sandstone after exposure to abrasion and polishing. Quartz sand grains protrude above the micaceous matrix, giving rough microtecture. Length of scale bar = 0.5 mm.

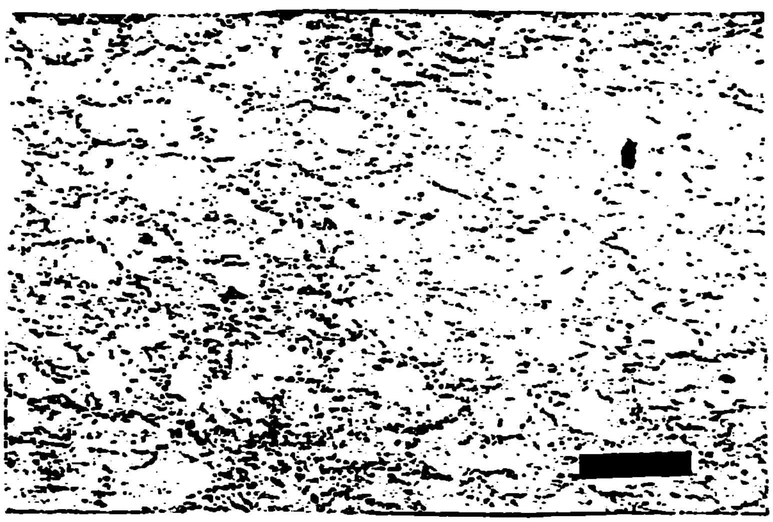

Figure 20. Photomicrograph under plane light of the micaceous sandstone shown in Figure 19. Angular quartz grains surrounded by muscovite mica. Length of scale bar = 0.2 mm.

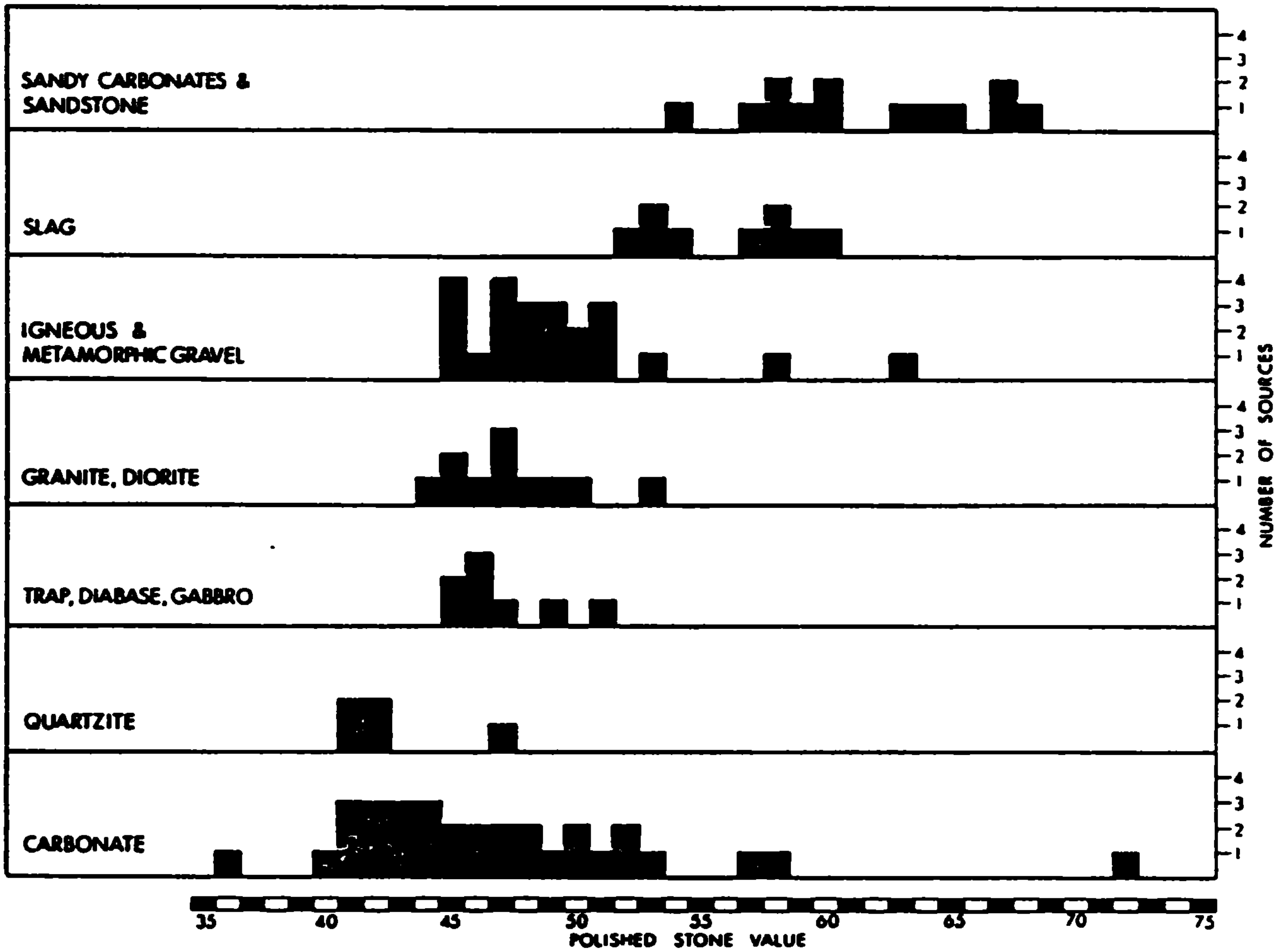

Figure 21. Frequency plot of polished stone values for different aggregate types.

absorption of synthetic materials increases, resistance to abrasion is reduced (Figure 22), which, in turn, reduces macrotexture. A similar relationship was found by Heaton *et al.* (1976), who showed that, as porosity increased, resistance to abrasion and impact measured by the Los Angeles test was reduced. Hosking (1976) also reported that increased porosity resulted in decreased abrasion resistance as measured by AAV.

4. Hard igneous or metamorphic rocks, such as basalt, gabbro, gneiss and granite. Initial microtexture is determined by the fracture characteristics of the rock when crushed. Equigranular, medium-grained (0.5 to 1 mm) rocks appear to perform best, giving a rough initial microtexture. The fine-grained basalts and coarse-grained pegmatitic granites give relatively smooth initial microtexture. Subsequent microtexture development and retention is determined by the relative hardness of the individual minerals; quartz-rich rocks retain their initial texture the longest. With sufficient time, however, nearly all rocks in this group give relatively smooth, polished surfaces, the only exceptions being rocks with significant amounts of relatively soft biotite mica that develop the texture described in Type 1.

5. Soft rocks with low resistance to abrasion which polish rapidly. The sedimentary carbonate rocks are typical of this group. The initial microtexture is determined by the porosity and grain size of the rock. Lithographic limestone gives a smooth, flat surface, while equigranular, medium crystalline dolostone gives a rough initial microtexture. In the pavement surface, the angular edges and microtexture are quickly lost, giving a smooth, polished surface with little macrotexture. Medium crystalline dolostones polish less quickly than their finer grained equivalents or limestones. This is probably due to their better initial microtexture taking longer to wear away, macroporous, reefal dolostones giving the best microtexture. Porosity, hard

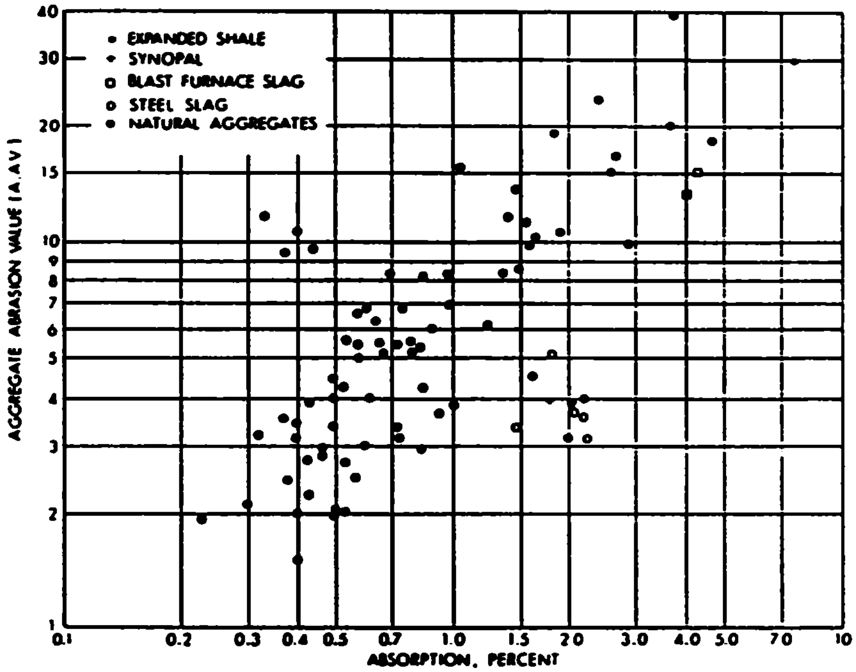

Figure 22. Aggregate abrasion value (AAV) plotted against percent absorption.

mineral content (insoluble residue), grain size and mineralogy are important factors controlling the final microtexture and rate at which it is developed.

Some carbonates give high PSV's (see Figure 21). These are the rocks with low resistance to abrasion. Figure 23 shows that, for the carbonate rocks, as resistance to abrasion decreased (higher AAV), PSV increased. Dahir (1978) reported a similar relationship between friction and percent wear in a jar-mill, for a group of eight aggregates of various rock types. In the polishing test, there is a continual loss of material by abrasion, due to the extreme hardness of the emery abrasive used (Moh 9). As a result, the polish attained under field conditions, where the maximum hardness of the abrasive is Moh 7, is never reached.

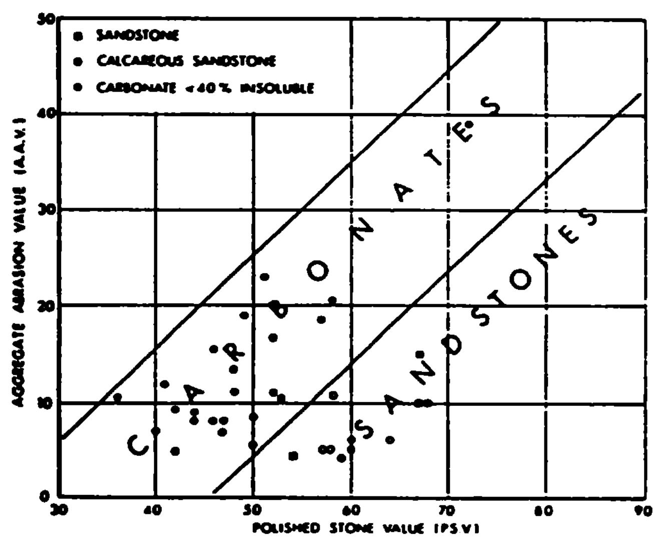

Figure 23. Aggregate abrasion value (AAV) plotted against polished stone value (PSV) for sedimentary rocks.

6. Porous, weakly cemented rocks composed of hard minerals. Porous, weakly cemented sandstone is a typical example. These rocks, when crushed, break around, rather than through, the individual sand grains, giving excellent initial microtexture. The hardness of the individual grains makes them resistant to wear. Microtexture is renewed over the life of the pavement by plucking of individual grains, exposing fresh, unpolished surfaces. Samples of these sandstones gave PSV's between 62 and 68.

These rocks are, unfortunately, extremely susceptible to frost action. Freezing and thawing in the presence of water results in deterioration and loss of macrotexture. This action, combined with attrition of the individual grains results in depressions rather than projections in the pavement surface.

CONCLUSIONS

1. The frictional performance of aggregate is determined by its mineralogy, grain size, and porosity. This can be predicted by laboratory tests, such as polished stone value, and aggregate abrasion value tempered by experience derived from field performance.

2. Locally available aggregate sources of previously unsuspected quality and utility may sometimes be found, using geological and petrographic criteria, confirmed by laboratory testing. The use of these aggregates may lead to cost savings and improvements in the frictional properties of the pavements in which they are used.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the work and assistance of a number of individuals in obtaining and compiling the data for this study. The assistance of D. Boothe, D. D'Archivio, J. Emery, K. Ganesh, A. Hanks, D. Hanna, B. Heaton, Z. Koniuszy, G. Musgrove, D. Newman, S. Osellame, J. Smith, C. Truax-Harrison, O. Valkirs, and J. O'Brien is gratefully acknowledged.

The laboratory testing was carried out in the Soils and Aggregates Laboratories of the Ministry of Transportation and Communications and in the Civil Engineering Laboratories at McMaster University.

The assistance of aggregate suppliers throughout Ontario who provided samples and access to their properties is also gratefully acknowledged.

REFERENCES

ASTM E 445-76: Standard test method for stopping distance on paved surfaces using a passenger automobile equipped with full-scale tires; American Society for Testing and Materials, Philadelphia, Annual Standards, Part 15.

ASTM E 274-79: Standard test method for skid resistance of paved surfaces using a full-scale tire; American Society for Testing and Materials, Philadelphia, Annual Standards, Part 15.

ASTM E 670-79: Standard test method for side force friction on paved surfaces using the Mu-Meter; American Society for Testing and Materials, Philadelphia, Annual Standards, Part 15.

ASTM D 3042-79: Standard test method for insoluble residue in carbonate aggregates; American Society for Testing and Materials, Philadelphia, Annual Standards, Part 15.

ASTM C 109-80: Standard test method for compressive strength of hydraulic cement mortars; American Society for Testing and Materials, Philadelphia, Annual Standards, part 13.

ASTM E 770-80: Standard test method for classifying pavement surface textures; American Society for Testing and Materials, Philadelphia, Annual Standards, Part 15.

BS 812, 1975: Methods for sampling and testing of mineral aggregates, sands and fillers; Part 3. Mechanical Properties; British Standards Institution, London.

Burchett, J. L., and Rizenbergs, R. L.
1982: Frictional performance of pavements and estimates of accident probability; American Society for Testing and Materials, Philadelphia; ASTM STP 763, p.73-97.

Clarke, R. H.
1980: Surface texture on hot rolled asphalt; Journal Institution of Highway Engineers, July, p.15-22.

Dahir, S. H.
1978: Petrographic insights into susceptibility of aggregates to wear and polishing; Transportation Research Board, Record No. 695, p.20-27.
1979: A review of aggregate selection criteria for improved wear resistance and skid resistance of bituminous surfaces; Journal of Testing and Evaluation, vol.7, p.245-253.

Dahir, S. H. and Henry, J.J.
1979: Seasonal and short-term variations in skid resistance; Transportation Research Board Record No.715, p.69-76.

Giles, C.G., Sabey, B. E. and Cardew, K. H. F.
1964: Development and performance of the portable skid-resistance tester; Transport and Road Research Laboratory, U.K., Technical Paper No. 66, 28p.

Harwood, D. W., Blackburn, R. R., St. John, A. D. and Sharp, M. C.
1976: Evaluation of accident rate-skid number relationships for a nationwide sample of highway sections; Transportation Research Board, Record No. 624, p.142-150.

Heaton, B. S., Richards, S. R., Lanigan, P. G. and Hart, A. T.
1976: Skid resistance of steelworks slags as road surfacing stone; Australian Road Research Board Proceedings vol. 8, session 16, p.25-30.

Heaton, B.S., Kamel, N., Emery, J. J. and Lee, M. A.
1978: Asphalt pavement skid resistance prediction models; Proceedings Canadian Technical Asphalt Association, vol. 23, p.470-489.

Hegmon, R. R.
1982: Reliability of locked-wheel skid resistance tester confirmed; Public Roads, December, p.92-101.

Hill, B. J. and Henry, J. J.
1981: Short-term, weather-related skid resistance variations; Transportation Research Board Record No. 836, p.76-81.

Holt, F. B. and Musgrove G. R.
1977: Skid resistance: Photo-interpreters' Manual: a guide to determining wet pavement skid resistance using the Schonfeld Photo-Interpretation Technique; Ontario Ministry of Transportation and Communications, Research and Development Division.
1982: Surface texture classifications: a guide to pavement skid resistance; American Society for Testing and Materials, Philadelphia, ASTM STP 763, p.31-44.

Hosking, J. R.
1968: Factors affecting the results of polished stone value tests; Transport and Road Research Laboratory, U.K., Laboratory Report 216.
1973: The effect of aggregate on the skidding resistance of bituminous surfacings: Factors other than resistance to polishing; Transport and Road Research Laboratory, U.K., Report LR553.
1976: Aggregates for skid-resistant roads; Transport and Road Research Laboratory, U.K. Report LR 693.

Howerter, E. D. and Rudd, T. J.
1976: Automation of the Schonfeld method for highway surface texture classification; Transportation Research Board, Record No. 602, p.57-61.

Kamel, N. and Corkill, J. T.
1979: Construction and performance of bituminous friction course sections at Lindsay, Ontario; Ontario, Ministry of Transporta-

tion and Communications, Research and Development Division Report.

Kamel, N. and Gartshore, T.
1982: Ontario's wet pavement accident reduction program; American Society for Testing and Materials, Philadelphia, ASTM STP 763, p.98-117.

Kamel, N., Musgrove, G. R. and Rutka, A.
1982: Design and performance of bituminous friction-course mixes; Transportation Research Board, Record No. 843, p.40-50

Knight, B. H. and Knight, R. G.
1948: Road Aggregates: Their uses and testing; Edward Arnold and Co., London, Second Edition, 259p.

Knill, D. C.
1961: Petrographical aspects of polishing of natural roadstones; Crushed Stone Journal, June, p.13-20.

Maclean, D. J. and Shergold, F. A.
1959: The polishing of roadstones in relation to their selection for use in road surfaces; Proceedings First International Skid Prevention Conference, Charlottesville, Virginia, p.497-508.

MTC-LS-603, 604, 606, 609, 613, Aggregate Test Methods; Ontario Ministry of Transportation and Communications, Engineering Materials Office, Laboratory Testing Manual.

Orchard, D. F., Yandell, W. O. and Lye, B. R. X.
1970: A quick method of measuring the surface texture of aggregate; Australian Road Research Board Proceedings, vol. 5, p.325-341.

Rogers, C. A.
1980: Search for skid resistant aggregates in Eastern Ontario; Ontario Ministry of Transportation and Communications, Engineering Materials Office, Report EM 36, May, 72p.

Rose, J. G., Hutchinson, J. W. and Gallaway, B. M.
1972: Summary and analysis of the attributes of methods of surface texture measurement; American Society for Testing and Materials, Philadelphia, ASTM STP 530, p.60-77.

Ryell, J., Corkill, J. T. and Musgrove, G. R.
1979: Skid resistance of bituminous pavement test sections: Toronto by-pass project; Transportation Research Board, Record No. 712, p.51-60.

Sabey, B. E. and Lupton, G. N.
1967: Measurement of road surface texture using photogrammetry; Transport and Road Research Laboratory, U.K., Laboratory Report 57.

Schonfeld, R.
1970: Photo-interpretation of skid resistance; Highway Research Board, Record No. 311, p.11-25.
1974: Photo-interpretation of pavement skid resistance: Ontario Ministry of Transportation and Communications, Research Report 188.

Smith, P. and Schonfeld, R.
1972: Thoughts on tolerable pavement wear; Ontario Ministry of Transportation and Communications, Research Report RR179, May, 9p.

Szatowski, W. S. and Hosking, J. R.
1972: The effect of traffic and aggregate on the skidding resistance of bituminous surfacings; Transport and Road Research Laboratory, U.K., Report LR 504.

Truax-Harrison, C. M.
1979: Selected annotated bibliography of the relationship of polishing and wearing characteristics of aggregates to their petrography; Ontario Ministry of Transportation and Communications, Engineering Materials Office, Unpublished Report, Sept., 55 p.

Underwood, J. P., Hankins, K. D. and Garana, E.
1971: Aggregate polishing characteristics: The British wheel test and the insoluble residue test; Texas Highway Department, Research Report 126-2.

Yager, T.J., and Buhlmann, F.
1982: Macrotexture and Drainage Measurements on a Variety of Concrete and Pavement Surfaces; American Society for Testing and Materials, Philadelphia, ASTM STP 763, p.16-30.

ASHWARREN
ENGINEERING SERVICES

LABORATORY
2283 ARGENTIA ROAD, UNIT 15
MISSISSAUGA, ONT., CANADA
L5N 5Z2
TELEPHONE (416) 542-2265
FAX (416) 542-7328

June 6, 1994

Smelter Bay Aggregates Incorporated
P.O. Box 400
Thessalon, Ontario
POR 1L0

ATTENTION: Mr. Reg Gardiner, District Manager

Dear Sirs:

Aggregate Testing, Traprock Stone

As requested, Ashwarren Engineering Services has completed aggregate testing on the sample of traprock delivered to our laboratory.

The aggregate was crushed through a small laboratory jaw crusher to maximum size of 3/4". After crushing the aggregate was tested for washed sieve analysis (LS-602). The traprock aggregate was then split with the stone retained on the 4.75 mm sieve tested for the following analysis: Los Angeles abrasion loss (LS-603), percent crushed (LS-617), magnesium sulphate soundness loss (LS-606), specific gravity (LS-604), absorption (LS-604), flats and elongated (LS-608), crushed particles (LS-607), and petrographic analysis (LS-609).

The test results are shown in Table 1 and the crushed aggregate meets the current Ontario Provincial Standards Specification 1003 for HL 1 Stone.

Recommendation is for further testing for the Micro-Deval Abrasion Test, insoluble residue, and Immersion Marshall testing for resistance to stripping in hot mix.

Should you have any questions please call our office.

Yours very truly,
ASHWARREN ENGINEERING SERVICES

Paul Lum, P.Eng.
Manager

SUMMARY OF AGGREGATE TEST RESULTS

Traprock Aggregate, Smelter Bay Aggregates
June 6, 1994

Test	Test Result	Specifications
Los Angeles Abrasion Loss (%)	8.7	N.A.
Magnesium Sulphate Soundness Loss (%)	0.25	5 max.
Specific Gravity	2.983	
Absorption (%)	0.562	1.0 max.
Flat and Elongated Particles (%)	12.5	20 max.
Crushed Particles (%)	100	N.A.
Petrograhic Number (H.L.)	100	120 max.

Sieve Analysis

Sieve Size	Test Result*
26.5 mm	100.0
19.0 mm	98.5
16.0 mm	84.2
13.2 mm	76.5
9.5 mm	64.0
6.7 mm	51.7
4.75 mm	48.1
2.36 mm	41.0
1.18 mm	32.3
600 um	22.2
300 um	15.0
150 um	11.0
75 um	7.5

* Traprock stone was crushed through a laboratory 3/4" jaw crusher.

Clifton Associates Ltd.
CONSULTING GEOTECHNICAL ENGINEERS

TEL: (306) 721-7611
FAX: (306) 721-8128
340 MAXWELL CRESCENT
REGINA, SK S4N 5Y5

10 February 1992
File R1.212.2

Smelter Bay Aggregates Incorporated
P.O. Box 400
Boundary Road Industrial Park
THESSALON, Ontario
P0R 1L0

ATTENTION: Mr. Reginald Gardiner, Manager

Dear Sir:

SUBJECT: Ballast Testing
Petrographic, Chemical and Physical Characterization

One rock sample was crushed and subjected to petrographic, physical and chemical testing according to CP Rail Specifications for Ballast. The results are attached and summarized briefly below.

The sample is comprised entirely of diabase. Plagioclase and pyroxene are both relatively unaltered. No deleterious minerals are present in the rock.

The rock has a high hardness and a high toughness. It meets all the CP Rail physical test specifications. See attached *Summary of Ballast Test Results.*

Chemical testing indicates that the rock chemistry meets Ontario guidelines for metals in soils, (see Table 1). Acid-base accounting indicates less than 0.1% sulphide sulphur is present in the rock and the acid generating potential is low, (see Table 2). Leachate extract analysis meets the guidelines in all elements tested, (see Table 3).

Should you have any questions or comments, please do not hesitate to call.

Yours truly,

CLIFTON ASSOCIATES LTD.

WILLIAM A. JEALOUS, SENIOR GEOLOGIST
WAJ/ic

VISUAL PETROGRAPHIC ANALYSIS
NORTHERN ONTARIO

CLIENT: Smelter Bay Aggregates Incorporated

Sample No. L4889

This sample was submitted to Clifton Associates Ltd. by Smelter Bay Aggregates for physical testing and visual petrographic analysis according to CP Rail ballast specifications.

ROCK TYPE

Diabase

This rock is dark grey green in color and massive. It is composed of 50% fine to predominantly medium grained (1-2 mm), subhedral amphiboles and pyroxene; 50 % fine to predominantly medium grained (1-2 mm) subhedral plagioclase lathes; trace amounts (<1 %) of anhedral disseminated sulphides; trace amounts of chlorite, predominantly seen on the weathered surfaces; and minor alteration products of plagioclase (saussurite, composed of epidote, carbonate and feldspar).

STRUCTURE AND TEXTURE

This rock is massive, fine to medium grained (consistently in the 1 - 2 mm range) and has a diabasic texture.

HARDNESS

This rock is very hard, this the result of the high hardness of the constituent minerals (plagioclase - Moh's hardness scale value of 6, pyroxene - Moh's hardness scale value of 6 and amphiboles - Moh's hardness scale value of 6).

TOUGHNESS

This rock is anticipated to have a high toughness due to the massive, diabasic texture, the fine to medium grain size, the hard constituent minerals and the absence of deleterious amounts of soft secondary alteration minerals

FINES, FRACTURE FACES, AND SHAPE

This rock is expected to generate a negligible amount of fines. The rock fractures into more equidimensional fragments in the coarser fractions, with a tendency towards more flattened and elongated fragments in the finer fractions. The fracture faces are moderately rough and the fragment edges are uniformly angular.

FREEZE/THAW AND WETTING/DRYING

The susceptibility of this rock to effects of freeze/thaw is expected to be low due to the massive texture. This rock should have a low susceptibility to wet/dry processes.

CHEMICAL WEATHERING

This rock should have a low susceptibility to chemical weathering because the carbonate makes up a very small percentage of the rock.

PHYSICAL TESTING

A full suite of physical testing has been done and the results are presented at the end of this report.

COMMENTS

This rock has very good hardness and toughness characteristics. The tendency towards flattened and elongated pieces in the finer fractions can be corrected during crushing and sieving. This rock meets all C P Rail specifications for a Grade 4 ballast.

PHIL R. SCALIA, GEOLOGIST
07 FEBRUARY, 1992

SUMMARY OF BALLAST TEST RESULTS

CLIENT:	Smelter Bay Agg.	SAMPLE RECEIVED:	92/01/30
PROJECT NO.:	R1.212.2	LOCATION:	Ontario
CAL SAMPLE NO.:	L4889	TRACK CLASSIFICATION:	Main Line CWR
CLIENT SAMPLE NO:		BALLAST GRADING:	4.5

TEST		TEST RESULTS	SPECIFICATIONS
Los Angeles Abrasion Loss (%)		8.3	45 max.
Mill Abrasion Loss (%)		2.3	9 max.
Abrasion No.		19.8	65 max.
Specific Gravity		2.97	2.60 min.
Absorbtion (%)		0.17	0.5 max.
Magnesium Sulphate Soundness Loss (%)		0.10	1.0 max.
Fractured Faces (%)	Minus 2" plus 1 1/2"		90
	Minus 1 1/2" plus 1"	96.6	90
	Minus 1" plus 3/4"	95.1	90
	Minus 3/4" plus 1/2"	95.1	90
	Minus 1/2" plus 3/8"		90
	Minus 3/8" plus #4		90
Shape Factor	Minus 2" plus 1 1/2"		
	Minus 1 1/2" plus 1"	2.01	
	Minus 1" plus 3/4"	2.26	
[1]Sieve Analysis, Finer Than Sieve(%)	2 1/2"	100.0	100
	2"	100.0	90-100
	1 1/2"	99.1	60-80
	1"	59.6	15-35
	3/4"	26.9	0-5
	1/2"	11.7	
	3/8"	7.4	
	#4	4.2	0-3
	#200	0.6	0-2

[1]CIRCUMSTANCES PROHIBITED CRUSHER SAMPLE; PRIMARY BLAST SAMPLE WAS LABORATORY CRUSHED FOR ALL TESTING PURPOSES, ACCOUNTING FOR THE DISPARITY IN SIEVE SPECIFICATIONS.

File R1.212.2

THIN SECTION ANALYSIS
SMELTER BAY AGGREGATES
ONTARIO

Client: Smelter Bay Aggregates, Ltd.

Sample L4889

ROCK TYPE

Diabase

MINERALOGY

Plagioclase Feldspar	60%
Pyroxene	30%
Amphibole	10%
Biotite	Trace
Chlorite	Trace
Opaques	Trace

TEXTURE

This rock exhibits a well developed diabasic texture. Euhedral, fine to medium grained lathes of plagioclase feldspar enclose anhedral to subhedral, fine to medium grained pyroxene crystals, forming an interlocking texture. The rock is massive, with no closely spaced microfractures or shears evident in thin section.

ALTERATION

The plagioclase feldspars are very "fresh", minimal saussuritization noted. The pyroxenes are occasionally altered on their crystal margins to amphibole which comprises up 10% of the rock.. These primary pyroxene crystals are altered along cleavage planes, along their edges and pervasively.

COMMENTS

This rock is anticipated to have good hardness and toughness characteristics. The extensive uralitization of the pyroxenes has not proven to have a deleterious effect on rock toughness on tests done on other uralitized gabbro and diorite samples. The plagioclase feldspars are relatively unaltered. The diabasic texture will likely result in good toughness characteristics.

WILLIAM A. JEALOUS, SENIOR GEOLOGIST
10 FEBRUARY, 1992

Ministry of Northern Development and Mines
Ontario

Report of Work Conducted After Recording Claim

Mining Act

Transaction Number
DOCUMENT No. W9450.00062

Personal information collected on this form is obtained under the authority of the Mini
this collection should be directed to the Provincial Manager, Mining Lands, Minist
Sudbury, Ontario, P3E 6A5, telephone (705) 670-7264.

41J05SE0007 2.15538 LEFROY

900

Instructions: [redacted]
- Refer to the Mining Act and Regulations for requi. Recorder.
- A separate copy of this form must be completed for each Work Group.
- Technical reports and maps must accompany this form in duplicate.

[redacted]

Recorded Holder(s)		Client No.
WARREN PAVING & MATERIALS GROUP Ltd		222271
Address: 72 ASHWARREN DOWNSVIEW ONT. M3J 1Z6		Telephone No. (416) 633-9670
Mining Division: Sault Ste. Marie	Township/Area: Lefroy	M or G Plan No. G 3294
Dates Work Performed From: July 21, 1992	To: JUNE 6, 1994	

Work Performed (Check One Work Group Only)

Work Group		Type
	Geotechnical Survey	
	Physical Work, Including Drilling	
	Rehabilitation	
✓	Other Authorized Work	SECTION 18 ONLY INDUSTRIAL MINERAL TESTING & MARKETING (4)
	Assays	
	Assignment from Reserve	

RECEIVED
AUG 0 8 1994
MINING LANDS BRANCH

RECORDED
JUL 29 1994
Receipt

Total Assessment Work Claimed on the Attached Statement of Costs $ 6086.00

Note: The Minister may reject for assessment work credit all or part of the assessment work submitted if the recorded holder cannot verify expenditures claimed in the statement of costs within 30 days of a request for verification.

Persons and Survey Company Who Performed the Work (Give Name and Address of Author of Report)

Name	Address
Raymond Hickerson (Report Writer)	P.O. BOX 222 THESSALON ONT P0R 1L0
ASHWARREN ENGINEERING SERVICES (Paul Burns P.ENG)	2283 Argentia Rd. UNIT 15, MISSISSAUGA, ONT L5N 5Z2

(attach a schedule if necessary)

Certification of Beneficial Interest * See Note No. 1 on reverse side

I certify that at the time the work was performed, the claims covered in this work report were recorded in the current holder's name or held under a beneficial interest by the current recorded holder.	Date: July 29/94	Recorded Holder or Agent (Signature): [signature]

Certification of Work Report

I certify that I have a personal knowledge of the facts set forth in this Work report, having performed the work or witnessed same during and/or after its completion and annexed report is true.		
Name and Address of Person Certifying: RAYMOND T. HICKERSON P.O. BOX 222 THESSALON, ONT. P0R 1L0		
Telepone No. (705) 842-2597	Date: July 29/94	Certified By (Signature): [signature]

For Office Use Only

Total Value Cr. Recorded	Date Recorded	Mining Recorder (acting)	Received Stamp
$4800.00 Reserve $1,286.00	July 29/94	Paul Morra	SAULT STE. MARIE MINING DIVISION RECEIVED JUL 29 1994 AM 7,8,9,10,11,12,1,2,3,4,5,6 PM
	Deemed Approval Date: OCT 27/94	Date Approved	
	Date Notice for Amendments Sent		

0241 (03/91)

Work Report Number for Applying Reserve	Claim Number (see Note 2)	Number of Claim Units	Value of Assessment Work Done on this Claim	Value Applied to this Claim	Value Assigned from this Claim	Reserve: Work to be Claimed at a Future Date
	SSM 782863	2	6086.00	~~6086.00~~ [illegible]		~~6086.~~ 1286

Total Number of Claims	Total Value Work Done	Total Value Work Applied	Total Assigned	Total Reserve
1	6086.00	4800.00		~~2086.~~ 1286.00

Credits you are claiming in this report may be cut back. In order to minimize the adverse effects of such deletions, please indicate from which claims you wish to priorize the deletion of credits. Please mark (✓) one of the following:

- ☐ Credits are to be cut back starting with the claim listed last, working backwards.
- ☐ Credits are to be cut back equally over all claims contained in this report of work.
- ☐ Credits are to be cut back as priorized on the attached appendix.

In the event that you have not specified your choice of priority, option one will be implemented.

1: Examples of beneficial interest are unrecorded transfers, option agreements, memorandum of agreements, etc., with respect to the mining claims.

2: If work has been performed on patented or leased land, please complete the following:

I certify that the recorded holder had a beneficial interest in the patented or leased land at the time the work was performed.	Signature	Date

Ontario

Ministry of
Northern Development
and Mines

Ministère du
Développement du Nord
et des mines

Statement of Costs for Assessment Credit

État des coûts aux fins du crédit d'évaluation

Transaction No./N° de transaction

DOCUMENT No.
W9450.00062

Mining Act/Loi sur les mines

Personal information collected on this form is obtained under the authority of the Mining Act. This information will be used to maintain a record and ongoing status of the mining claim(s). Questions about this collection should be directed to the Provincial Manager, Minings Lands, Ministry of Northern Development and Mines, 4th Floor, 159 Cedar Street, Sudbury, Ontario P3E 6A5, telephone (705) 670-7264.

Les renseignements personnels contenus dans la présente formule sont recueillis en vertu de la Loi sur les mines et serviront à tenir à jour un registre des concessions minières. Adresser toute question sur la collece de ces renseignements au chef provincial des terrains miniers, ministère du Développement du Nord et des Mines, 159, rue Cedar, 4[e] étage, Sudbury (Ontario) P3E 6A5, téléphone (705) 670-7264.

1. Direct Costs/Coûts directs

Type	Description	Amount Montant	Totals Total global
Wages Salaires	Labour Main-d'oeuvre	150.00	
	Field Supervision Supervision sur le terrain	750.00	[illegible]
Contractor's and Consultant's Fees Droits de l'entrepreneur et de l'expert-conseil	Type: Consbec Inc	2038	
	Le Roy Const.	936	
	Gilbertson Enterp.	356	5786
Supplies Used Fournitures utilisées	Type	↑↑	
	Ashwarren Engineering Serv.	1856	
			[illegible]
Equipment Rental Location de matériel	Type		
			[illegible]
	Total Direct Costs Total des coûts directs		[illegible]

2. Indirect Costs/Coûts indirects

** Note: When claiming Rehabilitation work Indirect costs are not allowable as assessment work.
Pour le remboursement des travaux de réhabilitation, les coûts indirects ne sont pas admissibles en tant que travaux d'évaluation.

Type	Description	Amount Montant	Totals Total global
Transportation Transport	Type		
Food and Lodging Nourriture et hébergement			
Mobilization and Demobilization Mobilisation et démobilisation			
	Sub Total of Indirect Costs Total partiel des coûts indirects		
	Amount Allowable (not greater than 20% of Direct Costs) Montant admissible (n'excédant pas 20 % des coûts directs)		
	Total Value of Assessment Credit (Total of Direct and Allowable Indirect costs) Valeur totale du crédit d'évaluation (Total des coûts directs et indirects admissibles)		

Note: The recorded holder will be required to verify expenditures claimed in this statement of costs within 30 days of a request for verification. If verification is not made, the Minister may reject for assessment work all or part of the assessment work submitted.

Note : Le titulaire enregistré sera tenu de vérifier les dépenses demandées dans le présent état des coûts dans les 30 jours suivant une demande à cet effet. Si la vérification n'est pas effectuée, le ministre peut rejeter tout ou une partie des travaux d'évaluation présentés.

Filing Discounts

1. Work filed within two years of completion is claimed at 100% of the above Total Value of Assessment Credit.
2. Work filed three, four or five years after completion is claimed at 50% of the above Total Value of Assessment Credit. See calculations below:

Total Value of Assessment Credit		Total Assessment Claimed
	× 0.50 =	

Remises pour dépôt

1. Les travaux déposés dans les deux ans suivant leur achèvement sont remboursés à 100 % de la valeur totale susmentionnée du crédit d'évaluation.
2. Les travaux déposés trois, quatre ou cinq ans après leur achèvement sont remboursés à 50 % de la valeur totale du crédit d'évaluation susmentionné. Voir les calculs ci-dessous.

Valeur totale du crédit d'évaluation		Évaluation totale demandée
	× 0.50 =	

Certification Verifying Statement of Costs

I hereby certify:
that the amounts shown are as accurate as possible and these costs were incurred while conducting assessment work on the lands shown on the accompanying Report of Work form.

that as [signature] (Recorded Holder, Agent, Position in Company) I am authorized

to make this certification

Attestation de l'état des coûts

J'atteste par la présente :
que les montants indiqués sont le plus exact possible et que ces dépenses ont été engagées pour effectuer les travaux d'évaluation sur les terrains indiqués dans la formule de rapport de travail ci-joint.

Et qu'à titre de ____________ (titulaire enregistré, représentant, poste occupé dans la compagnie) je suis autorisé

à faire cette attestation.

Signature	Date
[signature]	July 29/94

0212 (04/91)

Nota : Dans cette formule, lorsqu'il désigne des personnes, le masculin est utilisé au sens neutre

Ministry of Northern Development and Mines

Ontario

Report of Work Conducted After Recording Claim

Mining Act

Transaction Number: DOCUMENT No. W9450.00063

Personal information collected on this form is obtained under the authority of the Mining Act. This information will be used for correspondence. Questions about this collection should be directed to the Provincial Manager, Mining Lands, Ministry of Northern Development and Mines, Fourth Floor, 159 Cedar Street, Sudbury, Ontario, P3E 6A5, telephone (705) 670-7264.

2.15538

Instructions:
- Please type or print and submit in duplicate.
- Refer to the Mining Act and Regulations for requirements of filing assessment work or consult the Mining Recorder.
- A separate copy of this form must be completed for each Work Group.
- Technical reports and maps must accompany this form in duplicate.
- A sketch, showing the claims the work is assigned to, must accompany this form.

Recorded Holder(s): WARREN Paving & Materials Group Ltd.	Client No.: 222271
Address: 72 ASHWARREN Rd., Downsview, ONT. M3J-1Z6	Telephone No.: (416)-633-9670
Mining Division: Sault Ste. Marie	Township/Area: Lefroy
M or G Plan No.: G 3294	
Dates Work Performed From: July 21, 1992	To: June 6, 1994

Work Performed (Check One Work Group Only)

Work Group	Type
Geotechnical Survey	
Physical Work, Including Drilling	
Rehabilitation	
Other Authorized Work	SECTION 18 ONLY ✓ INDUSTRIAL Mineral testing & Marketing
Assays	
Assignment from Reserve	

Total Assessment Work Claimed on the Attached Statement of Costs $ 74239.00

Note: The Minister may reject for assessment work credit all or part of the assessment work submitted if the recorded holder cannot verify expenditures claimed in the statement of costs within 30 days of a request for verification.

Persons and Survey Company Who Performed the Work (Give Name and Address of Author of Report)

Name	Address
RAYMOND T. HICKERSON	P.O. BOX 222 THESSALON, ONT. P0R 1L0
CONSBEC INC	P.O BOX 520 2225 BELISLE DR VAL CARON, ONT. P0M 3A0

(attach a schedule if necessary)

Certification of Beneficial Interest * See Note No. 1 on reverse side

I certify that at the time the work was performed, the claims covered in this work report were recorded in the current holder's name or held under a beneficial interest by the current recorded holder.	Date: July 29, 1994	Recorded Holder or Agent (Signature): [signature]

Certification of Work Report

I certify that I have a personal knowledge of the facts set forth in this Work report, having performed the work or witnessed same during and/or after its completion and annexed report is true.

Name and Address of Person Certifying: RAYMOND T. HICKERSON P.O. BOX 222 THESSALON, ONT. P0R 1L0		
Telepone No.: 842-2597	Date: July 29/94	Certified By (Signature): [signature]

For Office Use Only

Total Value Cr. Recorded: Reserve $74,239	Date Recorded: July 29/94	Mining Recorder (ACTING): [signature]	Received Stamp: SAULT STE. MARIE MINING DIVISION RECEIVED JUL 29 1994 AM PM 7,8,9,10,11,12,1,2,3,4,5,6
	Deemed Approval Date: Oct 27/94	Date Approved	
	Date Notice for Amendments Sent		

0241 (03/91)

Work Report Number for Applying Reserve	Claim Number (see Note 2)	Number of Claim Units	Value of Assessment Work Done on this Claim	Value Applied to this Claim	Value Assigned from this Claim	Reserve: Work to be Claimed at a Future Date
	073000	[illegible]	[illegible]	0		74239

SECTION 18 ONLY

Total Number of Claims	Total Value Work Done	Total Value Work Applied	Total Assigned From	Total Reserve
	74239	0		74239

Credits you are claiming in this report may be cut back. In order to minimize the adverse effects of such deletions, please indicate from which claims you wish to priorize the deletion of credits. Please mark (✓) one of the following:

1. ☐ Credits are to be cut back starting with the claim listed last, working backwards.
2. ☐ Credits are to be cut back equally over all claims contained in this report of work.
3. ☐ Credits are to be cut back as priorized on the attached appendix.

In the event that you have not specified your choice of priority, option one will be implemented.

Note 1: Examples of beneficial interest are unrecorded transfers, option agreements, memorandum of agreements, etc., with respect to the mining claims.

Note 2: If work has been performed on patented or leased land, please complete the following:

I certify that the recorded holder had a beneficial interest in the patented or leased land at the time the work was performed.	Signature	Date

Ministry of Northern Development and Mines
Ontario

Ministère du Développement du Nord et des mines

Statement of Costs for Assessment Credit

État des coûts aux fins du crédit d'évaluation

DOCUMENT No. W9450 . 00063

Mining Act/Loi sur les mines

Personal information collected on this form is obtained under the authority of the Mining Act. This information will be used to maintain a record and ongoing status of the mining claim(s). Questions about this collection should be directed to the Provincial Manager, Minings Lands, Ministry of Northern Development and Mines, 4th Floor, 159 Cedar Street, Sudbury, Ontario P3E 6A5, telephone (705) 670-7264.

Les renseignements personnels contenus dans la présente formule sont recueillis en vertu de la Loi sur les mines et serviront à tenir à jour un registre des concessions minières. Adresser toute question sur la collecte de ces renseignements au chef provincial des terrains miniers, ministère du Développement du Nord et des Mines, 159, rue Cedar, 4e étage, Sudbury (Ontario) P3E 6A5, téléphone (705) 670-7264.

1. Direct Costs/Coûts directs

Type	Description	Amount Montant	Totals Total global
Wages Salaires	Labour Main-d'oeuvre		
	Field Supervision Supervision sur le terrain	1284	1284
Contractor's and Consultant's Fees Droits de l'entrepreneur et de l'expert-conseil	Type LeRoy Cons.	2657	
	Consbec	37545	
	Gilbertson Enterprise	20380	60582
Supplies Used Fournitures utilisées	Type		
Equipment Rental Location de matériel	Type		
			[illegible]
		Total Direct Costs Total des coûts directs	[illegible]

2. Indirect Costs/Coûts indirects

** **Note:** When claiming Rehabilitation work Indirect costs are not allowable as assessment work.
Pour le remboursement des travaux de réhabilitation, les coûts indirects ne sont pas admissibles en tant que travaux d'évaluation.

Type	Description	Amount Montant	Totals Total global
Transportation Transport	Type Transport Sample	25511	
			[illegible]
Food and Lodging Nourriture et hébergement			[illegible]
Mobilization and Demobilization Mobilisation et démobilisation			[illegible]
		Sub Total of Indirect Costs Total partiel des coûts indirects	[illegible]

Amount Allowable (not greater than 20% of Direct Costs) Montant admissible (n'excédant pas 20 % des coûts directs) [illegible]

Total Value of Assessment Credit (Total of Direct and Allowable Indirect costs) **Valeur totale du crédit d'évaluation (Total des coûts directs et indirects admissibles)** [illegible]

Note: The recorded holder will be required to verify expenditures claimed in this statement of costs within 30 days of a request for verification. If verification is not made, the Minister may reject for assessment work all or part of the assessment work submitted.

Note : Le titulaire enregistré sera tenu de vérifier les dépenses demandées dans le présent état des coûts dans les 30 jours suivant une demande à cet effet. Si la vérification n'est pas effectuée, le ministre peut rejeter tout ou une partie des travaux d'évaluation présentés.

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Total Value of Assessment Credit		Total Assessment Claimed
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Et qu'à titre de ______ je suis autorisé
(titulaire enregistré, représentant, poste occupé dans la compagnie)

à faire cette attestation.

Signature: [signature] Date: July 29/94

0212 (04/91)

Nota : Dans cette formule, lorsqu'il désigne des personnes, le masculin est utilisé au sens neutre.

Ontario

Ministry of Northern Development and Mines

Ministère du Développement du Nord et des Mines

Geoscience Approvals Office
933 Ramsey Lake Road
6th Floor
Sudbury, Ontario
P3E 6B5

Telephone: (705) 670-5853
Fax: (705) 670-5863

November 7, 1994

Our File: 2.15538
Transaction #: W9450.00062
.00063

Mining Recorder
Ministry of Northern Development
and Mines
60 Church Street
Sault Ste. Marie, Ontario
P6A 3H3

Dear Sir/Madam:

Subject: APPROVAL OF ASSESSMENT WORK CREDITS ON MINING CLAIMS SSM.782863 & 73000 IN LEFROY TOWNSHIP

The deficiencies in the original submission have been rectified.

Assessment work credits have been approved as outlined on the attached Assessment Work Credit Form for the submission. The credits have been approved under Section 18, (INDUS), Mining Act Regulations.

The approval date is November 7, 1994.

If you have any questions regarding this correspondence, please contact Lucille Jerome at (705) 670-5861.

ORIGINAL SIGNED BY:

Ron C Gashinski

Ron C. Gashinski
Senior Manager, Mining Lands Section
Mining and Land Management Branch
Mines and Minerals Division

LJ/jl
Enclosures:

cc: Resident Geologist
Sault Ste Marie, Ontario

Assessment Files Library
Sudbury, Ontario

ASSESSMENT WORK CREDIT FORM

FILE NO: 2.15538

TRANSACTION NO: W.9450.00062 & W.9450.00063

RECORDED HOLDER: Warren Paving and Materials Group Ltd.

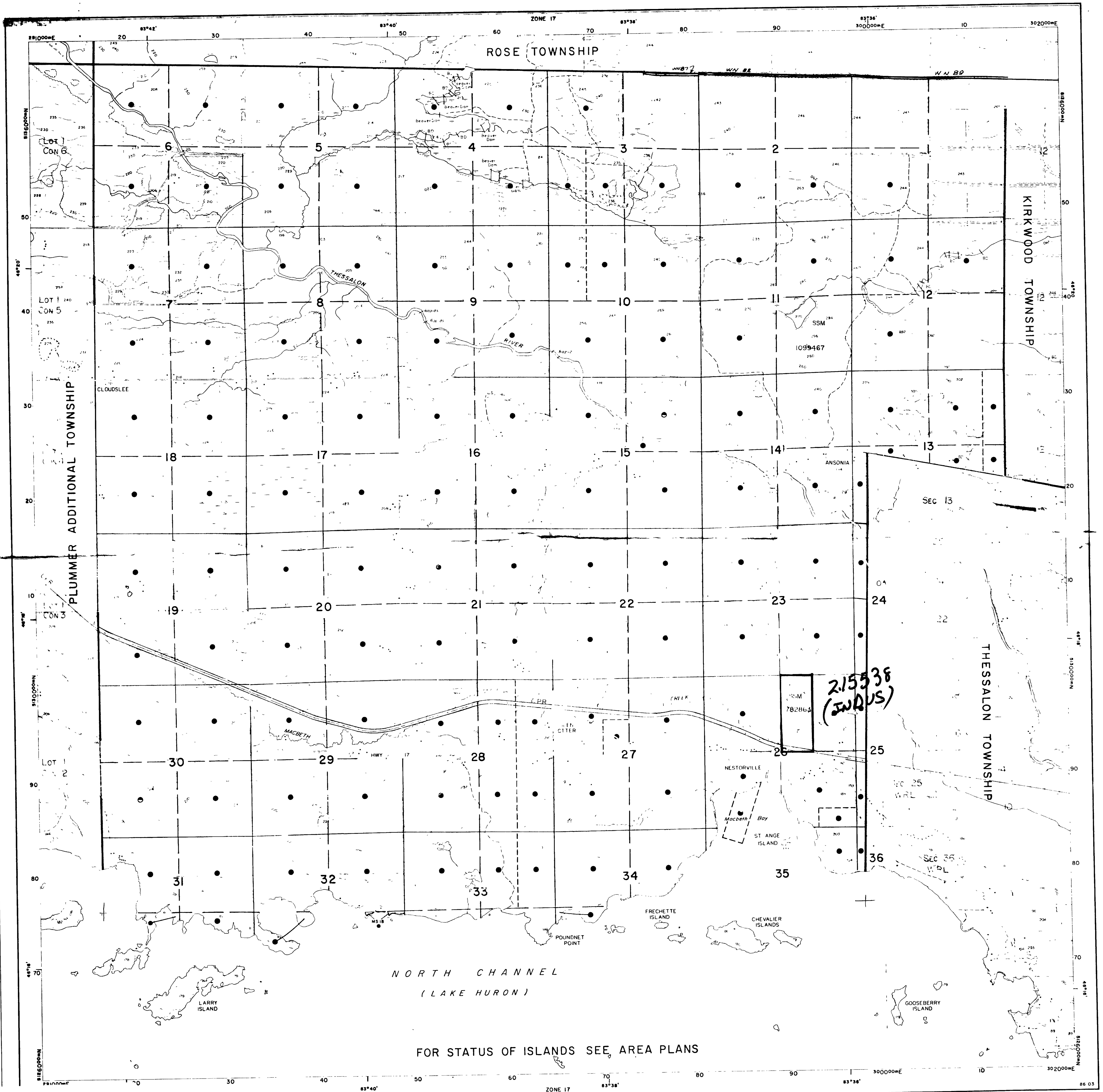
DATE: NOVEMBER 7, 1994

W9450.00062

CLAIM NO.	VALUE OF WORK DONE ON CLAIM	VALUE APPLIED TO CLAIM	RESERVE
782863	5432	4800	632

W9450.00063

73000	72315	0	72315



Ministry of Natural Resources / Ministry of Northern Development and Mines
Ontario

INDEX TO LAND DISPOSITION

PLAN
G-3294

DOCUMENT No. W9450.00062/63

TOWNSHIP
LEFROY

M.N.R. ADMINISTRATIVE DISTRICT
BLIND RIVER
MINING DIVISION
SAULT STE. MARIE
LAND TITLES/REGISTRY DIVISION
ALGOMA

Scale 1:20 000

Contour Interval 10 Metres

AREAS WITHDRAWN FROM DISPOSITION

MRO - Mining Rights Only
SRO - Surface Rights Only
M + S - Mining and Surface Rights

Description	Order No	Date	Disposition	File

SYMBOLS

Boundary
Township, Meridian, Baseline
Road allowance, surveyed; shoreline
Lot/Concession, surveyed; unsurveyed
Parcel, surveyed; unsurveyed
Right-of-way, road; railway; utility
Reservation
Cliff, Pit, Pile
Contour; Interpolated; Approximate; Depression
Control point (horizontal)
Flooded land
Mine head frame
Pipeline (above ground)
Railway, single track; double track; abandoned
Road, highway, county, township; access; trail, bush
Shoreline (original)
Transmission line
Wooded area

NOTES

LAND UNDER LAKE HURON WITHDRAWN FROM STAKING BY ORDER IN COUNCIL DATED APRIL 30, 1912

DATE OF ISSUE
AUG 8 1994
SAULT STE. MARIE MINING RECORDER'S OFFICE

DATE OF ISSUE
SAULT STE. MARIE MINING RECORDER'S OFFICE

DISPOSITION OF CROWN LANDS

Patent
Surface & Mining Rights
Surface Rights Only
Mining Rights Only
Lease
Surface & Mining Rights
Surface Rights Only
Mining Rights Only
Licence of Occupation
Order-in-Council
Cancelled
Reservation
Sand & Gravel

THE INFORMATION THAT APPEARS ON THIS MAP HAS BEEN COMPILED FROM VARIOUS SOURCES, AND ACCURACY IS NOT GUARANTEED. THOSE WISHING TO STAKE MINING CLAIMS SHOULD CONSULT WITH THE MINING RECORDER, MINISTRY OF NORTHERN DEVELOPMENT AND MINES, FOR ADDITIONAL INFORMATION ON THE STATUS OF THE LANDS SHOWN HEREON.

Map base and land disposition drafting by Surveys and Mapping Branch, Ministry of Natural Resources

The disposition of land, location of lot fabric and parcel boundaries on this index was compiled for administrative purposes only.

41J05SE0007 2.15538 LEFROY

200