TECHNICAL REPORT

LEVELTON
Engineering Solutions

Our file: 100-0865
October 4, 2000

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C. V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip Rap Testing, Polaris Mine
SUBJECT: **Sulphate Soundness Test (CSA A23.2-9A/ASTM C-88)**

Material Tested: "D" samples

Source: Polaris Minesite **Sampled by:** Westmar
Sample: Sawn blocks, approximately 15 cm x 3.5 cm x 10 cm

Samples	Solution			Number of Cycles
	Magnesium Sulphate			5
	Original Mass (g)	Final Mass (g)		Percent Loss
		Actual (*)	Estimated (*)	
D1a	1979.0	1981.8	1972	0.35%
D1b	1591.8	1593.8	1585	0.43%
AVERAGE LOSS BY MASS (%)				0.39%

Notes: 1. (*) The actual mass of the samples was greater at the conclusion of the test than the initial mass, even though the samples had undergone loss of material, via flaking and splitting. It is postulated that sulphate crystallization may have developed within the rock in areas of porosity. To account for the lost material which flaked or split from the samples, the residual particles were weighed. The lost mass is considered to be an estimate only.

REPORTED BY: F. Shrimer, P. Geo. DATE: Oct 4, 2000

PROFESSIONAL GEOSCIENTIST — PROVINCE OF BRITISH COLUMBIA — F. H. SHRIMER

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TECHNICAL REPORT

Our file: 100-0865
October 4, 2000

LEVELTON
Engineering Solutions

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C. V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip Rap Testing, Polaris Mine
SUBJECT: **Sulphate Soundness Test (CSA A23.2-9A/ASTM C-88)**

Material Tested: L samples

Source: Polaris Minesite **Sampled by:** Westmar
Sample: Sawn blocks, approximately 15 cm x 3.5 cm x 10 cm

Samples	Solution			Number of Cycles
	Magnesium Sulphate			5
	Original Mass (g)	Final Mass (g)		Percent Loss
		Actual (*)	Estimated (*)	
L1	3057.8	3059.9	3045	0.42%
L4	2758.5	2731.0	--	1.00%
AVERAGE LOSS BY MASS (%)				0.69%

Notes: 1. (*) The actual mass of the L1 sample was greater at the conclusion of the test than its initial mass, even though the sample had undergone loss of material, via flaking and splitting. It is postulated that sulphate crystallization may have developed within the rock in areas of porosity. To account for the lost material which flaked or split from the samples, the residual particles were weighed. The lost mass is considered to be an estimate only.

2. It is further postulated that the L4 sample may have had a net loss which was greater than indicated, due to uptake of $MgSO_4$. Thus, the loss may be underestimated.

REPORTED BY: F. Shrimer, P. Geo.

PROFESSIONAL F. H. SHRIMER PROVINCE OF BRITISH COLUMBIA GEOSCIENTIST

DATE: Oct 4, 2000

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TECHNICAL REPORT

Our file: 100-0865
October 4, 2000

LEVELTON
Engineering Solutions

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C. V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip Rap Testing, Polaris Mine
SUBJECT: **Sulphate Soundness Test (CSA A23.2-9A/ASTM C-88)**

Material Tested: Mine Waste

Source: Polaris Minesite
Sample: Crushed gravel

Sampled by: Westmar

Sample	Solution				Number of Cycles		
50 x 5 mm crush	Magnesium Sulphate				5		
Loss per Sieve Fraction							
Sieve Fraction	50 mm	37.5 mm	25 mm	19 mm	12.5 mm	9.5 mm	4.75 mm
Loss (%)	38.6	23.8	28.6	39.6	35.1	35.1	35.1
Original Grading (%)	17.4	28.5	20.9	10.8	9.7	4.7	8.0
Weighted Loss (%)	6.717	6.796	5.984	4.275	3.401	1.648	2.805
Total Weighted Loss (%)							31.6%

Notes: 1. Extensive disintegration of samples by end of second cycle.

REPORTED BY: ______ DATE: Oct 4, 2000
F. Shrimer, P. Geo.

PROFESSIONAL GEOSCIENTIST PROVINCE OF BRITISH COLUMBIA F. H. SHRIMER

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TECHNICAL REPORT

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Engineering Solutions

Our file: 100-0865
October 4, 2000

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C. V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip Rap Testing, Polaris Mine
SUBJECT: **Sulphate Soundness Test (CSA A23.2-9A/ASTM C-88)**

Material Tested: [illegible] Sample

Source: Polaris Minesite
Sample: Crushed gravel

Sampled by: Westmar

Sample	Solution				Number of Cycles		
50 x 5 mm crush	Magnesium Sulphate				5		
Loss per Sieve Fraction							
Sieve Fraction	50 mm	37.5 mm	25 mm	19 mm	12.5 mm	9.5 mm	4.75 mm
Loss (%)	0.115	1.081	0.743	0.781	3.699	3.699	3.699
Original Grading (%)	32.3	26.2	20.1	7.6	6.7	2.8	4.3
Weighted Loss (%)	0.037	0.283	0.149	0.059	0.248	0.104	0.159
Total Weighted Loss (%)							1.00%

Notes: 1. Some widening of cracks, some edges flaking.

PROFESSIONAL GEOSCIENTIST
PROVINCE OF BRITISH COLUMBIA
F. H. SHRIMER

REPORTED BY: ______________ DATE: Oct 4, 2000
F. Shrimer, P. [illegible]

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TECHNICAL REPORT

LEVELTON
Engineering Solutions

Our file: 100-0865
October 4, 2000

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C. V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip Rap Testing, Polaris Mine
SUBJECT: **Sulphate Soundness Test (CSA A23.2-9A/ASTM C-88)**

Material Tested: "D" sample

Source: Polaris Minesite
Sample: Crushed gravel

Sampled by: Westmar

Sample	Solution				Number of Cycles		
50 x 5 mm crush	Magnesium Sulphate				5		
Loss per Sieve Fraction							
Sieve Fraction	50 mm	37.5 mm	25 mm	19 mm	12.5 mm	9.5 mm	4.75 mm
Loss (%)	0.209	0.450	1.451	1.451	1.451	1.451	1.451
Original Grading (%)	49.9	24.3	13.8	4.2	3.8	1.6	2.4
Weighted Loss (%)	0.104	0.109	0.200	0.061	0.055	0.023	0.035
Total Weighted Loss (%)							0.60%

Notes: 1. Some minor disintegration.
2. Cracks have widened after test completed.

REPORTED BY: F. Shrimer, P. Geo. DATE: Oct 4, 2000

PROFESSIONAL PROVINCE OF F. H. SHRIMER BRITISH COLUMBIA GEOSCIENTIST

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APPENDIX F-3

October 4, 2000 – Petrographic Examinations and Table

LEVELTON
Engineering Solutions

Fax Transmittal

Levelton Engineering Ltd.

150-12791 Clarke Place
Richmond, B.C.
Canada V6V 2H9
Tel: 604 278-1411
Fax: 604 278-1042
E-Mail: info@levelton.com

To	Norm Allyn, P. Eng. – WESTMAR	Fax/phone number	985-2581/985-6488
cc		Fax/phone number	
From	Fred Shrimer, P. Geo.	Project number	100-0865
Date	October 4, 2000	Total number of pages (including cover page)	5

PROJECT: Testing of Polaris Rip-Rap

Norm:

Accompanying this cover are Technical Reports for the Petrographic Examinations.

I have also included, for reference, a comparative table which provides all the data in a single page.

My review of the project file indicates that all tests have been completed and reported, with the exception of the Freeze-Thaw test.

I cannot find any reference in my file indicating that you wanted any assessment of the Acid Rock Drainage characteristics of the materials – primarily the Mine Waste rock. Please advise.

Please call if you have any questions.

Regards,

Fred Shrimer, P. Geo.

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Please call 604-278-1411 if any pages are missing.

TECHNICAL REPORT

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C. V7M 1B3

LEVELTON
Engineering Solutions

ATTENTION: Mr. Norm Allyn, P. Eng.

Our file: 100-0865
September 21, 2000

PROJECT: Rip Rap Testing -- Polaris Mine
SUBJECT: **Petrographic Examination (ASTM C-295)**

Sample: Mottled Mine Waste Rock ("M" samples)

PETROGRAPHIC DESCRIPTION

Mineralized limestone -- altered fine-grained micritic and crystalline limestone, mineralization throughout consists of lead-zinc-iron sulphides, and possible oxides. Concentration of metals variable between the three chunk samples provided. Numerous common voids/vugs in the rock are preferential zones of weakness. The rock is generally of moderate strength, but some zones are crumbly and weak. Occasional zones are almost of good strength.

In thin-section, samples comprised of colliform texture of metallic sulphides, mostly galena and sphalerite. Groundmass is calcite and/or dolomite. Some dendritic galena. Dolomite is the primary carbonate, and occurs mostly as well-defined crystals, although there is some calcite as crystals also.

COMMENTS

The rock is not very competent, due to the presence of crystalline galena, sphalerite, pyrite and other metallic minerals, and also because of vugs, voids and fissures in the rock material.

QUALITY

The mineralized mine waste rock is generally not suitable for construction applications, other than for use as fill, due to its low strength, high porosity, and high metals content. Although the host material is carbonate, the rock may well contribute to acid-rock drainage under certain circumstances. Regulations governing the use of potentially acid-drainage-producing rock should be reviewed to determine whether ARD tests may be needed, if the rock were used as fill in environmentally-sensitive areas.

Petrographic Number of the sample was '191', which is equivalent to an overall rating of "Poor" for physical-mechanical quality.

SUMMARY

The mine waste rock is not considered suitable for construction applications, with the possible exception of "fill".

PETROGRAPHER: [signature] F. Shrimer, P. Geo.

PROFESSIONAL GEOSCIENTIST — PROVINCE OF BRITISH COLUMBIA — F. H. SHRIMER

DATE: Oct 4, 2000

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TECHNICAL REPORT

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C. V7M 1B3

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Engineering Solutions

ATTENTION: Mr. Norm Allyn, P. Eng.

Our file: 100-0865
September 21, 2000

PROJECT: Rip Rap Testing -- Polaris Mine
SUBJECT: Petrographic Examination (ASTM C-295)

Sample: Grey Rock -- "L" samples

PETROGRAPHIC DESCRIPTION

Limestone -- very fine-grained micritic limestone, dense, very strong.

In thin-section, these rocks are limestone composed of a mixture of finely crystalline and micritic calcite. Dense-textured. A little bit of porosity, evidenced in vuggy cavities, with coarser material in them. Fairly pure calcite, no discernible extraneous sediments detected. One section would be termed "organo-clastic limestone", reflecting considerable amount of shell fragments (up to 30%) in the section (e.g., L-2). Organic-derived material includes brachiopod and gastropod shell fragments. Parts of the rock are recrystallized.

COMMENTS

The limestone was quite strong. A few calcite-filled veins cut the rock.

QUALITY

The limestone was judged to be of good physical quality.

"Good" quality material was 96.6% by mass, while "Fair" quality material was 3.4%, giving a Petrographic Number of "107". For aggregate sizes, this equates with an overall quality rating of "Excellent".

SUMMARY

The grey limestone samples were judged to be of overall satisfactory quality for engineering construction applications.

PETROGRAPHER: [signature]
F. Shrimer, P. Geo.

PROFESSIONAL GEOSCIENTIST — PROVINCE OF BRITISH COLUMBIA — F. H. SHRIMER

DATE: Oct 4, 2000

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Levelton Engineering Ltd., 150 - 12791 Clarke Place, Richmond, B.C. Canada V6V 2H9 Tel: 604-278-1411 Fax: 604-278-1042

TECHNICAL REPORT

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C. V7M 1B3

LEVELTON
Engineering Solutions

ATTENTION: Mr. Norm Allyn, P. Eng.

Our file: 100-0865
September 21, 2000

PROJECT: Rip Rap Testing -- Polaris Mine
SUBJECT: **Petrographic Examination (ASTM C-295)**

Sample: Buff-Beige Rock -- "D" samples

PETROGRAPHIC DESCRIPTION

Limestone -- fine-grained micritic limestone, dense, very strong.

In thin-section, these rocks are limestone composed of a mixture of finely crystalline and micritic calcite. Dense-textured. Minor porosity. Patchy appearance. Some vuggy zones, and small amount of shell and other organic fragments. Many trilobite fragments in one section, some brachiopod and ostracods, algae.

COMMENTS

The material was quite strong.

QUALITY

The buff-beige limestone was strong and judged to be of good physical quality. Petrographic Number analysis determined a PN of '111', which rates the aggregate as being of "Good" physical-mechanical quality, when compared with other aggregates. "Good" quality material comprised 94.7% by mass of the sample, while "Fair" quality material accounted for 5.3% of the sample, by mass.

SUMMARY

The buff-beige limestone was judged to be of overall satisfactory quality for engineering construction applications.

PETROGRAPHER: F. Shrimer, P. Geo.

PROFESSIONAL PROVINCE OF F. H. SHRIMER BRITISH COLUMBIA GEOSCIENTIST

DATE: Oct 4, 2000

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Notice: The test data given in this report pertain to the sample provided, and may not be applicable to material other than that represented by the sample. This test report constitutes a testing service. Interpretation may be provided on request.

TECHNICAL REPORT

LEVELTON
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WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C. V7M 1B3

October 4, 2000
Our file: 100-0865

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip Rap Testing, Polaris Mine
SUBJECT: **Comparison of Test Results**

TEST	CRUSHED GRAVEL SAMPLES			SAWN ROCK SAMPLES		
	"MW"	"L"	"D"	"MW"	"L"	"D"
Los Angeles Abrasion loss (%)	44.8	17.1	17.3	--	--	--
Durability Index	71	92	82	--	--	--
Specific Gravity	3.536	2.720	2.689	3.760	2.739	2.626
Absorption (%)	1.35	0.43	1.40	1.723	0.985	1.565
Sulphate Soundness loss (%)	31.6	1.00	0.60	40.1	0.69	0.39
Petrographic Number	191	107	111	--	--	--
Petrographic Quality	Poor	Excellent	Good	--	--	--

Reported by: ____________
F. Shrimer, P. Geo.

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Notice: The test data given herein pertain to the sample provided, and may not be applicable to material from earlier or subsequent production, or from other zones. Reporting of these data constitutes a testing service. Interpretation may be provided upon request.

APPENDIX F-4

October 31, 2000 – Freeze-Thaw Tests

F_x Transmittal

LEVELTON
Engineering Solutions

Levelton Engineering Ltd.

150-12791 Clarke Place
Richmond, B.C.
Canada V6V 2H9
Tel: 604 278-1411
Fax: 604 278-1042
E-Mail: info@levelton.com

To	Norm Allyn, P. Eng. – WESTMAR	Fax/phone number	985-2581/985-6488
cc		Fax/phone number	
From	Fred Shrimer, P. Geo.	Project number	100-0865
Date	October 31, 2000	Total number of pages (including cover page)	4

PROJECT: Testing of Polaris Rip-Rap

Norm:

Accompanying this cover are Technical Reports for the Freeze-Thaw test (CIRIA method).

The method given in the CIRIA volume is somewhat vague in terms of determination of loss, and other procedural details. At any rate, the results are provided on the test report forms. The observational data are of some significance, and would indicate that the "limestone" samples were the materials which performed the best in these tests.

I have taken photographs of the samples at the beginning of as well as at the conclusion of the test, which I will forward to you, once the film's been developed.

My reading of the test method suggests that their limit is 0.5% maximum loss (?).

The test method says that the "stone must have no cracks in it", which simply was not possible to do. Two of the rocks (the ones that failed) had joints in them. My thought is that the test has now enabled an assessment as to the structural (e.g., rock mechanics) implications of those joints. (Some joints are acceptable, while others may not be.)

I trust that this is the information you need. Please call to discuss, or if you have any questions.

Regards,

Fred Shrimer, P. Geo.

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Please call 604-278-1411 if any pages are missing.

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TECHNICAL REPORT

Our file: 100-0865
October 31, 2000

LEVELTON
Engineering Solutions

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C. V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip Rap Testing, Polaris Mine
SUBJECT: **Freeze-Thaw Test of Rock Specimens (CIRIA Spec. Pub. 83, A2.4)**

Material Tested: Mine Waste

Source: Polaris Minesite **Sampled by:** Westmar
Sample: Mine rock

PARAMETER	RESULT
Absorption (%)	1.72
Weight loss (%)	0.7
Duration of test (# cycles)	25 (21 Sept - 26 Oct, 2000)
Crack propagation	Sample 'X' has developed minor cracks, extending from previously-existing voids in the rock. Sample 'Z' has developed a number of extensive open cracks, which have extended nearly 70% through the rock.

Notes: 1. Two specimens prepared from the sample.

REPORTED BY: F. Shrimer, P. Geo.

PROFESSIONAL PROVINCE OF BRITISH COLUMBIA F. H. SHRIMER GEOSCIENTIST

DATE: Oct 31, 2000

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Notice: The test data given in this report pertain to the sample provided, and may not be applicable to samples from production other than that represented by the sample. This test report constitutes a testing service. Interpretation may be provided on request.

Levelton Engineering Ltd., #150 - 12791 Clarke Place, Richmond, B.C. V6V 2H9 Canada Tel: 604-278-1411 Fax: 604-278-1042

TECHNICAL REPORT

Our file: 100-0865
October 31, 2000

LEVELTON
Engineering Solutions

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C. V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip Rap Testing, Polaris Mine
SUBJECT: **Freeze-Thaw Test of Rock Specimens (CIRIA Spec. Pub. 83, A2.4)**

Material Tested: Dolomite

Source: Polaris Minesite **Sampled by:** Westmar
Sample: "Dolomite" (buff-beige rock)

PARAMETER	RESULT
Absorption (%)	1.57
Weight loss (%)	Sa. A: 10.0 ; Sa. B: 0.3 Average: 5.2
Duration of test (# cycles)	25 (21 Sept - 26 Oct, 2000)
Crack propagation	Sample 'A' has been fragmented by several major open cracks, breaking into two larger parts and numerous smaller chips and pieces. Fractures have developed both along pre-existing joints as well as through the rock fabric itself. Sample 'B' has developed one significant crack which has nearly extended through the rock (75% complete), and the specimen is in danger of being broken imminently.

Notes: 1. Two specimens prepared from the sample.

PROFESSIONAL PROVINCE OF F. H. SHRIMER BRITISH COLUMBIA GEOSCIENTIST

REPORTED BY: [signature] DATE: Oct 31, 2000
F. Shrimer, P. Geo.

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Notice: The test data given in this report pertain to the sample provided, and may not be applicable to samples from production other than that represented by the sample. This test report constitutes a testing service. Interpretation may be provided on request.

Levelton Engineering Ltd., #150 - 12791 Clarke Place, Richmond, B.C. V6V 2H9 Canada Tel: 604-278-1411 Fax: 604-278-1042

TECHNICAL REPORT

Our file: 100-0865
October 31, 2000

LEVELTON
Engineering Solutions

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C. V7M 1B3

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip Rap Testing, Polaris Mine
SUBJECT: **Freeze-Thaw Test of Rock Specimens (CIRIA Spec. Pub. 83, A2.4)**

Material Tested: [illegible] "Limestone" [illegible]

Source: Polaris Minesite **Sampled by:** Westmar
Sample: "Limestone" (brown-grey rock)

PARAMETER	RESULT
Absorption (%)	0.99
Weight loss (%)	0.03
Duration of test (# cycles)	25 (21 Sept - 26 Oct, 2000)
Crack propagation	No noticeable development of cracks in Sample 'C'. A few flakes have been removed at the conclusion of the test from edges. Sample 'D' was noted to have a very slight initiation of a crack in the specimen, and both completed as well as incipient flaking failures along edges of the specimen.

Notes: 1. Two samples prepared from the sample.

REPORTED BY: F. Shrimer, P. Geo.

PROFESSIONAL GEOSCIENTIST — PROVINCE OF BRITISH COLUMBIA — F. H. SHRIMER

DATE: Oct 31, 2000

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Levelton Engineering Ltd., #150 - 12791 Clarke Place, Richmond, B.C. V6V 2H9 Canada Tel: 604-278-1411 Fax: 604-278-1042

APPENDIX F-5

March 13, 2001 – Summary of Rock Quality Tests

LEVELTON
Engineering Solutions

Fax Transmittal

Levelton Engineering Ltd.

150-12791 Clarke Place
Richmond, B.C.
Canada V6V 2H9
Tel: 604 278-1411
Fax: 604 278-1042
E-Mail: info@levelton.com

To	Gang Yang, EIT. – WESTMAR	Fax/phone number	985-2581/985-6488
cc		Fax/phone number	
From	Fred Shrimer, P. Geo.	Project number	100-0865
Date	March 13, 2001	Total number of pages (including cover page)	2

PROJECT: Testing of Polaris Rip-Rap

Gang:

Accompanying is the revised table listing the test data from the testing of the Polaris rock samples.

I hope our discussion this afternoon was of help in interpreting the results. Please call me if you have any further questions.

Regards,

Fred Shrimer, P. Geo.

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Please call 604-278-1411 if any pages are missing.

TECHNICAL REPORT

LEVELTON
Engineering Solutions

WESTMAR CONSULTANTS INC.
#400 - 233 West First Street
NORTH VANCOUVER, B.C. V7M 1B3

March 13, 2001
Our file: 100-0865

ATTENTION: Mr. Norm Allyn, P. Eng.

PROJECT: Rip Rap Testing, Polaris Mine
SUBJECT: **Comparison of Test Results**

TEST	CRUSHED GRAVEL SAMPLES			SAWN ROCK SAMPLES		
	"MW"	"L"	"D"	"MW"	"L"	"D"
Los Angeles Abrasion loss (%)	44.8	17.1	17.3	--	--	--
Durability Index	71	92	82	--	--	--
Specific Gravity	3.536	2.720	2.689	3.760	2.739	2.626
Absorption (%)	1.35	0.43	1.40	1.723	0.985	1.565
Freeze-Thaw Test loss (%)	--	--	--	0.7	0.03	5.2
Sulphate Soundness loss (%)	31.6	1.00	0.60	40.1	0.69	0.39
Petrographic Number	191	107	111	--	--	--
Petrographic Quality	Poor	Excellent	Good	--	--	--

Reported by: ____________
F. Shrimer, P. Geo.

PROFESSIONAL GEOSCIENTIST
PROVINCE OF BRITISH COLUMBIA
F. H. SHRIMER

March 13, 2001.

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Notice: The test data given herein pertain to the sample provided, and may not be applicable to material from earlier or subsequent production, or from other zones. Reporting of these data constitutes a testing service. Interpretation may be provided upon request.

APPENDIX G

CIRIA Freeze-Thaw Test Specifications

CONSTRUCTION JSTRY RESEARCH
AND INFORMATION ASSOCIATION

CENTRE ; CIVIL ENGINEERING
RESEARCH AND CODES

Manual on the use of rock in coastal and shoreline engineering

CIRIA SPECIAL PUBLICATION 83

CUR REPORT 154

$$C_{w3} = \frac{W_3}{W_t} \cdot 100$$

Calculate the number per cent of stones with length-to-thickness ratio greater than 3 and 2 using the formula:

$$C_{n_3} = \frac{n_3}{n} \cdot 100$$

$$C_{n_2} = \frac{n_2}{n} \cdot 100$$

A2.3.5 REPORT

The report must provide the following data:

1. The measured weight per cent of stones with length-to-thickness ratio greater than 3;
2. The measured number percent of stones with length-to-thickness ratio greater than 3, and greater than 2;
3. A reference to this standard;
4. A description of the sample, including the weight and the number of stones;
5. The source of the sample;
6. The date of the test.

Note: Box 35 in Section 3.6 of the main text gives practical guidance on taking length and thickness measurements.

A2.4 Determination of Resistance to Freeze/ Thaw Cycles

Note: This standard is based on Draft NEN 5184 and B5812.

A2.4.1 SUBJECT AND AREA OF APPLICATION

This standard gives the method to determine the resistance against freeze/thaw cycles of a stone of a grading class with a nominal size greater than the 31.5 mm sieve size.

A2.4.2 SAMPLE FOR ANALYSIS

The stone must be taken at random from the largest fraction of stone material set by the requirements for gradings. If the stone is heavier than 20 kg, the test will have to be carried out on a representative part of at least 10 kg. The stone must have no cracks in it.

A2.4.3 EQUIPMENT AND OTHER AIDS

A2.4.3.1 Drying oven or other appropriate apparatus, capable of adjustable temperature of (110 ± 5)°C;
A2.4.3.2 Weighing equipment, accurate up to 0.01% of the weight of the stone;
A2.4.3.3 Freezer-box with air circulation in which the stone can be exposed to the temperature described in Section A2.4.4.2;
A2.4.3.4 Vessel with a volume at least six times the volume of the stone;
A2.4.3.5 Saw for use in case the stone has a volume in excess of 150 ml;

A2.4.3.6 Plas ilm, brush.

A2.4.4 METHOD OF OPERATION

A2.4.4.1 Water absorption at atmospheric pressure

Cut from the stone a representative piece, using the saw, if the stone has a volume in excess of 150 ml. The representative part of the stone should have a volume of at least 50 ml and, at most, 150 ml. Determine the water absorption, in accordance with Section A2.7, of the stone or part of the stone.

End the test if the water absorption does not exceed 0.5%, as in that case the stone is considered to be (satisfactorily) resistant to freeze/thaw cycles. Carry out freeze test in accordance with A2.4.4.2 below if the water absorption exceeds 0.5%

A2.4.4.2 Execution of the freeze test

Let the stone absorb water in accordance with Section A2.7. Wrap the stone in plastic film and place it in the freezer-box. Adjust the temperature control in such a way that the temperature in the stone reaches a level of −15°C or lower in a time of about 5 hours. Maintain that temperature for at least 2 hours. Remove the plastic film and immerse the stone directly in the water in the vessel, which contains drinking water with at least five times the volume of the stone at a temperature of 15–20°C.

Leave the stone submerged for at least 2 hours. Repeat the freeze–thaw cycle 25 times. At the end of these tests, dry the stone in the oven at a temperature of (110 ± 5)°C until the stone reaches a stage when its weight remains constant.

Determine the weight loss of the stone and check to see if any cracks have developed.

A2.4.5 REPORT

1. Water absorption;
2. Weight loss in per cent and rounded to 0.1%;
3. The development of any cracks during the test;
4. Resistance against freeze/thaw cycles (weight loss less than 0.5% and no crack development);
5. Reference to this standard;
6. Description of the stone, including the weight loss;
7. Source of stone;
8. Duration of the tests.

A2.5 Determination of Dynamic Crushing Strength

Note: This standard is based on Draft NEN 5185.

A2.5.1 SUBJECT AND AREA OF APPLICATION

This standard provides the method for the determination of the dynamic crushing strength of natural stone and of other types of stone and stone-type materials. The dynamic crushing strength is determined as the average test result from a duplicated test.

APPENDIX H

Preliminary General Blast Design

Blasting Permafrost Conditions – Sheet Pile Cell Dock

Introduction

The dock facility was constructed in 1981 and is comprised of four circular sheet pile cells, each approximately 26 m in diameter. Three interconnecting arcs on the front face tied the four cells together. The wall thickness of an individual steel sheet pile is approximately 1/2-inch. The cells were constructed by driving sheet piles through the ice and backfilled with rock and overburden available locally. The face of the dock is approximately 90 m long with a depth of approximately 13 m at low water.

Blasting in or near Canadian fisheries waters has demonstrated to cause disturbance, injury and/or death to fish and marine mammals and the alteration, disruption or destruction of marine habitat. The Department of Fisheries and Oceans (DFO) has prepared guidelines to assist proponents in conservation methods to protect marine life and habitat from the destructive forces of explosives. The guidelines entitled, "Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters, 1998", forms the basis of blast design for the Polaris project

The Need for Blasting

The substrate underlying the sheet pile cell dock is comprised of overburden excavated from the barge dry dock facility that has been backfilled into the cells and compacted. The Polaris site exhibits permafrost conditions exceeding 100 m in depth and blasting will be required to sufficiently fragment the frozen fill to allow for cost effective excavation.

Type of Explosives

The "Guidelines for the Use of Explosives In or Near Canadian Fisheries Water, 1998" state: "No use of ammonium nitrate-fuel oil mixtures occurs in or near water due to the production of toxic by-products (ammonia)."

Permafrost blasting is to be performed using nitroglycerin (NG) based dynamite, such as Orica Powerfrac in cartridge form.

Linear shape charges may be used to sever the steel sheet pile at the designed depth underwater. Linear shape charges (LSC) do not normally have trade names and are commonly manufactured to meet specific project conditions. Typically, RDX explosive is used in linear shape charges.

Blast Design

Overpressure calculations, set at a peak pulse of 100kPa, were performed for the dock site and the results are presented in Figure 1. These calculations form the basis of blast design and configuration for the project area. The charge weight per delay limitations are depicted linearly in metres from the dock face towards the process barge. The use of a bubble curtain to limit blast-induced overpressure in close proximity to the dock face is mandatory.

Permafrost blasting requires approximately twice the powder factor required to break normal rock. The approximate volume of material in the dock area to blast is 28,700 cubic metres requiring approximately 34,500 kilograms of explosives in total (see Figure 2). Blasting must be performed in small discrete shots, within the overpressure guidelines, so that excavation equipment can dig out the shot material before it refreezes. Actual blast size will depend on the size and capability of the excavator on site. A generalized blast plan is illustrated in Figure 3, showing an 8-blasthole shot containing about 50 cubic metres of material. Maximum depth of blasting in the sheet pile cell dock area is about 7 metres.

Multi-deck loading and blasting techniques are required. Between 2 to 4 explosives decks per hole will be required to fragment the cell material in order to maintain the overpressure guidelines. The charge weight per delay will vary depending upon the proximity of the shot to the front face of dock (see Figure 1). The blasting contractor must: have a full understanding of marine blasting; be able to blast to Fisheries guidelines; have the ability to calculate the specific charge weight per delay for each blast; and be able to adjust the blast pattern or utilize a bubble curtain as the need arises. Experience in blasting permafrost conditions is also required.

Overpressure modeling was performed for the use of linear shape charges (LSC) to sever the sheet pile below water level (see Table 1). Since bubble cutains have effectively reduced the pressure pulse by a 10-fold factor, the overpressure limit for the model was set at 1,000kPa for various linear shaped charges. The results indicate that a 10-foot length of LSC may be detonated, within the Fisheries guidelines, with the proper use of a bubble curtain.

Detonation Depth

Blast depth varies throughout the project site, however, a maximum depth of 7 m is to be blasted in the sheet pile cell dock area. As noted previously, the charge weight per delay will depend on the distance of the blast from the water as illustrated on Figure 1. Detailed calculations for setback distances from 1 meter to 14 meters can be found in Tables 2-15 in the Appendix.

Method of Detonation – Electrical Sequential Blasting

The method of detonation is critical to the success of the project, both in the terms of safety and the ability to control blast-induced overpressures and limit marine life mortality.

Electric sequential blasting techniques must be employed for two reasons:

Safety: Due to the high powder factor required to blast permafrost, blasting mats must be used to contain fly rock. Nonel or shock tube type detonators are subject to damage when blasting mats are placed over the tubes, resulting in cutoffs, the blast firing out of sequence, excessive fly rock and extremely high overpressures at the water. Overpressure limitations will be exceeded if the designed delay sequence is not achieved due to damaged shock tubes. The safety of personnel and equipment are also at risk from fly rock as a result of a violent, uncontrolled blast caused by damaged shock tubes.

Accuracy: All shock tube type detonators contain +/- delay scatter time because of the inaccuracy of the pyrotechnic delay elements in the blasting caps. In order to control overpressure generated by blasting, tight control must be placed on the delay timing sequence. The multi-deck holes require accurate delay times between explosive decks and from hole-to-hole to limit the blast-induced overpressure to 100kPa. The only methods available for the accuracy required for this project are through the use of electronic detonators or electrical sequential blasting. Electronic detonators are not commonly used at present and are costly. Experienced blasting contractors commonly perform electric sequential blasting.

Polaris Mine
Decommissioning Sheet Pile Dock

Generalized Blast Design
Electrical Sequential Tie-in : Delay Sequence Decked Holes

2- Decks per hole

142ms	192ms	242ms	292ms	Upper Deck Delay Sequence	← POWERFRAC
					← stemming
167ms	217ms	267ms	317ms	Lower Deck Delay Sequence	← POWERFRAC

100ms	150ms	200ms	250ms	Upper Deck Delay Sequence	← POWERFRAC
					← stemming
125ms	175ms	225ms	275ms	Lower Deck Delay Sequence	← POWERFRAC

Generalized Pattern Size - 4ft x 4ft (1.22m x 1.22m)

↑

To Blasting Machine

Note - Leg wires omitted for sake of clarity
- **Not to scale**
- **Only 2-row shot shown. Additional rows may be required depending on size of blast**

PATTERN	EXPLOSIVES
4x4' (1.22mx1.22m)	2x16 Powerfrac Cartridges
4x4' (1.22mx1.22m)	2x16 Powerfrac Cartridges

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Figure 3

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Design Criteria
for
Guidelines for the Use of Explosives In or
Near Canadian Fisheries Waters

Table No. 2
Charge Weight Calculations for a 1.0 m Setback

Table 1 - From " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998
Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"

	Substrate	Dr ($g \cdot cm^{-3}$)	Cr ($cm \cdot s^{-1}$)	Cw ($cm \cdot s^{-1}$)	K	Dw ($g \cdot cm^{-3}$)	Pw (kPa)	PPV ($mm \cdot sec^{-1}$)
1	Rock	2.64	457200	146300	5.03	1.00	100.00	13.00
2	Frozen Soil	1.92	304800	146300	3.20	1.00	100.00	13.00
3	Ice	0.98	304800	146300	2.10	1.00	100.00	13.00
4	Saturated Soil	2.06	146300	146300	2.13	1.00	100.00	13.00
5	Unsaturated Soil	1.92	45700	146300	0.98	1.00	100.00	13.00

PROJECT DESIGN CRITERIA

Project Location:	Polaris Mine - Little Cornwallis Island, Nunavut	
Water Course:	Crozier Strait	
Substrate:	Quarry Fill	Frozen Soil (Fisheries Substrate Classification)
Nature of Jointing/Fractures:	N/A	
Overburden:	N/A	
Hole Depth:	2 m	
Explosive Type:	Orica Powerfrac (Gelatin Dynamite)	
Method of Detonation:	Electric, blasting cap	
Bubble Curtain Required:	Yes	

Table 2 - Calculations for : Polaris Mine - Little Cornwallis Island, Nunavut

	Project Substrate	Dr ($g \cdot cm^{-3}$)	Cr ($cm \cdot s^{-1}$)	Cw ($cm \cdot s^{-1}$)	K	Dw ($g \cdot cm^{-3}$)	Pw (kPa)	Vr ($mm \cdot sec^{-1}$)
2	Frozen Soil	1.92	304800	146300	3.2	1.00	100.00	13.00

0.05	Charge Weight (kg)	0.05	0.11 Lbs/delay
1	No. of Delays/Charge	1.0	
	Charge Weight/Delay	0.05	
1.0	Distance to Detonation	1.00	
	$\frac{Zw}{Zr} = \frac{DwCw}{DrCr}$	0.2500	
	$Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$ or $Pr = \frac{Pw(1+(Zw/Zr))}{2(Zw/Zr)}$	250.0	2.50 kPa or 2.50E+06 dynes - *to limit Pw to 100 kPa*
	$Vr = \frac{2Pr}{DrCr}$		8.54 $cm \cdot s^{-1}$ - *to limit Pw to 100kPa*
	$R = (w^{5})(Vr/100)^{-0.626}$		1.0 m *Minimum setback distance required to reduce overpressure to less than 100 kPa*
	$R = (w^{5})(Vr/100)^{-0.626}$		3.4 m *Minimum setback distance from a spawning area to maintain PPV @ 13* $mm \cdot sec^{-1}$
	$Vr=100(R/W^{.5})^{-1.6}$		9.10 $cm \cdot s^{-1}$ Calculated PPV at Design Criteria
	$Vr = \frac{2Pr}{DrCr}$ or $Pr = (DrCrVr)/2$		2.66E+06 Dynes Calculated Pressure in Substrate at Design Criteria
	$Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$		106.54 kPa Calculated Pressure in Water at Design Criteria

PROJECT SUMMARY	Fisheries Limit	Project Design
Pressure in Water (Pw) kPa	100.0	106.54
**Peak Particle Velocity (Vr) cm-s-1	13.0	91.03

** Limit for spawning bed during period of egg incubation

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Design Criteria
for
Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters
Table No. 3
Charge Weight Calculations for a 2.0 m Setback

Table 1 - From " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998
Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"

	Substrate	Dr ($g \cdot cm^{-3}$)	Cr ($cm \cdot s^{-1}$)	Cw ($cm \cdot s^{-1}$)	K	Dw ($g \cdot cm^{-3}$)	Pw (kPa)	PPV ($mm \cdot sec^{-1}$)
1	Rock	2.64	457200	146300	5.03	1.00	100.00	13.00
2	Frozen Soil	1.92	304800	146300	3.20	1.00	100.00	13.00
3	Ice	0.98	304800	146300	2.10	1.00	100.00	13.00
4	Saturated Soil	2.08	146300	146300	2.13	1.00	100.00	13.00
5	Unsaturated Soil	1.92	45700	146300	0.98	1.00	100.00	13.00

PROJECT DESIGN CRITERIA

Project Location:	Polaris Mine - Little Cornwallis Island, Nunavut	
Water Course:	Crozier Strait	
Substrate:	Quarry Fill	Frozen Soil (Fisheries Substrate Classification)
Nature of Jointing/Fractures:	N/A	
Overburden:	N/A	
Hole Depth:	2 m	
Explosive Type:	Orica Powerfrac (Gelatin Dynamite)	
Method of Detonation:	Electric, blasting cap	
Bubble Curtain Required:	Yes	

Table 3 - Calculations for : Polaris Mine - Little Cornwallis Island, Nunavut

	Project Substrate	Dr ($g \cdot cm^{-3}$)	Cr ($cm \cdot s^{-1}$)	Cw ($cm \cdot s^{-1}$)	K	Dw ($g \cdot cm^{-3}$)	Pw (kPa)	Vr ($mm \cdot sec^{-1}$)
2	Frozen Soil	1.92	304800	146300	3.2	1.00	100.00	13.00

0.18	Charge Weight (kg)	0.18	0.40 Lbs/delay
1	No. of Delays/Charge	1.0	
	Charge Weight/Delay	0.18	
2.0	Distance to Detonation	2.00	
	$\frac{Zw}{Zr} = \frac{DwCw}{DrCr}$	0.2500	
	$Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$ or $Pr = \frac{Pw(1+(Zw/Zr))}{2(Zw/Zr)}$	250.0	2.50 kPa or 2.50E+06 dynes - *to limit Pw to 100 kPa*
	$Vr = \frac{2Pr}{DrCr}$		8.54 $cm \cdot s^{-1}$ - *to limit Pw to 100kPa*
	$R = (w^{.5})(Vr/100)^{-0.625}$		2.0 m *Minimum setback distance required to reduce overpressure to less than 100 kPa*
	$R = (w^{.5})(Vr/100)^{-0.625}$		6.4 m *Minimum setback distance from a spawning area to maintain PPV @ 13 $mm \cdot sec^{-1}$*
	$Vr = 100(R/W^{.5})^{-1.6}$		8.37 $cm \cdot s^{-1}$ Calculated PPV at Design Criteria
	$Vr = \frac{2Pr}{DrCr}$ or $Pr = (DrCrVr)/2$		2.45E+06 Dynes Calculated Pressure in Substrate at Design Criteria
	$Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$		97.93 kPa Calculated Pressure in Water at Design Criteria

PROJECT SUMMARY	Fisheries Limit	Project Design
Pressure in Water (Pw) kPa	100.0	97.93
**Peak Particle Velocity (Vr) cm•s-1	13.0	83.67

** Limit for spawning bed during period of egg incubation

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Design Criteria
for
Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters
Table No. 4
Charge Weight Calculations for a 3.0 m Setback

Table 1 - From " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998
Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"

	Substrate	Dr ($g \cdot cm^{-3}$)	Cr ($cm \cdot s^{-1}$)	Cw ($cm \cdot s^{-1}$)	K	Dw ($g \cdot cm^{-3}$)	Pw (kPa)	PPV ($mm \cdot sec^{-1}$)
1	Rock	2.64	457200	146300	5.03	1.00	100.00	13.00
2	Frozen Soil	1.92	304800	146300	3.20	1.00	100.00	13.00
3	Ice	0.98	304800	146300	2.10	1.00	100.00	13.00
4	Saturated Soil	2.08	146300	146300	2.13	1.00	100.00	13.00
5	Unsaturated Soil	1.92	45700	146300	0.88	1.00	100.00	13.00

PROJECT DESIGN CRITERIA

Project Location:	Polaris Mine - Little Cornwallis Island, Nunavut	
Water Course:	Crozier Strait	
Substrate:	Quarry Fill	Frozen Soil (Fisheries Substrate Classification)
Nature of Jointing/Fractures:	N/A	
Overburden:	N/A	
Hole Depth:	2 m	
Explosive Type:	Orica Powerfrac (Gelatin Dynamite)	
Method of Detonation:	Electric, blasting cap	
Bubble Curtain Required:	Yes	

Table 4 - Calculations for : Polaris Mine - Little Cornwallis Island, Nunavut

	Project Substrate	Dr ($g \cdot cm^{-3}$)	Cr ($cm \cdot s^{-1}$)	Cw ($cm \cdot s^{-1}$)	K	Dw ($g \cdot cm^{-3}$)	Pw (kPa)	Vr ($mm \cdot sec^{-1}$)
2	Frozen Soil	1.92	304800	146300	3.2	1.00	100.00	13.00

0.42	Charge Weight (kg)	0.42	0.93 Lbs/delay
1	No. of Delays/Charge	1.0	
	Charge Weight/Delay	0.42	
3.0	Distance to Detonation	3.00	
	$\frac{Zw}{Zr} = \frac{DwCw}{DrCr}$	0.2500	
	$Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$ or $Pr = \frac{Pw(1+(Zw/Zr))}{2(Zw/Zr)}$	250.0	2.50 kPa or 2.50E+06 dynes - *to limit Pw to 100 kPa*
	$Vr = \frac{2Pr}{DrCr}$		8.64 $cm \cdot s^{-1}$ - *to limit Pw to 100kPa*
	$R = (w^{.5})(Vr/100)^{-0.625}$		3.0 m *Minimum setback distance required to reduce overpressure to less than 100 kPa*
	$R = (w^{.5})(Vr/100)^{-0.625}$		9.8 m *Minimum setback distance from a spawning area to maintain PPV @ 13 mm•sec*$^{-1}$
	$Vr = 100(R/W^{.5})^{-1.6}$		8.61 $cm \cdot s^{-1}$ Calculated PPV at Design Criteria
	$Vr = \frac{2Pr}{DrCr}$ or $Pr = (DrCrVr)/2$		2.52E+06 Dynes Calculated Pressure in Substrate at Design Criteria
	$Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$		100.82 kPa Calculated Pressure in Water at Design Criteria

PROJECT SUMMARY	Fisheries Limit	Project Design
Pressure in Water (Pw) kPa	100.0	100.82
**Peak Particle Velocity (Vr) cm-s-1	13.0	86.14

** Limit for spawning bed during period of egg incubation

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Design Criteria
for
Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters
Table No. 5
Charge Weight Calculations for a 4.0 m Setback

Table 1 - From " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998
Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"

	Substrate	Dr (g·cm^{-3})	Cr (cm·s^{-1})	Cw (cm·s^{-1})	K	Dw (g·cm^{-3})	Pw (kPa)	PPV (mm·sec^{-1})
1	Rock	2.64	457200	146300	5.03	1.00	100.00	13.00
2	Frozen Soil	1.92	304800	146300	3.20	1.00	100.00	13.00
3	Ice	0.98	304800	146300	2.10	1.00	100.00	13.00
4	Saturated Soil	2.08	146300	146300	2.13	1.00	100.00	13.00
5	Unsaturated Soil	1.92	45700	146300	0.98	1.00	100.00	13.00

PROJECT DESIGN CRITERIA

Project Location:	Polaris Mine - Little Cornwallis Island, Nunavut
Water Course:	Crozier Strait
Substrate:	Quarry Fill — **Frozen Soil (Fisheries Substrate Classification)**
Nature of Jointing/Fractures:	N/A
Overburden:	N/A
Hole Depth:	2 m
Explosive Type:	Orica Powerfrac (Gelatin Dynamite)
Method of Detonation:	Electric, blasting cap
Bubble Curtain Required:	Yes

Table 5 - Calculations for : Polaris Mine - Little Cornwallis Island, Nunavut

	Project Substrate	Dr (g·cm^{-3})	Cr (cm·s^{-1})	Cw (cm·s^{-1})	K	Dw (g·cm^{-3})	Pw (kPa)	Vr (mm·sec^{-1})
2	Frozen Soil	1.92	304800	146300	3.2	1.00	100.00	13.00

0.74	Charge Weight (kg)	0.74	1.63 Lbs/delay
1	No. of Delays/Charge	1.0	
	Charge Weight/Delay	0.74	
4.0	Distance to Detonation	4.00	
	Zw/Zr = DwCw/DrCr	0.2500	
	Pw = 2(Zw/Zr)Pr / 1+(Zw/Zr) or Pr = Pw(1+(Zw/Zr)) / 2(Zw/Zr)	250.0	2.50 kPa or 2.50E+06 dynes - *to limit Pw to 100 kPa*
	Vr = 2Pr / DrCr	8.54 cm·s^{-1} - *to limit Pw to 100kPa*	
	R = (w$^{.5}$)(Vr/100)$^{-0.625}$	4.0 m *Minimum setback distance required to reduce overpressure to less than 100 kPa*	
	R = (w$^{.5}$)(Vr/100)$^{-0.625}$	13.0 m *Minimum setback distance from a spawning area to maintain PPV @ 13 mm·sec^{-1}*	
	Vr=100(R/W$^{.5}$)$^{-1.6}$	8.65 cm·s^{-1} Calculated PPV at Design Criteria	
	Vr = 2Pr / DrCr or Pr = (DrCrVr)/2	2.50E+06 Dynes Calculated Pressure in Substrate at Design Criteria	
	Pw = 2(Zw/Zr)Pr / 1+(Zw/Zr)	100.10 kPa Calculated Pressure in Water at Design Criteria	

PROJECT SUMMARY	Fisheries Limit	Project Design
Pressure in Water (Pw) kPa	100.0	100.10
**Peak Particle Velocity (Vr) cm·s-1	13.0	85.52

** Limit for spawning bed during period of egg incubation

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Design Criteria
for
Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters
Table No. 6
Charge Weight Calculations for a 5.0 m Setback

Table 1 - From " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998
Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"

	Substrate	Dr ($g \cdot cm^{-3}$)	Cr ($cm \cdot s^{-1}$)	Cw ($cm \cdot s^{-1}$)	K	Dw ($g \cdot cm^{-3}$)	Pw (kPa)	PPV ($mm \cdot sec^{-1}$)
1	Rock	2.64	457200	146300	5.03	1.00	100.00	13.00
2	Frozen Soil	1.92	304800	146300	3.20	1.00	100.00	13.00
3	Ice	0.96	304800	146300	2.10	1.00	100.00	13.00
4	Saturated Soil	2.06	146300	146300	2.13	1.00	100.00	13.00
5	Unsaturated Soil	1.92	45700	146300	0.98	1.00	100.00	13.00

PROJECT DESIGN CRITERIA

Project Location:	Polaris Mine - Little Cornwallis Island, Nunavut	
Water Course:	Crozier Strait	
Substrate:	Quarry Fill	Frozen Soil (Fisheries Substrate Classification)
Nature of Jointing/Fractures:	N/A	
Overburden:	N/A	
Hole Depth:	2 m	
Explosive Type:	Orica Powerfrac (Gelatin Dynamite)	
Method of Detonation:	Electric, blasting cap	
Bubble Curtain Required:	Yes	

Table 6 - Calculations for : **Polaris Mine - Little Cornwallis Island, Nunavut**

	Project Substrate	Dr ($g \cdot cm^{-3}$)	Cr ($cm \cdot s^{-1}$)	Cw ($cm \cdot s^{-1}$)	K	Dw ($g \cdot cm^{-3}$)	Pw (kPa)	Vr ($mm \cdot sec^{-1}$)
2	Frozen Soil	1.92	304800	146300	3.2	1.00	100.00	13.00

1.15	Charge Weight (kg)	1.15	2.54 Lbs/delay
1	No. of Delays/Charge	1.0	
	Charge Weight/Delay	1.15	
5.0	Distance to Detonation	5.00	
	$\frac{Zw}{Zr} = \frac{DwCw}{DrCr}$	0.2500	
	$Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$ or $Pr = \frac{Pw(1+(Zw/Zr))}{2(Zw/Zr)}$	250.0	2.50 kPa or 2.50E+06 dynes - *to limit Pw to 100 kPa*
	$Vr = \frac{2Pr}{DrCr}$		8.54 $cm \cdot s^{-1}$ - *to limit Pw to 100kPa*
	$R = (w^{.5})(Vr/100)^{-0.626}$		5.0 m *Minimum setback distance required to reduce overpressure to less than 100 kPa*
	$R = (w^{.5})(Vr/100)^{-0.626}$		16.2 m *Minimum setback distance from a spawning area to maintain PPV @ 13 $mm \cdot sec^{-1}$*
	$Vr = 100(R/W^{.5})^{-1.6}$		8.52 $cm \cdot s^{-1}$ Calculated PPV at Design Criteria
	$Vr = \frac{2Pr}{DrCr}$ or $Pr = (DrCrVr)/2$		2.49E+06 Dynes Calculated Pressure in Substrate at Design Criteria
	$Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$		99.67 kPa Calculated Pressure in Water at Design Criteria

PROJECT SUMMARY	Fisheries Limit	Project Design
Pressure in Water (Pw) kPa	100.0	99.67
**Peak Particle Velocity (Vr) cm•s-1	13.0	85.15

** Limit for spawning bed during period of egg incubation

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Design Criteria
for
Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters
Table No. 7
Charge Weight Calculations for a 6.0 m Setback

Table 1 - From " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998
Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"

	Substrate	Dr ($g \cdot cm^{-3}$)	Cr ($cm \cdot s^{-1}$)	Cw ($cm \cdot s^{-1}$)	K	Dw ($g \cdot cm^{-3}$)	Pw (kPa)	PPV ($mm \cdot sec^{-1}$)
1	Rock	2.64	457200	146300	5.03	1.00	100.00	13.00
2	Frozen Soil	1.92	304800	146300	3.20	1.00	100.00	13.00
3	Ice	0.98	304800	146300	2.10	1.00	100.00	13.00
4	Saturated Soil	2.08	146300	146300	2.13	1.00	100.00	13.00
5	Unsaturated Soil	1.92	45700	146300	0.98	1.00	100.00	13.00

PROJECT DESIGN CRITERIA

Project Location:	Polaris Mine - Little Cornwallis Island, Nunavut	
Water Course:	Crozier Strait	
Substrate:	Quarry Fill	Frozen Soil (Fisheries Substrate Classification)
Nature of Jointing/Fractures:	N/A	
Overburden:	N/A	
Hole Depth:	2 m	
Explosive Type:	Orica Powerfrac (Gelatin Dynamite)	
Method of Detonation:	Electric, blasting cap	
Bubble Curtain Required:	Yes	

Table 7 - Calculations for : Polaris Mine - Little Cornwallis Island, Nunavut

	Project Substrate	Dr ($g \cdot cm^{-3}$)	Cr ($cm \cdot s^{-1}$)	Cw ($cm \cdot s^{-1}$)	K	Dw ($g \cdot cm^{-3}$)	Pw (kPa)	Vr ($mm \cdot sec^{-1}$)
2	Frozen Soil	1.92	304800	146300	3.2	1.00	100.00	13.00
1.66	Charge Weight (kg)	1.66	3.66 Lbs/delay					
1	No. of Delays/Charge	1.0						
	Charge Weight/Delay	1.66						
6.0	Distance to Detonation	6.00						
	Zw = DwCw / Zr DrCr	0.2500						
	Pw = 2(Zw/Zr)Pr / 1+(Zw/Zr) or Pr = Pw(1+(Zw/Zr)) / 2(Zw/Zr)	250.0	2.50 kPa or	2.50E+06 dynes - *to limit Pw to 100 kPa*				
	Vr = 2Pr / DrCr	8.54 $cm \cdot s^{-1}$ - *to limit Pw to 100kPa*						
	$R = (w^{.5})(Vr/100)^{-0.625}$	6.0 m *Minimum setback distance required to reduce overpressure to less than 100 kPa*						
	$R = (w^{.5})(Vr/100)^{-0.625}$	19.4 m *Minimum setback distance from a spawning area to maintain PPV @ 13 $mm \cdot sec^{-1}$*						
	$Vr=100(R/W^{.5})^{-1.6}$	8.53 $cm \cdot s^{-1}$ Calculated PPV at Design Criteria						
	Vr = 2Pr / DrCr or Pr = (DrCrVr)/2	2.50E+06 Dynes Calculated Pressure in Substrate at Design Criteria						
	Pw = 2(Zw/Zr)Pr / 1+(Zw/Zr)	99.86 kPa Calculated Pressure in Water at Design Criteria						

PROJECT SUMMARY	Fisheries Limit	Project Design
Pressure in Water (Pw) kPa	100.0	99.86
**Peak Particle Velocity (Vr) cm-s-1	13.0	85.32

** Limit for spawning bed during period of egg incubation

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Design Criteria for Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters

Table No. 8

Charge Weight Calculations for a 7.0 m Setback

Table 1 - From " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998

Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"

	Substrate	Dr ($g\cdot cm^{-3}$)	Cr ($cm\cdot s^{-1}$)	Cw ($cm\cdot s^{-1}$)	K	Dw ($g\cdot cm^{-3}$)	Pw (kPa)	PPV ($mm\cdot sec^{-1}$)
1	Rock	2.64	457200	146300	5.03	1.00	100.00	13.00
2	Frozen Soil	1.92	304800	146300	3.20	1.00	100.00	13.00
3	Ice	0.98	304800	146300	2.10	1.00	100.00	13.00
4	Saturated Soil	2.08	146300	146300	2.13	1.00	100.00	13.00
5	Unsaturated Soil	1.92	45700	146300	0.98	1.00	100.00	13.00

PROJECT DESIGN CRITERIA

Project Location:	Polaris Mine - Little Cornwallis Island, Nunavut	
Water Course:	Crozier Strait	
Substrate:	Quarry Fill	Frozen Soil (Fisheries Substrate Classification)
Nature of Jointing/Fractures:	N/A	
Overburden:	N/A	
Hole Depth:	2 m	
Explosive Type:	Orica Powerfrac (Gelatin Dynamite)	
Method of Detonation:	Electric, blasting cap	
Bubble Curtain Required:	Yes	

Table 8 - Calculations for : Polaris Mine - Little Cornwallis Island, Nunavut

	Project Substrate	Dr ($g\cdot cm^{-3}$)	Cr ($cm\cdot s^{-1}$)	Cw ($cm\cdot s^{-1}$)	K	Dw ($g\cdot cm^{-3}$)	Pw (kPa)	Vr ($mm\cdot sec^{-1}$)
2	Frozen Soil	1.92	304800	146300	3.2	1.00	100.00	13.00

2.26	Charge Weight (kg)	2.26	4.98 Lbs/delay
1	No. of Delays/Charge	1.0	
	Charge Weight/Delay	2.26	
7.0	Distance to Detonation	7.00	
	$\frac{Zw}{Zr} = \frac{DwCw}{DrCr}$	0.2500	
	$Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$ or $Pr = \frac{Pw(1+(Zw/Zr))}{2(Zw/Zr)}$	250.0	2.50 kPa or 2.50E+06 dynes - *to limit Pw to 100 kPa*
	$Vr = \frac{2Pr}{DrCr}$		8.64 $cm\cdot s^{-1}$ - *to limit Pw to 100kPa*
	$R = (w^{.5})(Vr/100)^{-0.625}$		7.0 m *Minimum setback distance required to reduce overpressure to less than 100 kPa*
	$R = (w^{.5})(Vr/100)^{-0.625}$		22.7 m *Minimum setback distance from a spawning area to maintain PPV @ 13 $mm\cdot sec^{-1}$*
	$Vr = 100(R/W^{.5})^{-1.6}$		8.53 $cm\cdot s^{-1}$ Calculated PPV at Design Criteria
	$Vr = \frac{2Pr}{DrCr}$ or $Pr = (DrCrVr)/2$		2.50E+06 Dynes Calculated Pressure in Substrate at Design Criteria
	$Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$		99.88 kPa Calculated Pressure in Water at Design Criteria

PROJECT SUMMARY	Fisheries Limit	Project Design
Pressure in Water (Pw) kPa	100.0	99.88
**Peak Particle Velocity (Vr) cm•s-1	13.0	85.34

** Limit for spawning bed during period of egg incubation

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Design Criteria
for
Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters

Table No. 9

Charge Weight Calculations for a 8.0 m Setback

Table 1 - From " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998
Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"

	Substrate	Dr ($g \cdot cm^{-3}$)	Cr ($cm \cdot s^{-1}$)	Cw ($cm \cdot s^{-1}$)	K	Dw ($g \cdot cm^{-3}$)	Pw (kPa)	PPV ($mm \cdot sec^{-1}$)
1	Rock	2.64	457200	146300	5.03	1.00	100.00	13.00
2	Frozen Soil	1.92	304800	146300	3.20	1.00	100.00	13.00
3	Ice	0.98	304800	146300	2.10	1.00	100.00	13.00
4	Saturated Soil	2.08	146300	146300	2.13	1.00	100.00	13.00
5	Unsaturated Soil	1.92	45700	146300	0.98	1.00	100.00	13.00

PROJECT DESIGN CRITERIA

Project Location:	Polaris Mine - Little Cornwallis Island, Nunavut
Water Course:	Crozier Strait
Substrate:	Quarry Fill — Frozen Soil (Fisheries Substrate Classification)
Nature of Jointing/Fractures:	N/A
Overburden:	N/A
Hole Depth:	2 m
Explosive Type:	Orica Powerfrac (Gelatin Dynamite)
Method of Detonation:	Electric, blasting cap
Bubble Curtain Required:	Yes

Table 9 - Calculations for : Polaris Mine - Little Cornwallis Island, Nunavut

	Project Substrate	Dr ($g \cdot cm^{-3}$)	Cr ($cm \cdot s^{-1}$)	Cw ($cm \cdot s^{-1}$)	K	Dw ($g \cdot cm^{-3}$)	Pw (kPa)	Vr ($mm \cdot sec^{-1}$)
2	Frozen Soil	1.92	304800	146300	3.2	1.00	100.00	13.00

2.96	Charge Weight (kg)	2.96	6.53 Lbs/delay
1	No. of Delays/Charge	1.0	
	Charge Weight/Delay	2.96	
8.0	Distance to Detonation	8.00	
	$\frac{Zw}{Zr} = \frac{DwCw}{DrCr}$	0.2600	
	$Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$ or $Pr = \frac{Pw(1+(Zw/Zr))}{2(Zw/Zr)}$	250.0	2.50 kPa or 2.50E+06 dynes - *to limit Pw to 100 kPa*
	$Vr = \frac{2Pr}{DrCr}$		8.64 $cm \cdot s^{-1}$ - *to limit Pw to 100kPa*
	$R = (w^{.5})(Vr/100)^{-0.825}$		8.0 m *Minimum setback distance required to reduce overpressure to less than 100 kPa*
	$R = (w^{.5})(Vr/100)^{-0.825}$		26.0 m *Minimum setback distance from a spawning area to maintain PPV @ 13 $mm \cdot sec^{-1}$*
	$Vr = 100(R/W^{.5})^{-1.8}$		8.55 $cm \cdot s^{-1}$ Calculated PPV at Design Criteria
	$Vr = \frac{2Pr}{DrCr}$ or $Pr = (DrCrVr)/2$		2.50E+06 Dynes Calculated Pressure in Substrate at Design Criteria
	$Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$		100.10 kPa Calculated Pressure in Water at Design Criteria

PROJECT SUMMARY	Fisheries Limit	Project Design
Pressure in Water (Pw) kPa	100.0	100.10
**Peak Particle Velocity (Vr) $cm \cdot s^{-1}$	13.0	85.52

** Limit for spawning bed during period of egg incubation

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Design Criteria for Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters

Table No. 10

Charge Weight Calculations for a 9.0 m Setback

Table 1 - From " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998
Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"

	Substrate	Dr ($g \cdot cm^{-3}$)	Cr ($cm \cdot s^{-1}$)	Cw ($cm \cdot s^{-1}$)	K	Dw ($g \cdot cm^{-3}$)	Pw (kPa)	PPV ($mm \cdot sec^{-1}$)
1	Rock	2.64	457200	146300	5.03	1.00	100.00	13.00
2	Frozen Soil	1.92	304800	146300	3.20	1.00	100.00	13.00
3	Ice	0.98	304800	146300	2.10	1.00	100.00	13.00
4	Saturated Soil	2.08	146300	146300	2.13	1.00	100.00	13.00
5	Unsaturated Soil	1.92	45700	146300	0.98	1.00	100.00	13.00

PROJECT DESIGN CRITERIA

Project Location:	Polaris Mine - Little Cornwallis Island, Nunavut	
Water Course:	Crozier Strait	
Substrate:	Quarry Fill	Frozen Soil (Fisheries Substrate Classification)
Nature of Jointing/Fractures:	N/A	
Overburden:	N/A	
Hole Depth:	2 m	
Explosive Type:	Orica Powerfrac (Gelatin Dynamite)	
Method of Detonation:	Electric, blasting cap	
Bubble Curtain Required:	Yes	

Table 10 - Calculations for : Polaris Mine - Little Cornwallis Island, Nunavut

	Project Substrate	Dr ($g \cdot cm^{-3}$)	Cr ($cm \cdot s^{-1}$)	Cw ($cm \cdot s^{-1}$)	K	Dw ($g \cdot cm^{-3}$)	Pw (kPa)	Vr ($mm \cdot sec^{-1}$)
2	Frozen Soil	1.92	304800	146300	3.2	1.00	100.00	13.00
3.74	Charge Weight (kg)	3.74	8.25 Lbs/delay					
1	No. of Delays/Charge	1.0						
	Charge Weight/Delay	3.74						
9.0	Distance to Detonation	9.00						
	Zw/Zr = DwCw/DrCr	0.2500						
	Pw = 2(Zw/Zr)Pr / 1+(Zw/Zr) or Pr = Pw(1+(Zw/Zr)) / 2(Zw/Zr)	250.0	2.50 kPa or		2.50E+06 dynes - *to limit Pw to 100 kPa*			
	Vr = 2Pr/DrCr	8.64 $cm \cdot s^{-1}$ - *to limit Pw to 100kPa*						
	$R = (w^{.5})(Vr/100)^{-0.625}$	9.0 m *Minimum setback distance required to reduce overpressure to less than 100 kPa*						
	$R = (w^{.5})(Vr/100)^{-0.625}$	29.2 m *Minimum setback distance from a spawning area to maintain PPV @ 13 mm•sec⁻¹*						
	$Vr=100(R/W^{.5})^{-1.6}$	8.84 $cm \cdot s^{-1}$ Calculated PPV at Design Criteria						
	Vr = 2Pr/DrCr or Pr = (DrCrVr)/2	2.50E+06 Dynes Calculated Pressure in Substrate at Design Criteria						
	Pw = 2(Zw/Zr)Pr / 1+(Zw/Zr)	99.96 kPa Calculated Pressure in Water at Design Criteria						

PROJECT SUMMARY	Fisheries Limit	Project Design
Pressure in Water (Pw) kPa	100.0	99.96
**Peak Particle Velocity (Vr) cm-s-1	13.0	85.41

** Limit for spawning bed during period of egg incubation

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Design Criteria
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Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters
Table No. 11
Charge Weight Calculations for a 10.0 m Setback

Table 1 - From " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998
Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"

	Substrate	Dr ($g\cdot cm^{-3}$)	Cr ($cm\cdot s^{-1}$)	Cw ($cm\cdot s^{-1}$)	K	Dw ($g\cdot cm^{-3}$)	Pw (kPa)	PPV ($mm\cdot sec^{-1}$)
1	Rock	2.64	457200	146300	5.03	1.00	100.00	13.00
2	Frozen Soil	1.92	304800	146300	3.20	1.00	100.00	13.00
3	Ice	0.98	304800	146300	2.10	1.00	100.00	13.00
4	Saturated Soil	2.08	146300	146300	2.13	1.00	100.00	13.00
5	Unsaturated Soil	1.92	45700	146300	0.98	1.00	100.00	13.00

PROJECT DESIGN CRITERIA

Project Location:	Polaris Mine - Little Cornwallis Island, Nunavut
Water Course:	Crozier Strait
Substrate:	Quarry Fill — Frozen Soil (Fisheries Substrate Classification)
Nature of Jointing/Fractures:	N/A
Overburden:	N/A
Hole Depth:	2 m
Explosive Type:	Orica Powerfrac (Gelatin Dynamite)
Method of Detonation:	Electric, blasting cap
Bubble Curtain Required:	Yes

Table 11 - Calculations for : Polaris Mine - Little Cornwallis Island, Nunavut

	Project Substrate	Dr ($g\cdot cm^{-3}$)	Cr ($cm\cdot s^{-1}$)	Cw ($cm\cdot s^{-1}$)	K	Dw ($g\cdot cm^{-3}$)	Pw (kPa)	Vr ($mm\cdot sec^{-1}$)
2	Frozen Soil	1.92	304800	146300	3.2	1.00	100.00	13.00
4.62	Charge Weight (kg)	4.62	10.19 Lbs/delay					
1	No. of Delays/Charge	1.0						
	Charge Weight/Delay	4.62						
10.0	Distance to Detonation	10.00						
	Zw = DwCw / Zr DrCr	0.2500						
	Pw = 2(Zw/Zr)Pr / 1+(Zw/Zr) or Pr = Pw(1+(Zw/Zr)) / 2(Zw/Zr)	250.0	2.50 kPa or	2.50E+06 dynes - *to limit Pw to 100 kPa*				
	Vr = 2Pr / DrCr	8.54 $cm\cdot s^{-1}$ - *to limit Pw to 100kPa*						
	$R = (w^{.5})(Vr/100)^{-0.625}$	10.0 m *Minimum setback distance required to reduce overpressure to less than 100 kPa*						
	$R = (w^{.5})(Vr/100)^{-0.625}$	32.4 m *Minimum setback distance from a spawning area to maintain PPV @ 13* $mm\cdot sec^{-1}$						
	$Vr = 100(R/W^{.5})^{-1.6}$	8.55 $cm\cdot s^{-1}$ Calculated PPV at Design Criteria						
	Vr = 2Pr / DrCr or Pr = (DrCrVr)/2	2.50E+06 Dynes Calculated Pressure in Substrate at Design Criteria						
	Pw = 2(Zw/Zr)Pr / 1+(Zw/Zr)	100.01 kPa Calculated Pressure in Water at Design Criteria						

PROJECT SUMMARY	Fisheries Limit	Project Design
Pressure in Water (Pw) kPa	100.0	100.01
**Peak Particle Velocity (Vr) cm-s-1	13.0	85.45

** Limit for spawning bed during period of egg incubation

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Design Criteria
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Guidelines for the Use of Explosives in or
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Table No. 12
Charge Weight Calculations for a 11.0 m Setback

Table 1 - From " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998
Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"

	Substrate	Dr (g•cm^{-3})	Cr (cm•s^{-1})	Cw (cm•s^{-1})	K	Dw (g•cm^{-3})	Pw (kPa)	PPV (mm•sec^{-1})
1	Rock	2.64	457200	146300	5.03	1.00	100.00	13.00
2	Frozen Soil	1.92	304800	146300	3.20	1.00	100.00	13.00
3	Ice	0.98	304800	146300	2.10	1.00	100.00	13.00
4	Saturated Soil	2.08	146300	146300	2.13	1.00	100.00	13.00
5	Unsaturated Soil	1.92	45700	146300	0.98	1.00	100.00	13.00

PROJECT DESIGN CRITERIA

Project Location:	Polaris Mine - Little Cornwallis Island, Nunavut	
Water Course:	Crozier Strait	
Substrate:	Quarry Fill	Frozen Soil (Fisheries Substrate Classification)
Nature of Jointing/Fractures:	N/A	
Overburden:	N/A	
Hole Depth:	2 m	
Explosive Type:	Orica Powerfrac (Gelatin Dynamite)	
Method of Detonation:	Electric, blasting cap	
Bubble Curtain Required:	Yes	

Table 12 - Calculations for : <u>Polaris Mine - Little Cornwallis Island, Nunavut</u>

	Project Substrate	Dr (g•cm^{-3})	Cr (cm•s^{-1})	Cw (cm•s^{-1})	K	Dw (g•cm^{-3})	Pw (kPa)	Vr (mm•sec^{-1})
2	Frozen Soil	1.92	304800	146300	3.2	1.00	100.00	13.00
5.59	Charge Weight (kg)	5.59	12.32 Lbs/delay					
1	No. of Delays/Charge	1.0						
	Charge Weight/Delay	5.59						
11.0	Distance to Detonation	11.00						
	Zw = DwCw / Zr DrCr	0.2500						
	Pw = 2(Zw/Zr)Pr / 1+(Zw/Zr) or Pr = Pw(1+(Zw/Zr)) / 2(Zw/Zr)	250.0	2.50 kPa or		2.50E+06 dynes - *to limit Pw to 100 kPa*			
	Vr = 2Pr / DrCr	8.54 cm•s^{-1} - *to limit Pw to 100kPa*						
	R = (w$^{.5}$)(Vr/100)$^{-0.625}$	11.0 m *Minimum setback distance required to reduce overpressure to less than 100 kPa*						
	R = (w$^{.5}$)(Vr/100)$^{-0.625}$	35.7 m *Minimum setback distance from a spawning area to maintain PPV @ 13 mm•sec^{-1}*						
	Vr=100(R/W$^{.5}$)$^{-1.6}$	8.54 cm•s^{-1} Calculated PPV at Design Criteria						
	Vr = 2Pr / DrCr or Pr = (DrCrVr)/2	2.50E+06 Dynes Calculated Pressure in Substrate at Design Criteria						
	Pw = 2(Zw/Zr)Pr / 1+(Zw/Zr)	100.01 kPa Calculated Pressure in Water at Design Criteria						

PROJECT SUMMARY	Fisheries Limit	Project Design
Pressure in Water (Pw) kPa	100.0	100.01
**Peak Particle Velocity (Vr) cm•s-1	13.0	85.45

** Limit for spawning bed during period of egg incubation

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Design Criteria
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Guidelines for the Use of Explosives in or
Near Canadian Fisheries Waters
Table No. 13
Charge Weight Calculations for a 12.0 m Setback

Table 1 - From " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998
Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"

	Substrate	Dr ($g\cdot cm^{-3}$)	Cr ($cm\cdot s^{-1}$)	Cw ($cm\cdot s^{-1}$)	K	Dw ($g\cdot cm^{-3}$)	Pw (kPa)	PPV ($mm\cdot sec^{-1}$)
1	Rock	2.64	457200	146300	5.03	1.00	100.00	13.00
2	Frozen Soil	1.92	304800	146300	3.20	1.00	100.00	13.00
3	Ice	0.98	304800	146300	2.10	1.00	100.00	13.00
4	Saturated Soil	2.08	146300	146300	2.13	1.00	100.00	13.00
5	Unsaturated Soil	1.92	45700	146300	0.98	1.00	100.00	13.00

PROJECT DESIGN CRITERIA

Project Location:	Polaris Mine - Little Cornwallis Island, Nunavut	
Water Course:	Crozier Strait	
Substrate:	Quarry Fill	Frozen Soil (Fisheries Substrate Classification)
Nature of Jointing/Fractures:	N/A	
Overburden:	N/A	
Hole Depth:	2 m	
Explosive Type:	Orica Powerfrac (Gelatin Dynamite)	
Method of Detonation:	Electric, blasting cap	
Bubble Curtain Required:	Yes	

Table 13 - Calculations for : **Polaris Mine - Little Cornwallis Island, Nunavut**

	Project Substrate	Dr ($g\cdot cm^{-3}$)	Cr ($cm\cdot s^{-1}$)	Cw ($cm\cdot s^{-1}$)	K	Dw ($g\cdot cm^{-3}$)	Pw (kPa)	Vr ($mm\cdot sec^{-1}$)
2	Frozen Soil	1.92	304800	146300	3.2	1.00	100.00	13.00
6.65	Charge Weight (kg)	6.65	14.66 Lbs/delay					
1	No. of Delays/Charge	1.0						
	Charge Weight/Delay	6.65						
12.0	Distance to Detonation	12.00						
	$\frac{Zw}{Zr} = \frac{DwCw}{DrCr}$	0.2500						
	$Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$ or $Pr = \frac{Pw(1+(Zw/Zr))}{2(Zw/Zr)}$	250.0	2.50 kPa or	2.50E+06 dynes - *to limit Pw to 100 kPa*				
	$Vr = \frac{2Pr}{DrCr}$	8.54 $cm\cdot s^{-1}$ - *to limit Pw to 100kPa*						
	$R = (w^{.5})(Vr/100)^{-0.625}$	12.0 m *Minimum setback distance required to reduce overpressure to less than 100 kPa*						
	$R = (w^{.5})(Vr/100)^{-0.625}$	38.9 m *Minimum setback distance from a spawning area to maintain PPV @ 13 $mm\cdot sec^{-1}$*						
	$Vr=100(R/W^{.5})^{-1.6}$	8.54 $cm\cdot s^{-1}$ Calculated PPV at Design Criteria						
	$Vr = \frac{2Pr}{DrCr}$ or $Pr = (DrCrVr)/2$	2.50E+06 Dynes Calculated Pressure in Substrate at Design Criteria						
	$Pw = \frac{2(Zw/Zr)Pr}{1+(Zw/Zr)}$	99.98 kPa Calculated Pressure in Water at Design Criteria						

PROJECT SUMMARY	Fisheries Limit	Project Design
Pressure in Water (Pw) kPa	100.0	99.98
**Peak Particle Velocity (Vr) cm•s-1	13.0	85.42

** Limit for spawning bed during period of egg incubation

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Design Criteria
for
Guidelines for the Use of Explosives In or
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Table No. 14
Charge Weight Calculations for a 13.0 m Setback

Table 1 - From " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998
Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"

	Substrate	Dr (g•cm^{-3})	Cr (cm•s^{-1})	Cw (cm•s^{-1})	K	Dw (g•cm^{-3})	Pw (kPa)	PPV (mm•sec^{-1})
1	Rock	2.64	457200	146300	5.03	1.00	100.00	13.00
2	Frozen Soil	1.92	304800	146300	3.20	1.00	100.00	13.00
3	Ice	0.98	304800	146300	2.10	1.00	100.00	13.00
4	Saturated Soil	2.06	146300	146300	2.13	1.00	100.00	13.00
5	Unsaturated Soil	1.92	45700	146300	0.98	1.00	100.00	13.00

PROJECT DESIGN CRITERIA

Project Location:	Polaris Mine - Little Cornwallis Island, Nunavut	
Water Course:	Crozier Strait	
Substrate:	Quarry Fill	Frozen Soil (Fisheries Substrate Classification)
Nature of Jointing/Fractures:	N/A	
Overburden:	N/A	
Hole Depth:	2 m	
Explosive Type:	Orica Powerfrac (Gelatin Dynamite)	
Method of Detonation:	Electric, blasting cap	
Bubble Curtain Required:	Yes	

Table 14 - Calculations for : **Polaris Mine - Little Cornwallis Island, Nunavut**

	Project Substrate	Dr (g•cm^{-3})	Cr (cm•s^{-1})	Cw (cm•s^{-1})	K	Dw (g•cm^{-3})	Pw (kPa)	Vr (mm•sec^{-1})
2	Frozen Soil	1.92	304800	146300	3.2	1.00	100.00	13.00
7.81	Charge Weight (kg)	7.81	17.22 Lbs/delay					
1	No. of Delays/Charge	1.0						
	Charge Weight/Delay	7.81						
13.0	Distance to Detonation	13.00						
	Zw = DwCw / Zr DrCr	0.2500						
	Pw = 2(Zw/Zr)Pr / 1+(Zw/Zr) or Pr = Pw(1+(Zw/Zr)) / 2(Zw/Zr)	250.0	2.50 kPa or	2.50E+06 dynes - *to limit Pw to 100 kPa*				
	Vr = 2Pr / DrCr	8.54 cm•s^{-1} - *to limit Pw to 100kPa*						
	R = (w$^{.5}$)(Vr/100)$^{-0.825}$	13.0 m *Minimum setback distance required to reduce overpressure to less than 100 kPa*						
	R = (w$^{.5}$)(Vr/100)$^{-0.825}$	42.2 m *Minimum setback distance from a spawning area to maintain PPV @ 13 mm•sec^{-1}*						
	Vr=100(R/W$^{.5}$)$^{-1.6}$	8.58 cm•s^{-1} Calculated PPV at Design Criteria						
	Vr = 2Pr / DrCr or Pr = (DrCrVr)/2	2.50E+06 Dynes Calculated Pressure in Substrate at Design Criteria						
	Pw = 2(ZwZr)Pr / 1+(Zw/Zr)	100.03 kPa Calculated Pressure in Water at Design Criteria						

PROJECT SUMMARY	Fisheries Limit	Project Design	
Pressure in Water (Pw) kPa	100.0	100.03	
**Peak Particle Velocity (Vr) cm•s-1	13.0	85.47	** Limit for spawning bed during period of egg incubation

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Design Criteria
for
Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters
Table No. 15
Charge Weight Calculations for a 14.0 m Setback

Table 1 - From " Canadian Technical Report of Fisheries and Aquatic Sciences 2107" , 1998
Titled - "Guidelines For the Use of Explosives In Or Near Canadian Fisheries Waters"

	Substrate	Dr (g•cm^{-3})	Cr (cm•s^{-1})	Cw (cm•s^{-1})	K	Dw (g•cm^{-3})	Pw (kPa)	PPV (mm•sec^{-1})
1	Rock	2.64	457200	146300	5.03	1.00	100.00	13.00
2	Frozen Soil	1.92	304800	146300	3.20	1.00	100.00	13.00
3	Ice	0.98	304800	146300	2.10	1.00	100.00	13.00
4	Saturated Soil	2.08	146300	146300	2.13	1.00	100.00	13.00
5	Unsaturated Soil	1.92	45700	146300	0.98	1.00	100.00	13.00

PROJECT DESIGN CRITERIA

Project Location:	Polaris Mine - Little Cornwallis Island, Nunavut	
Water Course:	Crozier Strait	
Substrate:	Quarry Fill	Frozen Soil (Fisheries Substrate Classification)
Nature of Jointing/Fractures:	N/A	
Overburden:	N/A	
Hole Depth:	2 m	
Explosive Type:	Orica Powerfrac (Gelatin Dynamite)	
Method of Detonation:	Electric, blasting cap	
Bubble Curtain Required:	Yes	

Table 15 - Calculations for : Polaris Mine - Little Cornwallis Island, Nunavut

	Project Substrate	Dr (g•cm^{-3})	Cr (cm•s^{-1})	Cw (cm•s^{-1})	K	Dw (g•cm^{-3})	Pw (kPa)	Vr (mm•sec^{-1})
2	Frozen Soil	1.92	304800	146300	3.2	1.00	100.00	13.00

9.05	Charge Weight (kg)	9.05	19.95 Lbs/delay
1	No. of Delays/Charge	1.0	
	Charge Weight/Delay	9.05	
14.0	Distance to Detonation	14.00	
	Zw/Zr = DwCw/DrCr	0.2500	
	Pw = 2(Zw/Zr)Pr / 1+(Zw/Zr) or Pr = Pw(1+(Zw/Zr)) / 2(Zw/Zr)	250.0	2.50 kPa or 2.50E+06 dynes - *to limit Pw to 100 kPa*
	Vr = 2Pr/DrCr		8.54 cm•s^{-1} - *to limit Pw to 100kPa*
	R = (w$^{.5}$)(Vr/100)$^{-0.526}$		14.0 m *Minimum setback distance required to reduce overpressure to less than 100 kPa*
	R = (w$^{.5}$)(Vr/100)$^{-0.526}$		45.4 m *Minimum setback distance from a spawning area to maintain PPV @ 13 mm•sec^{-1}*
	Vr=100(R/W$^{.5}$)$^{-1.9}$		8.54 cm•s^{-1} Calculated PPV at Design Criteria
	Vr = 2Pr/DrCr or Pr = (DrCrVr)/2	2.50E+06 Dynes	Calculated Pressure in Substrate at Design Criteria
	Pw = 2(Zw/Zr)Pr / 1+(Zw/Zr)	99.97 kPa	Calculated Pressure in Water at Design Criteria

PROJECT SUMMARY	Fisheries Limit	Project Design
Pressure in Water (Pw) kPa	100.0	99.97
**Peak Particle Velocity (Vr) cm•s-1	13.0	85.41

** Limit for spawning bed during period of egg incubation

APPENDIX I

Thermistor Data

TABLE 1: Dock Thermistor Readings – August 16, 1990 (Readings in Degrees Celsius)

Cable Location		South Cell West Edge	South Cell Centre	North Cell West Edge	North Cell North Edge
Plug No.	**Depth (m)**	**507**	**510**	**488**	**418**
1	1.5	-0.6	-1.9	+1.6	-1.6
2	2.5	-2.0	-4.0	-0.8	-3.0
3	3.5	-2.8	-5.5	-2.0	-4.3
4	4.5	-2.9	-6.7	-2.8	-5.0
5	5.5	-2.9	-7.3	-3.0	-5.4
6	6.5	-2.9	-7.6	-3.1	-5.4
7	9.25	-2.8	-5.7	-3.2	-5.5
8	12.0	-2.8	-6.9	-2.8	-4.4
9	14.75	-3.0	-5.6	-2.9	-4.3
10	17.5	-2.6	-5.0	-2.8	-3.7

TABLE 2: Dock Thermistor Readings (Thermistor Located in Centre of South Cell of the Dock Freezing Unit, not in Operation. Temperature in Degrees Celsius)

Date	Depth (m)									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
January 1985	-20.3	-15.3	-9.4	-6.1	-3.8	-2.7	-2.3	-2.1	-2.1	-2.1
June 1985	-7.5	-9.7	-10.2	-9.8	-9.2	-7.9	-4.0	-5.4	-3.4	-2.6
July 1985	-3.2	-5.7	-7.5	-7.8	-7.8	-7.3	-4.0	-5.4	-4.0	-3.4
May 1986	-17.1	-16.8	-15.3	-13.2	-11.6	-9.7	-5.1	-6.9	-5.2	-4.3
December 1986	-16.8	-12.7	-10.2	-7.5	-6.7	-5.7	-5.0	-5.0	-4.4	-4.0
June 1987	-9.5	-11.1	-11.9	-11.6	-11.0	-10.0	-5.6	-7.6	-5.6	-4.7
July 1987	-5.0	-7.1	-8.7	-9.4	-9.6	N/A	N/A	-7.4	N/A	-4.7
August 1987	-2.0	-4.5	-6.5	-7.4	-7.8	-7.8	-5.4	-6.0	-5.5	-4.6
September 1987	-1.6	-3.5	-5.0	-5.9	-6.7	-6.9	-5.2	-6.5	-5.2	-4.5
October 1987	-2.3	-3.1	-4.3	-5.0	-5.7	-6.1	-5.0	-5.8	-5.0	-4.4
November 1987	-7.5	-5.1	-4.4	-4.8	-5.2	-5.5	-4.8	-5.5	-4.9	-4.3