

## **APPENDIX B**

# **Geotechnical Investigations**

# MECHANICAL SIEVE ANALYSIS

Sample No. **BH16-112-01** Date Sampled **26-May-16** By **ST** of **SNC-Lavalin Inc.**  
 Location **Toad River** Sample Type **Bag** Natural Moisture **11.6** %  
 Description **Sand, gravelly, some silt and clay.** Tech **KB/AN**

Specifications

Comments

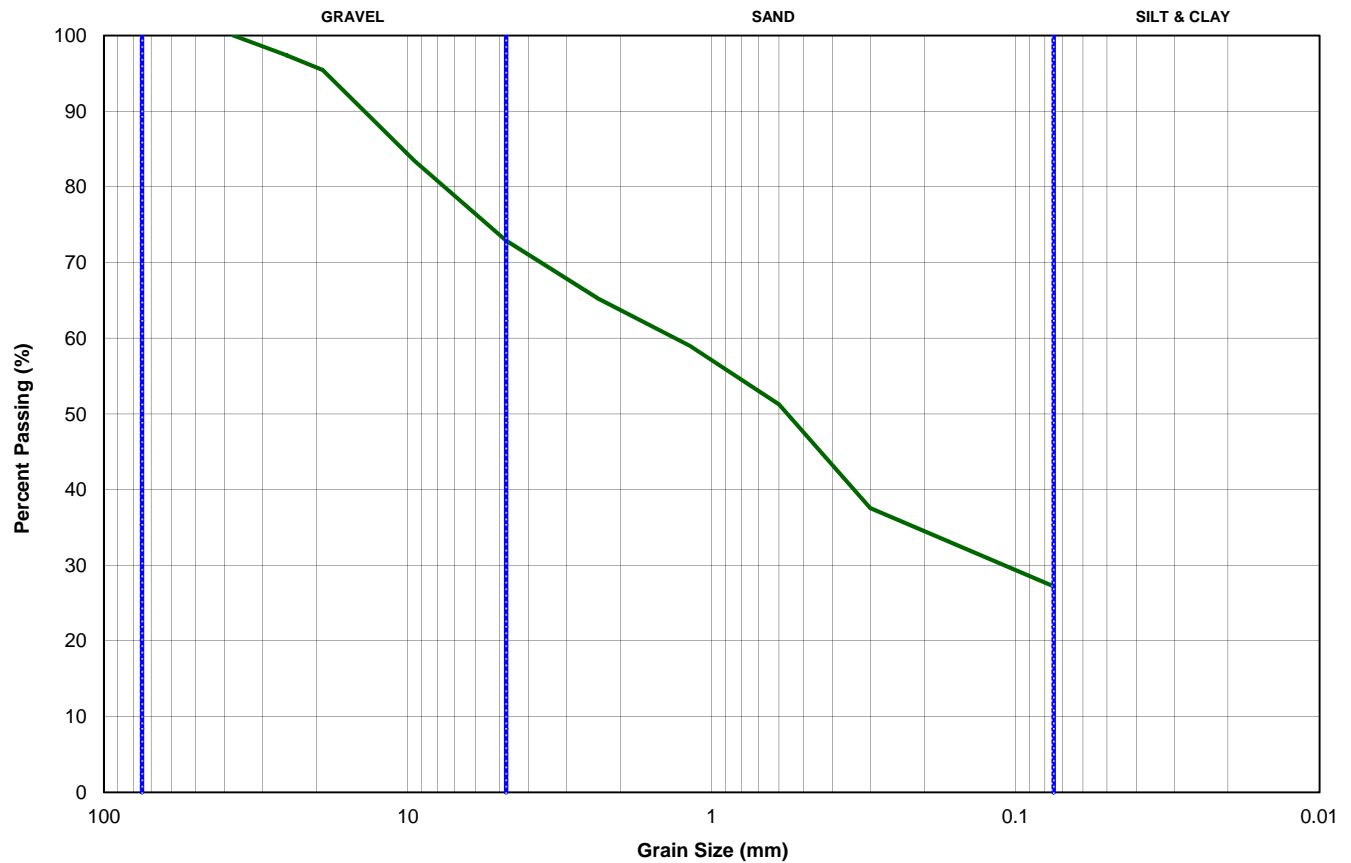
Fracture Method

N/A A

Sieve Results

|           |       |      |      |      |      |      |      |      |       |       |       |
|-----------|-------|------|------|------|------|------|------|------|-------|-------|-------|
| Sieve mm  | 37.5  | 25   | 19   | 12.5 | 9.5  | 4.75 | 2.36 | 1.18 | 0.600 | 0.300 | 0.075 |
| % Passing | 100.0 | 97.4 | 95.4 | 88.2 | 83.4 | 72.9 | 65.2 | 59.0 | 51.3  | 37.5  | 27.2  |

By Type Gravel = 27.1% Sand = 45.7% Silt & Clay = 27.2%



**SNC-LAVALIN**

Client **Public Works & Government Services**

Date **16-Jun-16**

Project **2016 Materials Testing**

File No. **635734**

Location **Toad River, British Columbia**

Sample No. **BH16-112-01**

# MECHANICAL SIEVE ANALYSIS

Sample No. **BH16-112-02** Date Sampled **26-May-16** By **ST** of **SNC-Lavalin Inc.**  
 Location **Toad River** Sample Type **Bag** Natural Moisture **4.0** %  
 Description **Sand, gravelly, trace silt and clay.** Tech **KB/AN**

Specifications

Comments

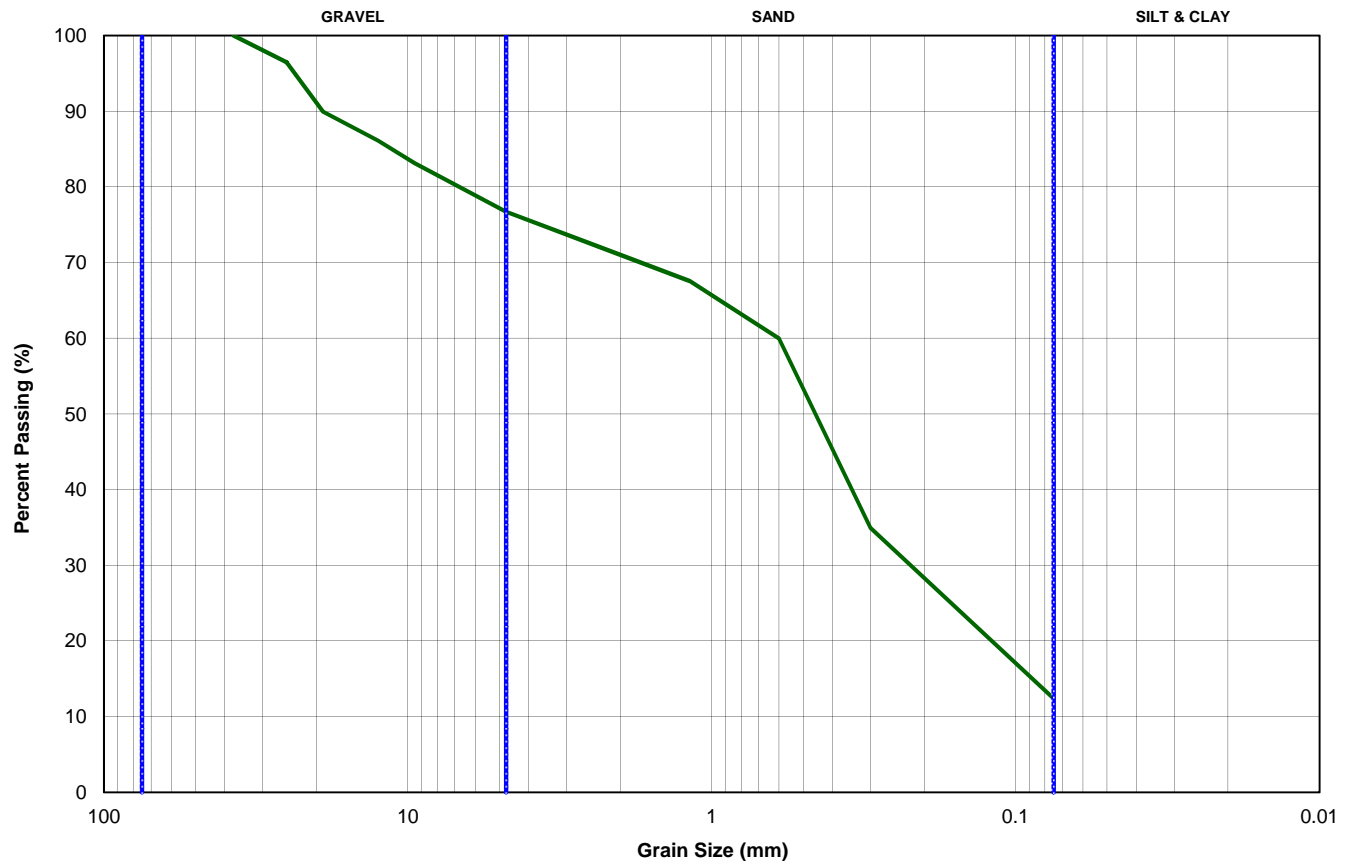
Fracture Method

N/A A

## Sieve Results

|           |       |      |      |      |      |      |      |      |       |       |       |
|-----------|-------|------|------|------|------|------|------|------|-------|-------|-------|
| Sieve mm  | 37.5  | 25   | 19   | 12.5 | 9.5  | 4.75 | 2.36 | 1.18 | 0.600 | 0.300 | 0.075 |
| % Passing | 100.0 | 96.4 | 89.9 | 86.1 | 83.2 | 76.7 | 72.1 | 67.6 | 60.0  | 34.9  | 12.4  |

By Type Gravel = 23.3% Sand = 64.3% Silt & Clay = 12.4%



**SNC-LAVALIN**

Client **Public Works & Government Services**

Date **16-Jun-16**

Project **2016 Materials Testing**

File No. **635734**

Location **Toad River, British Columbia**

Sample No. **BH16-112-02**

# MECHANICAL SIEVE ANALYSIS

Sample No. **BH16-112-03** Date Sampled **26-May-16** By **ST** of **SNC-Lavalin Inc.**  
 Location **Toad River** Sample Type **Bag** Natural Moisture **6.5** %  
 Description **Sand, some silt and clay, trace gravel.** Tech **KB/AN**

Specifications

Comments

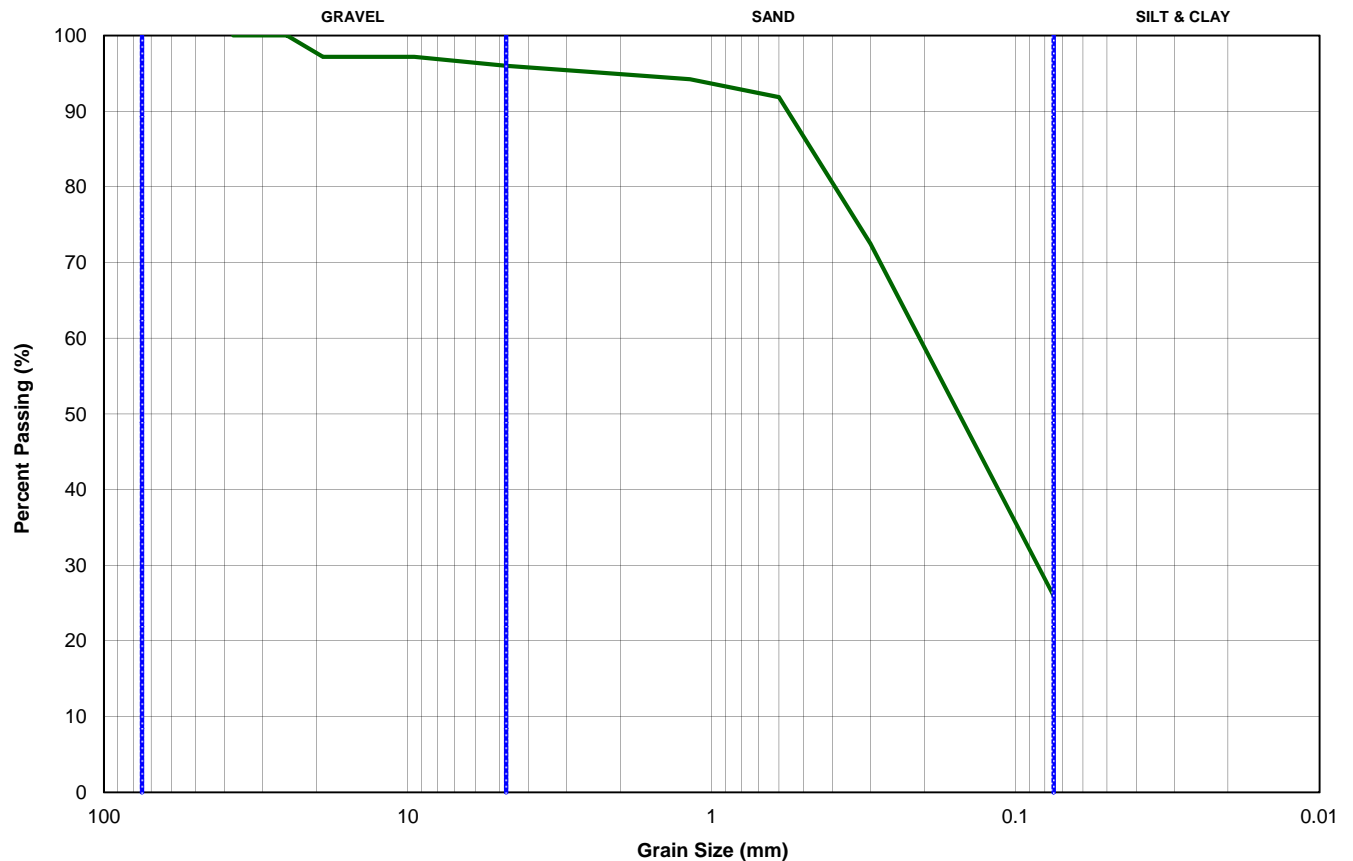
Fracture Method

N/A A

## Sieve Results

|           |       |       |      |      |      |      |      |      |       |       |       |
|-----------|-------|-------|------|------|------|------|------|------|-------|-------|-------|
| Sieve mm  | 37.5  | 25    | 19   | 12.5 | 9.5  | 4.75 | 2.36 | 1.18 | 0.600 | 0.300 | 0.075 |
| % Passing | 100.0 | 100.0 | 97.2 | 97.2 | 97.2 | 96.0 | 95.1 | 94.2 | 91.9  | 72.5  | 26.0  |

By Type Gravel = 4.0% Sand = 70.0% Silt & Clay = 26.0%



**SNC-LAVALIN**

Client **Public Works & Government Services**

Date **16-Jun-16**

Project **2016 Materials Testing**

File No. **635734**

Location **Toad River, British Columbia**

Sample No. **BH16-112-03**

# MECHANICAL SIEVE ANALYSIS

Sample No. **BH16-112-04** Date Sampled **26-May-16** By **ST** of **SNC-Lavalin Inc.**  
 Location **Toad River** Sample Type **Bag** Natural Moisture **8.0** %  
 Description **Sand, some silt and clay, trace gravel.** Tech **KB/AN**

Specifications

Comments

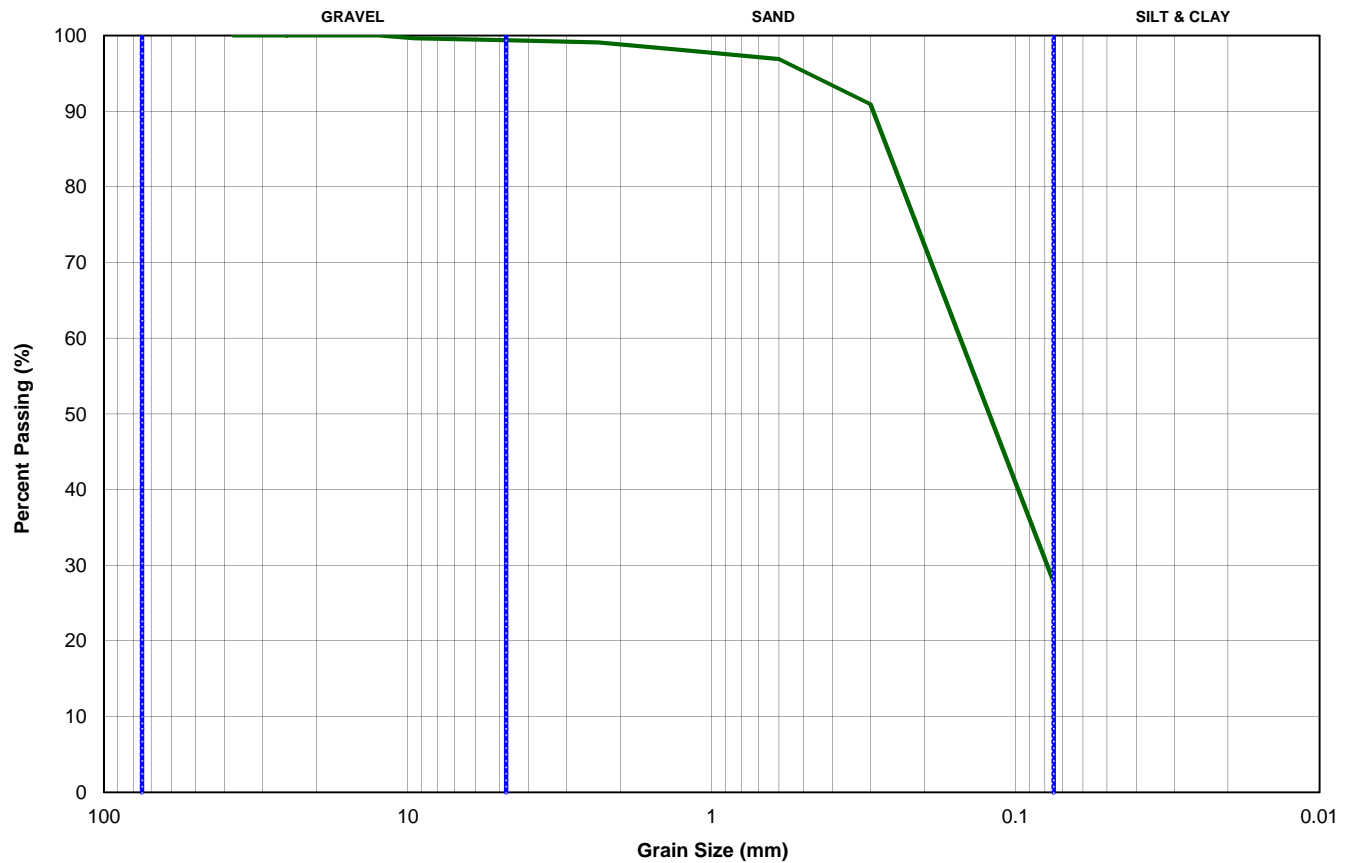
Fracture Method

N/A A

## Sieve Results

|           |       |       |       |       |      |      |      |      |       |       |       |
|-----------|-------|-------|-------|-------|------|------|------|------|-------|-------|-------|
| Sieve mm  | 37.5  | 25    | 19    | 12.5  | 9.5  | 4.75 | 2.36 | 1.18 | 0.600 | 0.300 | 0.075 |
| % Passing | 100.0 | 100.0 | 100.0 | 100.0 | 99.6 | 99.4 | 99.1 | 98.0 | 96.9  | 90.9  | 27.9  |

By Type Gravel = 0.6% Sand = 71.5% Silt & Clay = 27.9%



**SNC-LAVALIN**

Client **Public Works & Government Services**

Date **16-Jun-16**

Project **2016 Materials Testing**

File No. **635734**

Location **Toad River, British Columbia**

Sample No. **BH16-112-04**

# MECHANICAL SIEVE ANALYSIS

Sample No. **BH16-112-05** Date Sampled **26-May-16** By **ST** of **SNC-Lavalin Inc.**  
 Location **Toad River** Sample Type **Bag** Natural Moisture **10.0** %  
 Description **Silty, clayey, sandy, some gravel.** Tech **KB/AN**

Specifications

Comments

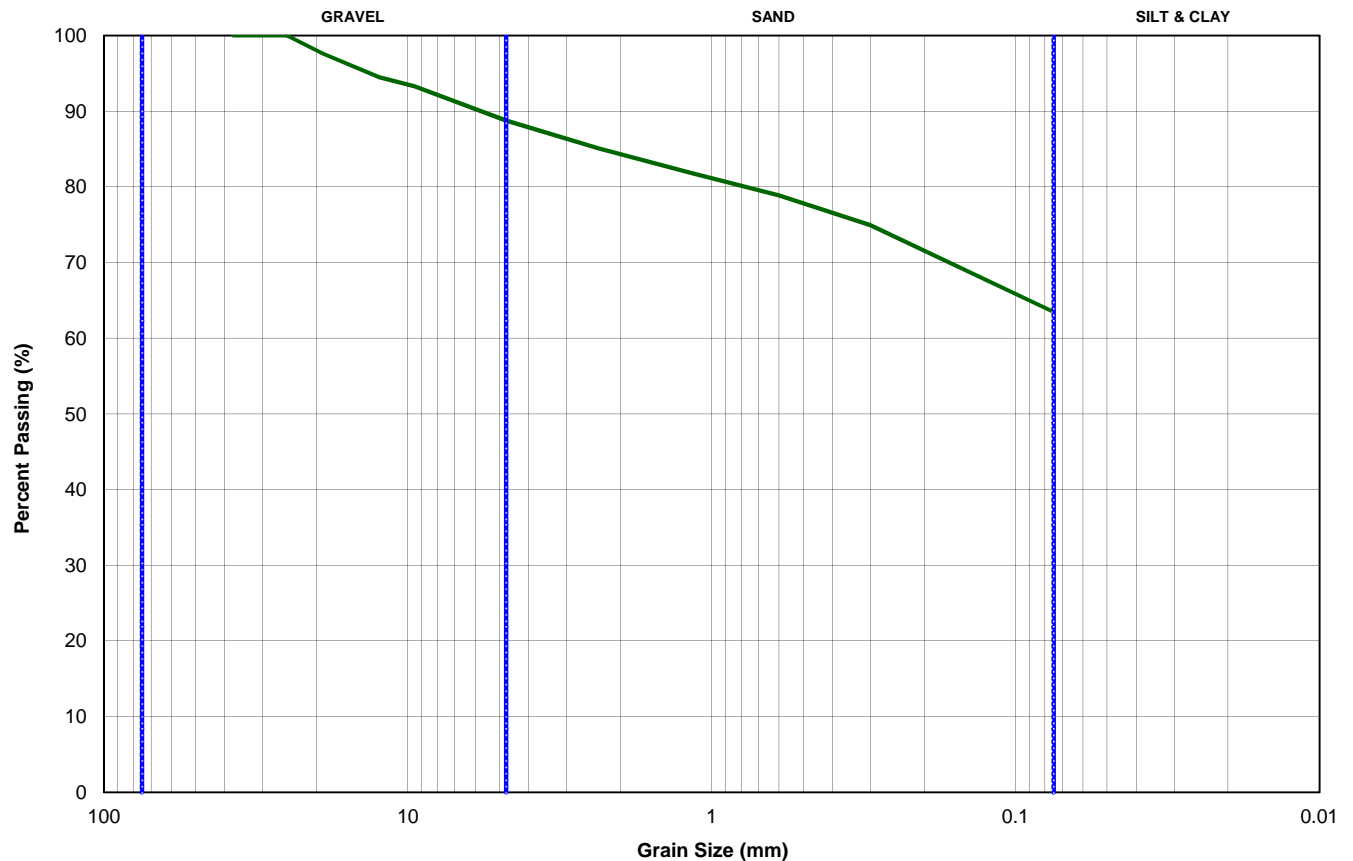
Fracture Method

N/A A

## Sieve Results

|           |       |       |      |      |      |      |      |      |       |       |       |
|-----------|-------|-------|------|------|------|------|------|------|-------|-------|-------|
| Sieve mm  | 37.5  | 25    | 19   | 12.5 | 9.5  | 4.75 | 2.36 | 1.18 | 0.600 | 0.300 | 0.075 |
| % Passing | 100.0 | 100.0 | 97.6 | 94.5 | 93.3 | 88.8 | 85.1 | 81.9 | 78.9  | 75.0  | 63.5  |

By Type Gravel = 11.2% Sand = 25.3% Silt & Clay = 63.5%



**SNC-LAVALIN**

Client **Public Works & Government Services**

Date **16-Jun-16**

Project **2016 Materials Testing**

File No. **635734**

Location **Toad River, British Columbia**

Sample No. **BH16-112-05**

# MECHANICAL SIEVE ANALYSIS

Sample No. **BH16-113-01** Date Sampled **26-May-16** By **ST** of **SNC-Lavalin Inc.**  
 Location **Toad River** Sample Type **Bag** Natural Moisture **7.1** %  
 Description **Gravel, sandy, trace silt and clay.** Tech **KB/AN**

Specifications

Comments

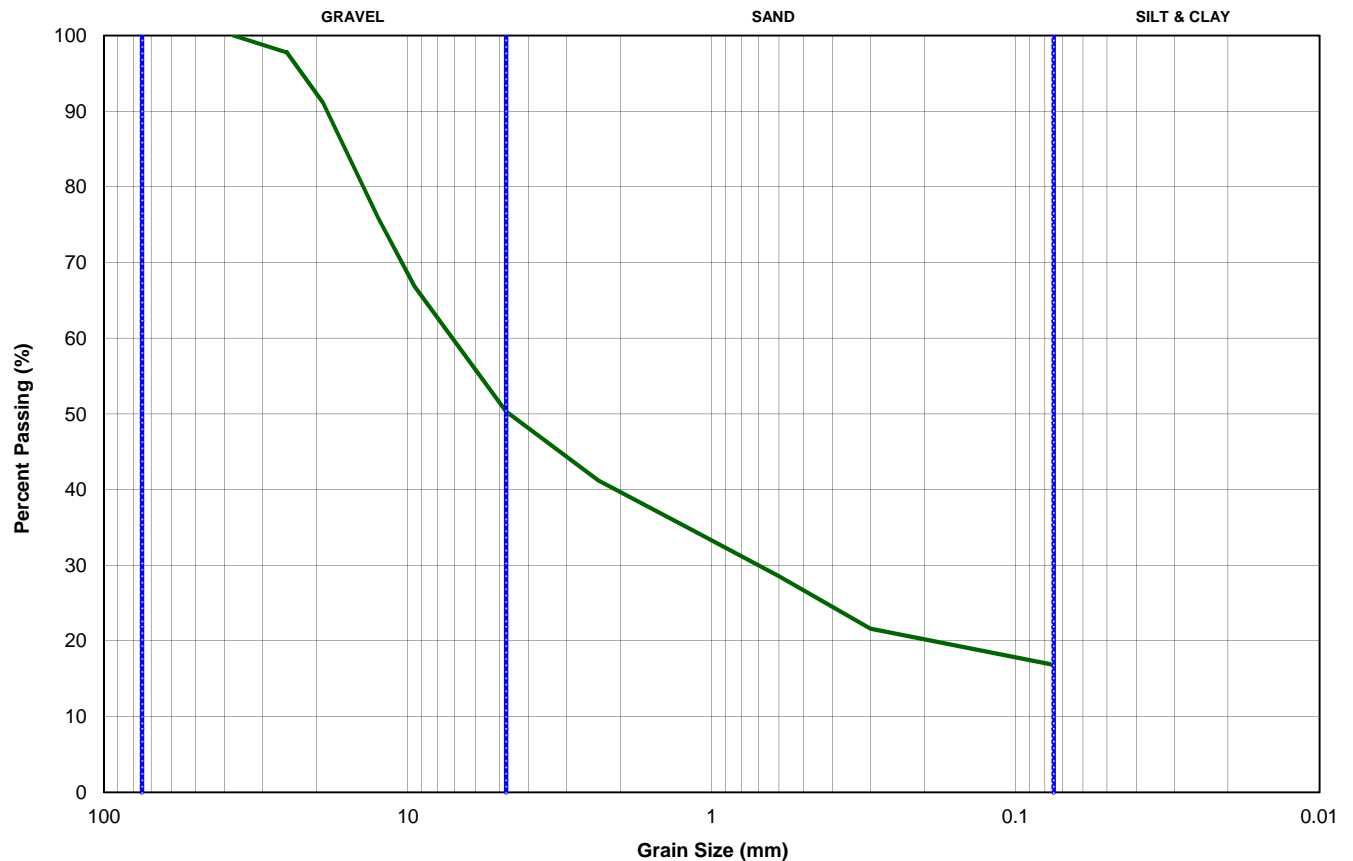
Fracture Method

N/A A

## Sieve Results

|           |       |      |      |      |      |      |      |      |       |       |       |
|-----------|-------|------|------|------|------|------|------|------|-------|-------|-------|
| Sieve mm  | 37.5  | 25   | 19   | 12.5 | 9.5  | 4.75 | 2.36 | 1.18 | 0.600 | 0.300 | 0.075 |
| % Passing | 100.0 | 97.8 | 91.1 | 75.9 | 66.9 | 50.3 | 41.2 | 34.8 | 28.6  | 21.6  | 16.8  |

By Type Gravel = **49.7%** Sand = **33.5%** Silt & Clay = **16.8%**



**SNC-LAVALIN**

Client **Public Works & Government Services**

Date **16-Jun-16**

Project **2016 Materials Testing**

File No. **635734**

Location **Toad River, British Columbia**

Sample No. **BH16-113-01**

# MECHANICAL SIEVE ANALYSIS

Sample No. **BH16-113-02** Date Sampled **26-May-16** By **ST** of **SNC-Lavalin Inc.**  
 Location **Toad River** Sample Type **Bag** Natural Moisture **4.0** %  
 Description **Sand and gravel, trace silt and clay.** Tech **KB/AN**

Specifications

Comments

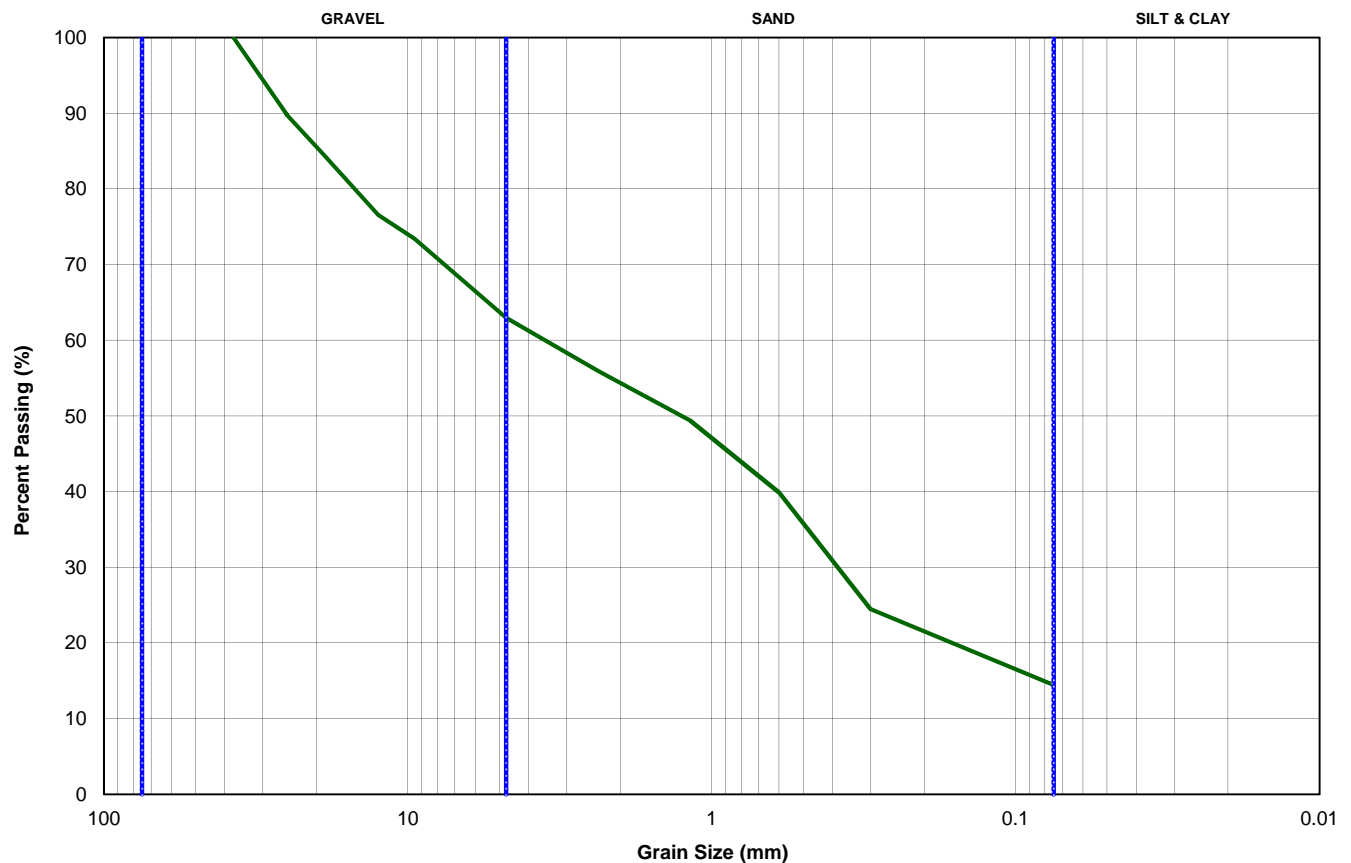
Fracture Method

N/A A

Sieve Results

|           |       |      |      |      |      |      |      |      |       |       |       |
|-----------|-------|------|------|------|------|------|------|------|-------|-------|-------|
| Sieve mm  | 37.5  | 25   | 19   | 12.5 | 9.5  | 4.75 | 2.36 | 1.18 | 0.600 | 0.300 | 0.075 |
| % Passing | 100.0 | 89.8 | 84.6 | 76.6 | 73.4 | 63.0 | 55.9 | 49.4 | 39.9  | 24.4  | 14.4  |

By Type Gravel = 37.0% Sand = 48.5% Silt & Clay = 14.5%



**SNC-LAVALIN**

Client **Public Works & Government Services**

Date **16-Jun-16**

Project **2016 Materials Testing**

File No. **635734**

Location **Toad River, British Columbia**

Sample No. **BH16-113-02**



# MECHANICAL SIEVE ANALYSIS

Sample No. **BH16-113-03** Date Sampled **26-May-16** By **ST** of **SNC-Lavalin Inc.**  
 Location **Toad River** Sample Type **Bag** Natural Moisture **5.3** %  
 Description **Sand, gravelly, trace silt and clay.** Tech **KB/AN**

Specifications

Comments

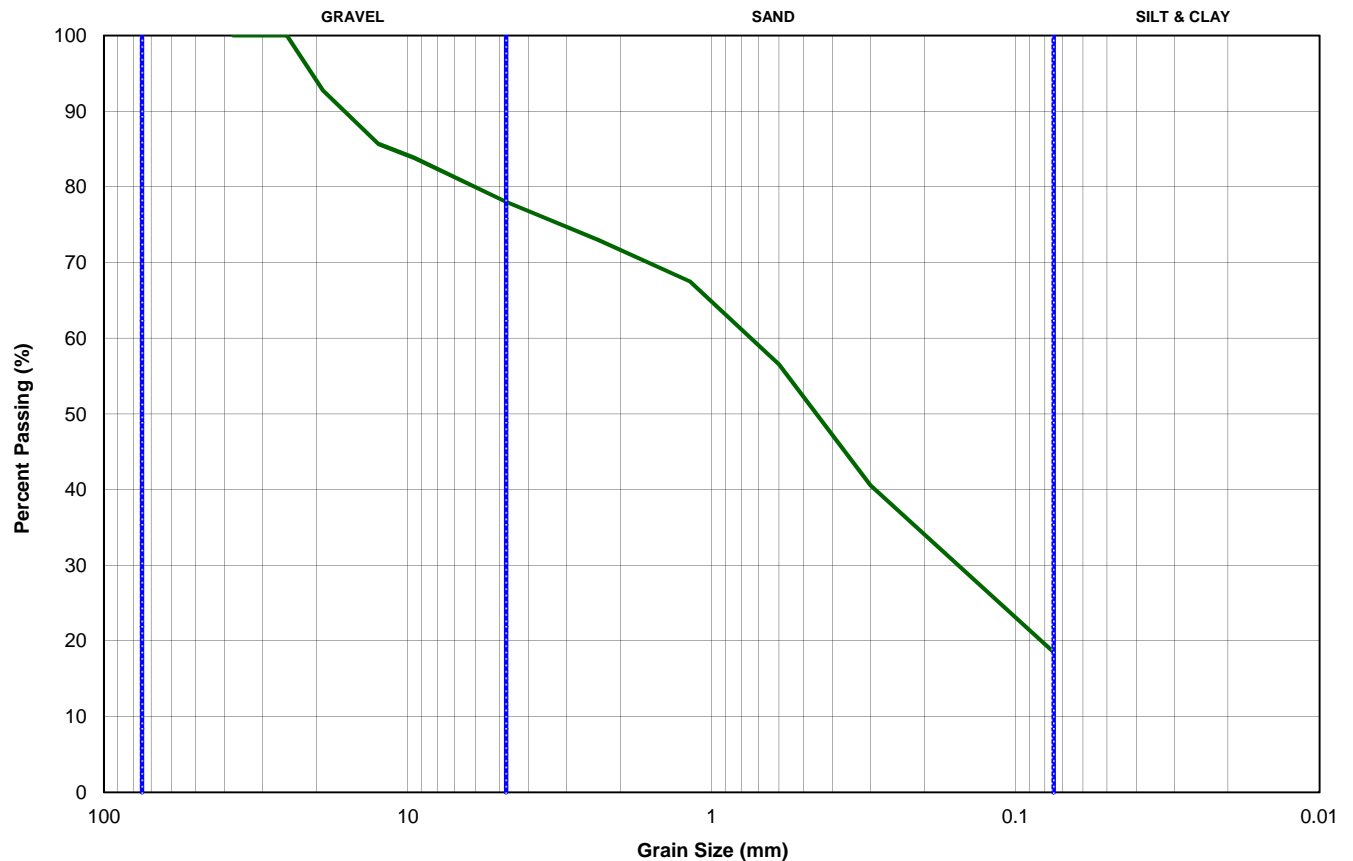
Fracture Method

N/A A

## Sieve Results

|           |       |       |      |      |      |      |      |      |       |       |       |
|-----------|-------|-------|------|------|------|------|------|------|-------|-------|-------|
| Sieve mm  | 37.5  | 25    | 19   | 12.5 | 9.5  | 4.75 | 2.36 | 1.18 | 0.600 | 0.300 | 0.075 |
| % Passing | 100.0 | 100.0 | 92.8 | 85.7 | 83.8 | 78.0 | 72.9 | 67.5 | 56.5  | 40.6  | 18.5  |

By Type Gravel = 22.0% Sand = 59.5% Silt & Clay = 18.5%



**SNC-LAVALIN**

Client **Public Works & Government Services**

Date **16-Jun-16**

Project **2016 Materials Testing**

File No. **635734**

Location **Toad River, British Columbia**

Sample No. **BH16-113-03**

# MECHANICAL SIEVE ANALYSIS

Sample No. **BH16-113-04** Date Sampled **26-May-16** By **ST** of **SNC-Lavalin Inc.**  
 Location **Toad River** Sample Type **Bag** Natural Moisture **11.0** %  
 Description **Sand, some silt and clay, trace gravel.** Tech **KB/AN**

Specifications

Comments

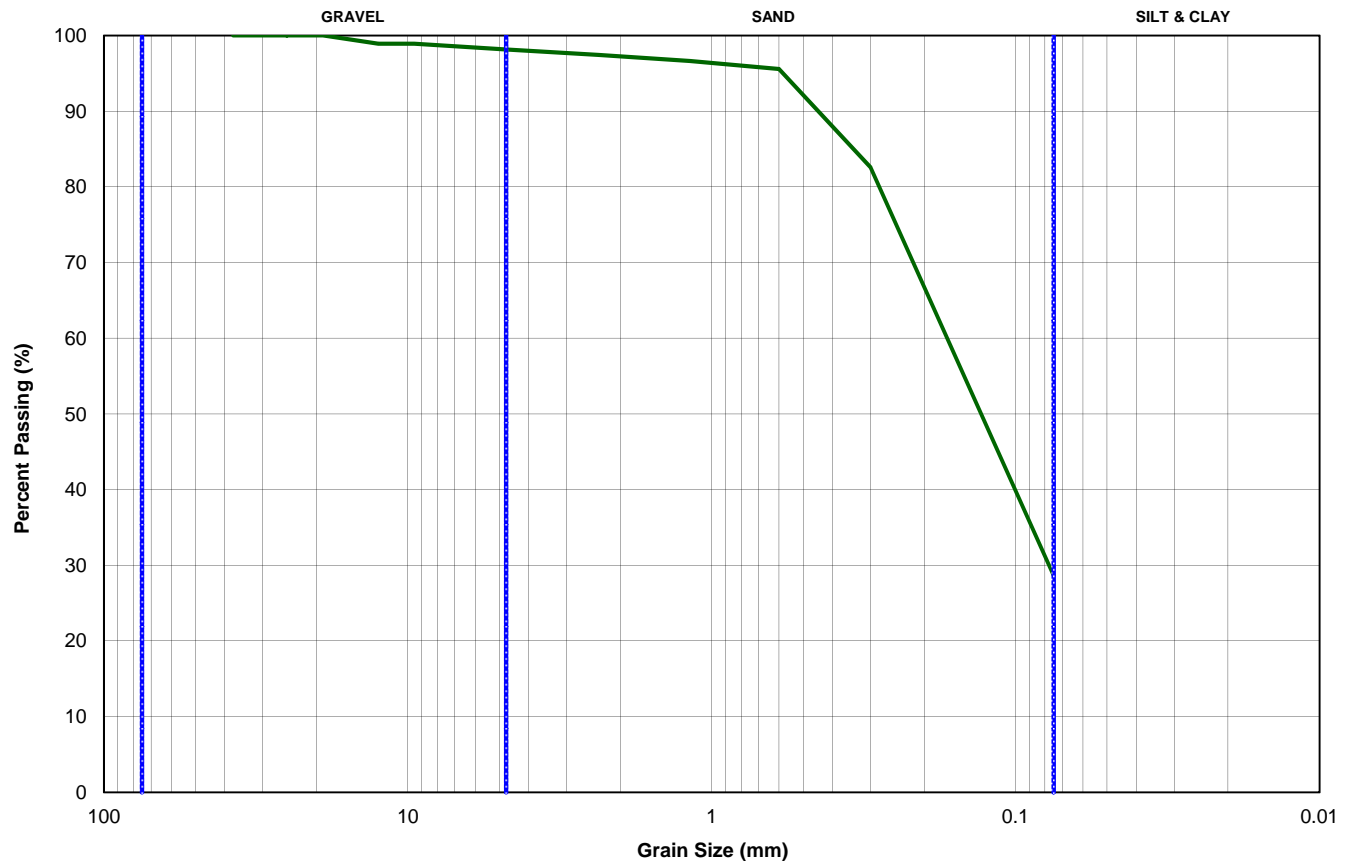
Fracture Method

N/A A

## Sieve Results

|           |       |       |       |      |      |      |      |      |       |       |       |
|-----------|-------|-------|-------|------|------|------|------|------|-------|-------|-------|
| Sieve mm  | 37.5  | 25    | 19    | 12.5 | 9.5  | 4.75 | 2.36 | 1.18 | 0.600 | 0.300 | 0.075 |
| % Passing | 100.0 | 100.0 | 100.0 | 98.9 | 98.9 | 98.2 | 97.4 | 96.6 | 95.6  | 82.6  | 28.7  |

By Type Gravel = 1.8% Sand = 69.5% Silt & Clay = 28.7%



**SNC-LAVALIN**

Client **Public Works & Government Services**

Date **16-Jun-16**

Project **2016 Materials Testing**

File No. **635734**

Location **Toad River, British Columbia**

Sample No. **BH16-113-04**

# MECHANICAL SIEVE ANALYSIS

Sample No. **BH16-135-01** Date Sampled **30-May-16** By **ST** of **SNC-Lavalin Inc.**  
 Location **Toad River** Sample Type **Bag** Natural Moisture **6.7** %  
 Description **Sand, gravelly, trace silt and clay.** Tech **KB/AN**

Specifications

Comments

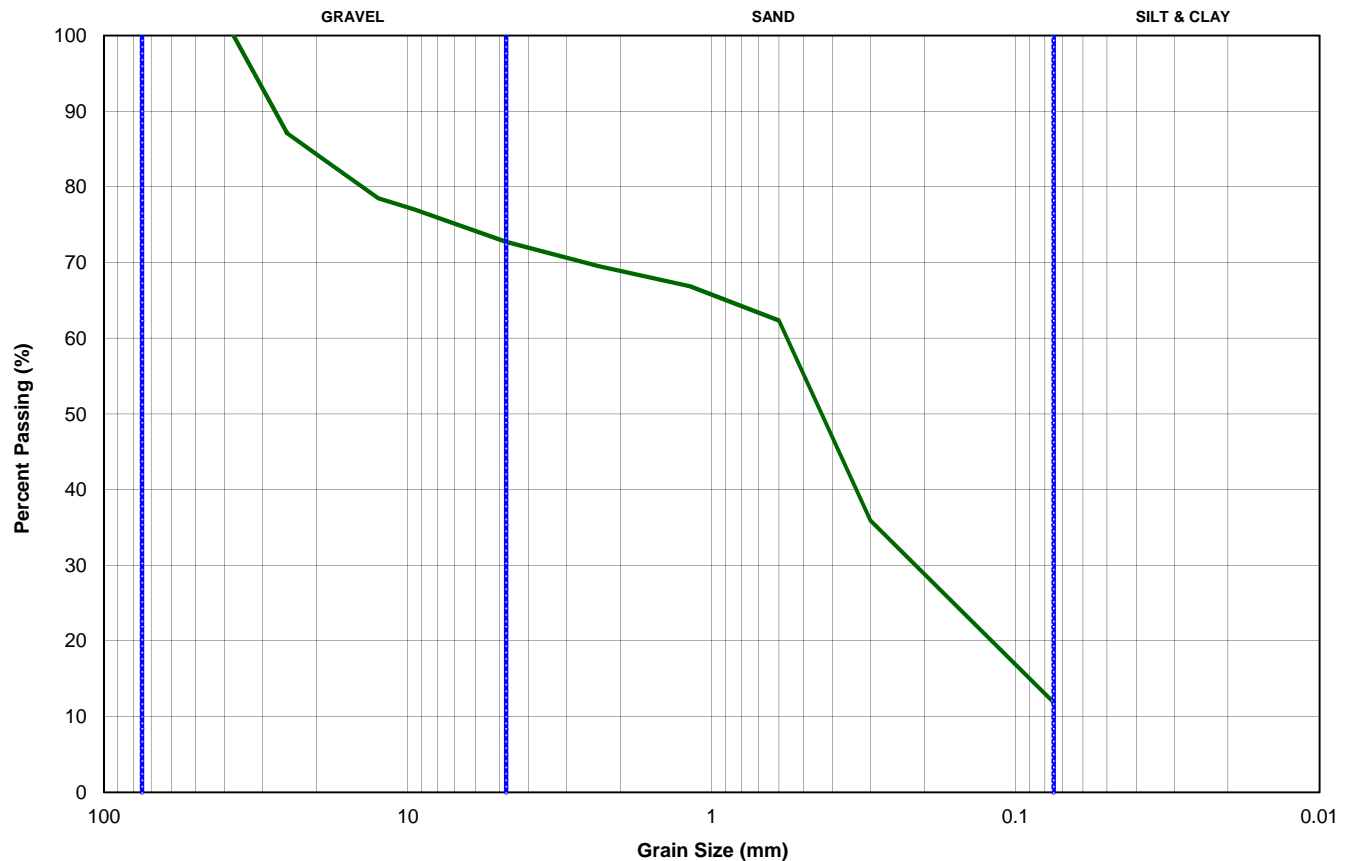
Fracture Method

N/A A

Sieve Results

|           |       |      |      |      |      |      |      |      |       |       |       |
|-----------|-------|------|------|------|------|------|------|------|-------|-------|-------|
| Sieve mm  | 37.5  | 25   | 19   | 12.5 | 9.5  | 4.75 | 2.36 | 1.18 | 0.600 | 0.300 | 0.075 |
| % Passing | 100.0 | 87.1 | 83.7 | 78.5 | 77.0 | 72.8 | 69.5 | 66.9 | 62.3  | 35.9  | 11.9  |

By Type Gravel = 27.2% Sand = 60.9% Silt & Clay = 11.9%



**SNC-LAVALIN**

Client **Public Works & Government Services**

Date **16-Jun-16**

Project **2016 Materials Testing**

File No. **635734**

Location **Toad River, British Columbia**

Sample No. **BH16-135-01**

# MECHANICAL SIEVE ANALYSIS

Sample No. **BH16-135-02** Date Sampled **30-May-16** By **ST** of **SNC-Lavalin Inc.**  
 Location **Toad River** Sample Type **Bag** Natural Moisture **4.3** %  
 Description **Gravel and sand, trace silt and clay.** Tech **KB/AN**

Specifications

Comments

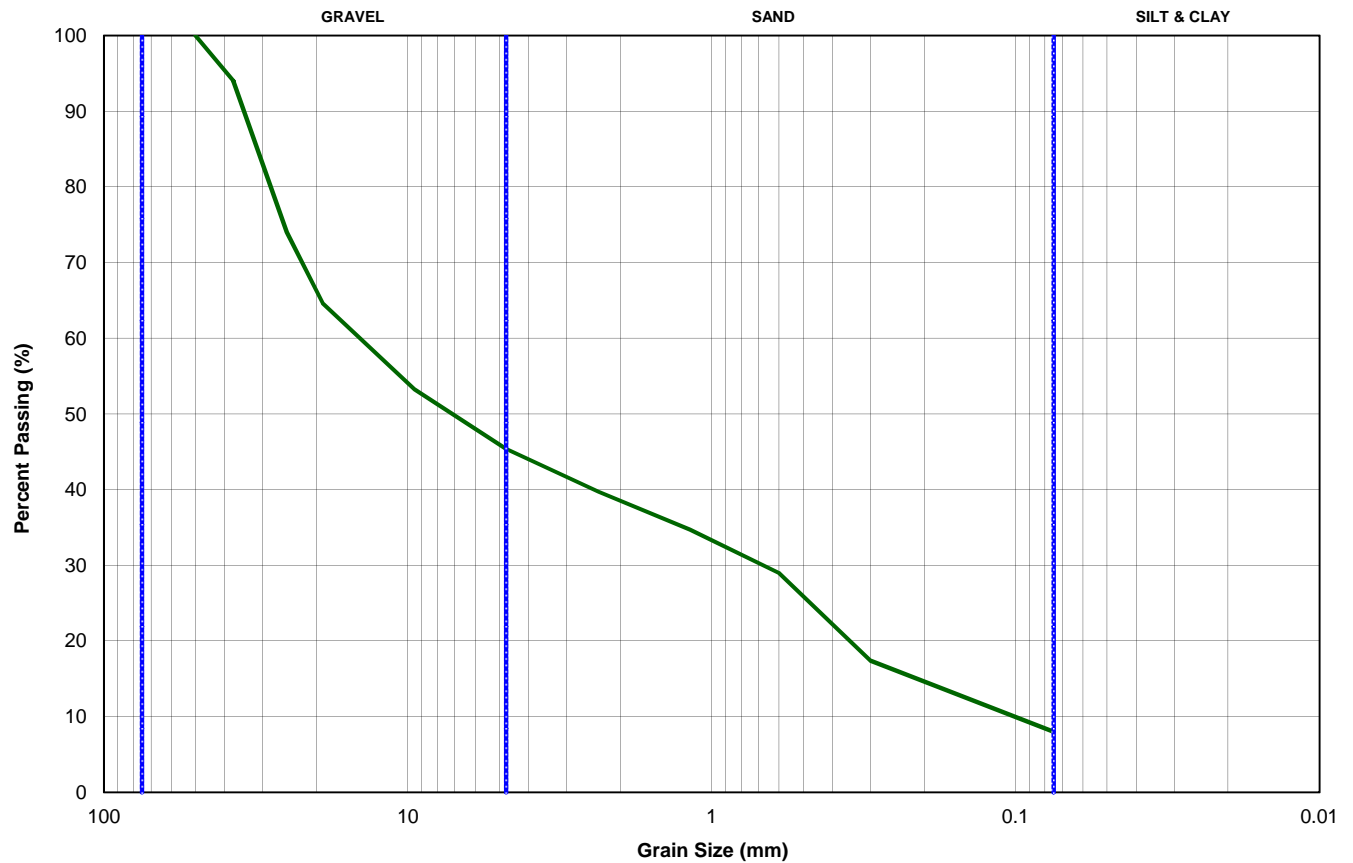
Fracture Method

N/A A

## Sieve Results

|           |       |      |      |      |      |      |      |      |       |       |       |
|-----------|-------|------|------|------|------|------|------|------|-------|-------|-------|
| Sieve mm  | 50    | 37.5 | 25   | 19   | 9.5  | 4.75 | 2.36 | 1.18 | 0.600 | 0.300 | 0.075 |
| % Passing | 100.0 | 94.0 | 74.0 | 64.6 | 53.2 | 45.4 | 39.7 | 34.7 | 29.0  | 17.4  | 8.0   |

By Type Gravel = **48.6%** Sand = **37.4%** Silt & Clay = **8.0%**



**SNC-LAVALIN**

Client **Public Works & Government Services**

Date **16-Jun-16**

Project **2016 Materials Testing**

File No. **635734**

Location **Toad River, British Columbia**

Sample No. **BH16-135-02**

# MECHANICAL SIEVE ANALYSIS

Sample No. **BH16-135-03** Date Sampled **30-May-16** By **ST** of **SNC-Lavalin Inc.**  
 Location **Toad River** Sample Type **Bag** Natural Moisture **6.6** %  
 Description **Sand, trace silt and clay.** Tech **KB/AN**

Specifications

Comments

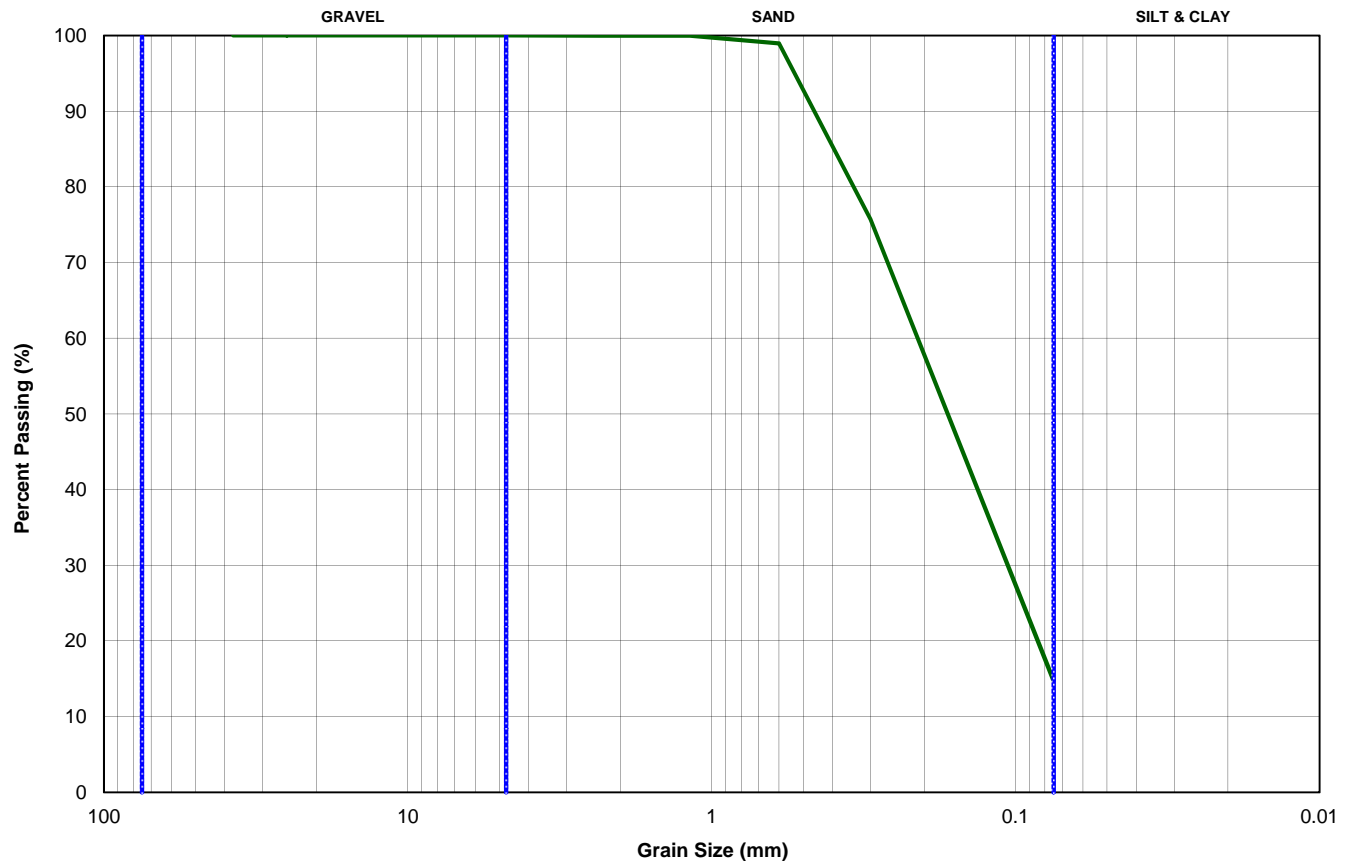
Fracture Method

N/A A

Sieve Results

|           |       |       |       |       |       |       |       |       |       |       |       |
|-----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Sieve mm  | 37.5  | 25    | 19    | 12.5  | 9.5   | 4.75  | 2.36  | 1.18  | 0.600 | 0.300 | 0.075 |
| % Passing | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 98.9  | 75.7  | 14.7  |

By Type Gravel = 0.0% Sand = 85.3% Silt & Clay = 14.7%



**SNC-LAVALIN**

Client **Public Works & Government Services**

Date **16-Jun-16**

Project **2016 Materials Testing**

File No. **635734**

Location **Toad River, British Columbia**

Sample No. **BH16-135-03**

# MECHANICAL SIEVE ANALYSIS

Sample No. **BH16-135-04** Date Sampled **30-May-16** By **ST** of **SNC-Lavalin Inc.**  
 Location **Toad River** Sample Type **Bag** Natural Moisture **2.0** %  
 Description **Gravel and sand, trace silt and clay.** Tech **KB/AN**

Specifications

Comments

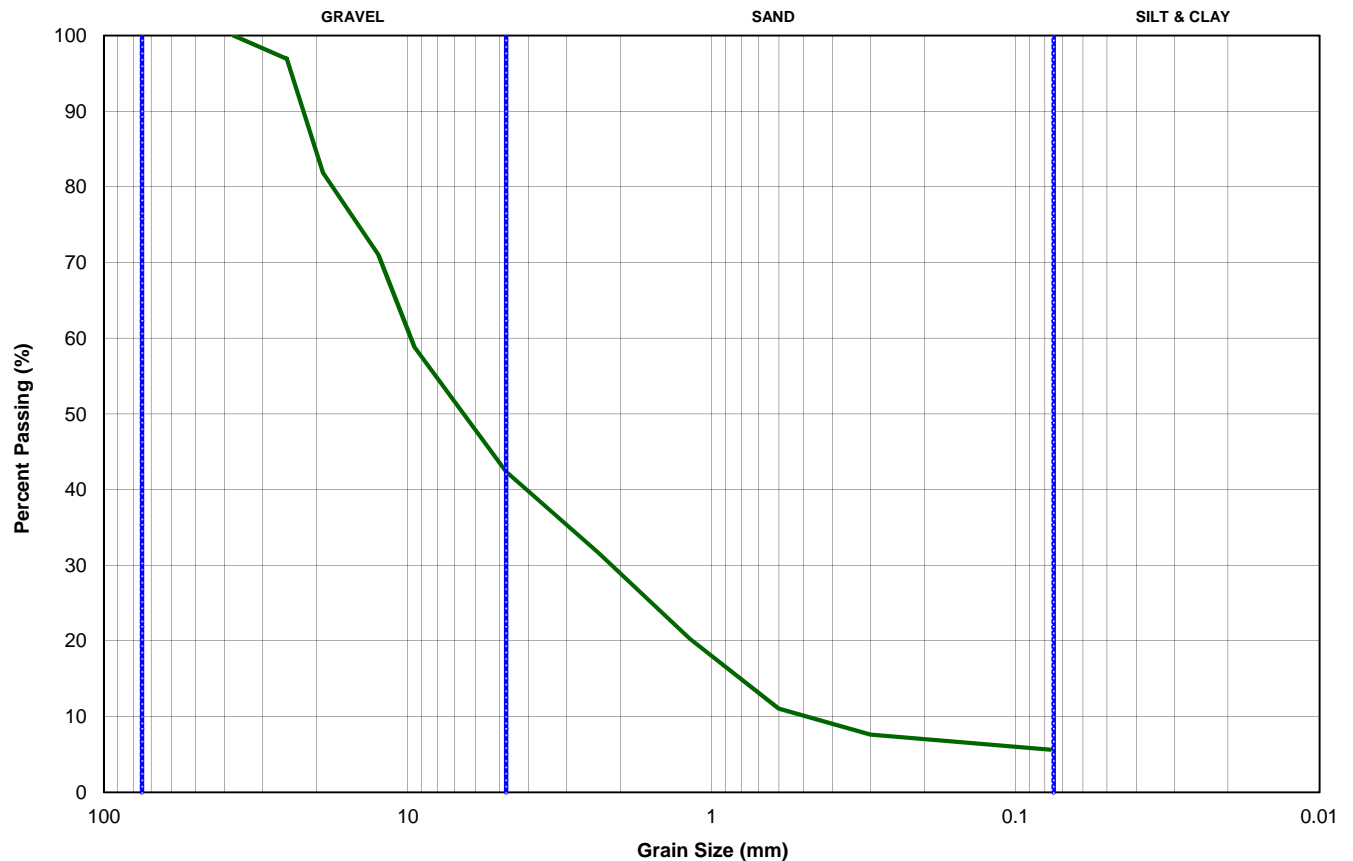
Fracture Method

N/A A

## Sieve Results

|           |       |      |      |      |      |      |      |      |       |       |       |
|-----------|-------|------|------|------|------|------|------|------|-------|-------|-------|
| Sieve mm  | 37.5  | 25   | 19   | 12.5 | 9.5  | 4.75 | 2.36 | 1.18 | 0.600 | 0.300 | 0.075 |
| % Passing | 100.0 | 96.9 | 81.9 | 71.1 | 58.8 | 42.4 | 31.7 | 20.3 | 11.0  | 7.6   | 5.6   |

By Type Gravel = 57.6% Sand = 36.8% Silt & Clay = 5.6%



**SNC-LAVALIN**

Client **Public Works & Government Services**

Date **16-Jun-16**

Project **2016 Materials Testing**

File No. **635734**

Location **Toad River, British Columbia**

Sample No. **BH16-135-04**

# MECHANICAL SIEVE ANALYSIS

Sample No. **BH16-135-05** Date Sampled **30-May-16** By **ST** of **SNC-Lavalin Inc.**  
 Location **Toad River** Sample Type **Bag** Natural Moisture **9.0** %  
 Description **Sandy, gravelly, silty, clayey.** Tech **KB/AN**

Specifications

Comments

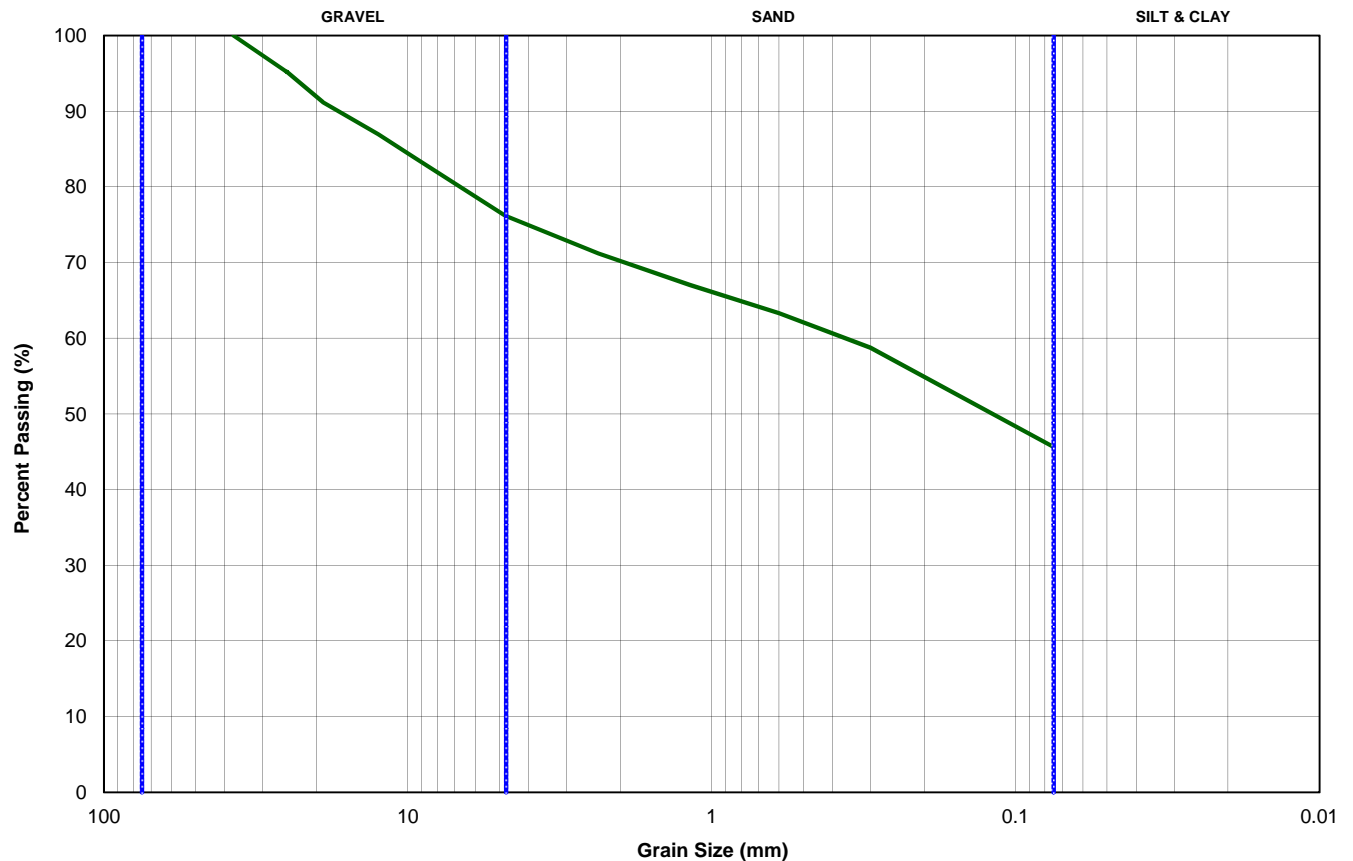
Fracture Method

N/A A

## Sieve Results

|           |       |      |      |      |      |      |      |      |       |       |       |
|-----------|-------|------|------|------|------|------|------|------|-------|-------|-------|
| Sieve mm  | 37.5  | 25   | 19   | 12.5 | 9.5  | 4.75 | 2.36 | 1.18 | 0.600 | 0.300 | 0.075 |
| % Passing | 100.0 | 95.2 | 91.2 | 86.9 | 83.9 | 76.1 | 71.2 | 67.0 | 63.3  | 58.8  | 45.6  |

By Type Gravel = 23.9% Sand = 30.5% Silt & Clay = 45.6%



**SNC-LAVALIN**

Client **Public Works & Government Services**

Date **16-Jun-16**

Project **2016 Materials Testing**

File No. **635734**

Location **Toad River, British Columbia**

Sample No. **BH16-135-05**

# MECHANICAL SIEVE ANALYSIS

Sample No. **BH16-135-06** Date Sampled **30-May-16** By **ST** of **SNC-Lavalin Inc.**  
 Location **Toad River** Sample Type **Bag** Natural Moisture **9.3** %  
 Description **Sandy, silty, clayey, some gravel.** Tech **KB/AN**

Specifications

Comments

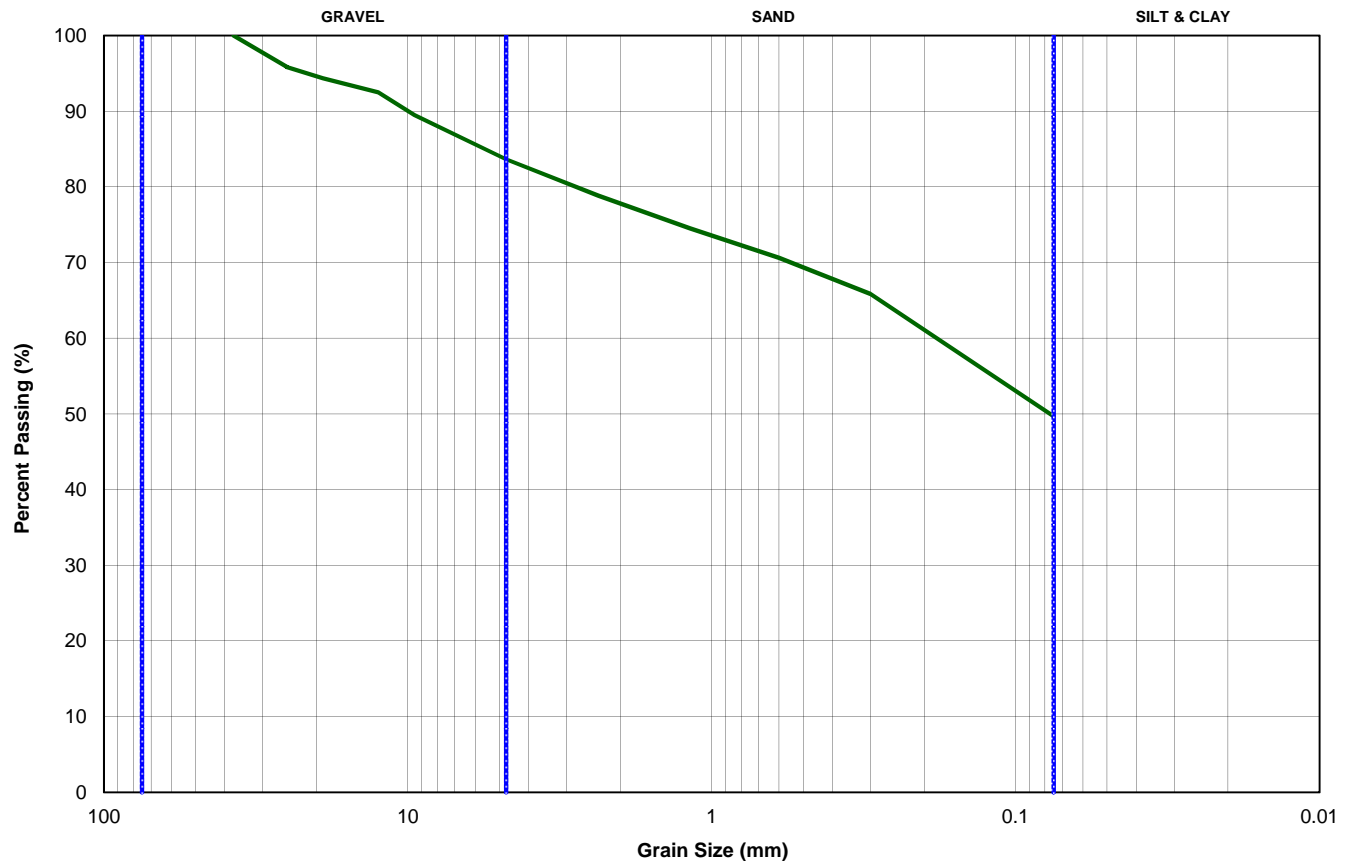
Fracture Method

N/A A

Sieve Results

|           |       |      |      |      |      |      |      |      |       |       |       |
|-----------|-------|------|------|------|------|------|------|------|-------|-------|-------|
| Sieve mm  | 37.5  | 25   | 19   | 12.5 | 9.5  | 4.75 | 2.36 | 1.18 | 0.600 | 0.300 | 0.075 |
| % Passing | 100.0 | 95.8 | 94.4 | 92.5 | 89.5 | 83.6 | 78.9 | 74.5 | 70.6  | 65.8  | 49.7  |

By Type Gravel = 16.4% Sand = 33.9% Silt & Clay = 49.7%



**SNC-LAVALIN**

Client **Public Works & Government Services**

Date **16-Jun-16**

Project **2016 Materials Testing**

File No. **635734**

Location **Toad River, British Columbia**

Sample No. **BH16-135-06**



## Sieve Analysis Summary

| Sample Location | Sample ID   | Sample Date<br>(yyyy mm dd) | Depth Interval<br>(m) | Soil classification (by type) |        |               | Sieve Analysis (% passing) |           |         |         |           |          |           |           |           |          |          |            |
|-----------------|-------------|-----------------------------|-----------------------|-------------------------------|--------|---------------|----------------------------|-----------|---------|---------|-----------|----------|-----------|-----------|-----------|----------|----------|------------|
|                 |             |                             |                       | Gravel %                      | Sand % | Silt & Clay % | 50 mm %                    | 37.5 mm % | 25 mm % | 19 mm % | 12.5 mm % | 9.5 mm % | 4.75 mm % | 2.36 mm % | 1.18 mm % | 0.6 mm % | 0.3 mm % | 0.075 mm % |
| BH16-112        | BH16-112-01 | 2016 05 26                  | 0.2 - 0.3             | 27.1                          | 45.7   | 27.2          | 100                        | 100       | 97.4    | 95.4    | 88.2      | 83.4     | 72.9      | 65.2      | 59        | 51.3     | 37.5     | 27.2       |
|                 | BH16-112-02 | 2016 05 26                  | 1.5 - 1.7             | 23.3                          | 64.3   | 12.4          | 100                        | 100       | 96.4    | 89.9    | 86.1      | 83.2     | 76.7      | 72.1      | 67.6      | 60       | 34.9     | 12.4       |
|                 | BH16-112-03 | 2016 05 26                  | 2.3 - 2.4             | 4                             | 70     | 26            | 100                        | 100       | 100     | 97.2    | 97.2      | 97.2     | 96        | 95.1      | 94.2      | 91.9     | 72.5     | 26         |
|                 | BH16-112-04 | 2016 05 26                  | 3.0 - 3.2             | 0.6                           | 71.5   | 27.9          | 100                        | 100       | 100     | 100     | 100       | 99.6     | 99.4      | 99.1      | 98        | 96.9     | 90.9     | 27.9       |
|                 | BH16-112-05 | 2016 05 26                  | 7.3 - 7.5             | 11.2                          | 25.3   | 63.5          | 100                        | 100       | 100     | 97.6    | 94.5      | 93.3     | 88.8      | 85.1      | 81.9      | 78.9     | 75       | 63.5       |
| BH16-113        | BH16-113-01 | 2016 05 26                  | 0.2 - 0.3             | 49.7                          | 33.5   | 16.8          | 100                        | 100       | 97.8    | 91.1    | 75.9      | 66.9     | 50.3      | 41.2      | 34.8      | 28.6     | 21.6     | 16.8       |
|                 | BH16-113-02 | 2016 05 26                  | 1.5 - 1.7             | 37                            | 48.5   | 14.5          | 100                        | 100       | 89.8    | 84.6    | 76.6      | 73.4     | 63        | 55.9      | 49.4      | 39.9     | 24.4     | 14.4       |
|                 | BH16-113-03 | 2016 05 26                  | 2.3 - 2.4             | 22                            | 59.5   | 18.5          | 100                        | 100       | 100     | 92.8    | 85.7      | 83.8     | 78        | 72.9      | 67.5      | 56.5     | 40.6     | 18.5       |
|                 | BH16-113-04 | 2016 05 26                  | 3.0 - 3.5             | 1.8                           | 69.5   | 28.7          | 100                        | 100       | 100     | 100     | 98.9      | 98.9     | 98.2      | 97.4      | 96.6      | 95.6     | 82.6     | 28.7       |
| BH16-135        | BH16-135-01 | 2016 05 30                  | 0.9 - 1.1             | 27.2                          | 60.9   | 11.9          | 100                        | 100       | 87.1    | 83.7    | 78.5      | 77       | 72.8      | 69.5      | 66.9      | 62.3     | 35.9     | 11.9       |
|                 | BH16-135-02 | 2016 05 30                  | 2.0 - 2.1             | 48.6                          | 37.4   | 8             | 100                        | 94        | 74      | 64.6    | -         | 53.2     | 45.4      | 39.7      | 34.7      | 89       | 17.4     | 8          |
|                 | BH16-135-03 | 2016 05 30                  | 2.9 - 3.0             | 0                             | 85.3   | 14.7          | 100                        | 100       | 100     | 100     | 100       | 100      | 100       | 100       | 100       | 98.9     | 75.7     | 14.7       |
|                 | BH16-135-04 | 2016 05 30                  | 4.1 - 4.3             | 57.6                          | 36.8   | 5.6           | 100                        | 100       | 96.9    | 81.9    | 71.1      | 58.8     | 42.4      | 31.7      | 20.3      | 11       | 7.6      | 5.6        |
|                 | BH16-135-05 | 2016 05 30                  | 5.9 - 6.1             | 23.9                          | 30.5   | 45.6          | 100                        | 100       | 95.2    | 91.2    | 86.9      | 83.9     | 76.1      | 71.2      | 67        | 63.3     | 58.8     | 45.6       |
|                 | BH16-135-06 | 2016 05 30                  | 0.9 - 1.1             | 16.4                          | 33.9   | 49.7          | 100                        | 100       | 95.8    | 94.4    | 92.5      | 89.5     | 83.6      | 78.9      | 74.5      | 70.6     | 65.8     | 49.7       |

## Standard Penetration Test Summary

| Sample Location | Sample Date<br>(yyyy mm dd) | Depth Interval<br>(m) | SPT Info    |                    |
|-----------------|-----------------------------|-----------------------|-------------|--------------------|
|                 |                             |                       | Blow Counts | N<br>(uncorrected) |
| BH16-111        | 2016 05 26                  | 1.5 - 2.0             | 8/18/30     | 48                 |
|                 | 2016 05 26                  | 2.3 - 2.7             | 11/13/10    | 23                 |
|                 | 2016 05 26                  | 3.0 - 3.5             | 6/8/8       | 16                 |
| BH16-112        | 2016 05 26                  | 0.2 - 0.5             | 26/40/11    | 51                 |
|                 | 2016 05 26                  | 1.5 - 2.0             | 20/23/19    | 42                 |
|                 | 2016 05 26                  | 2.3 - 2.7             | 8/10/9      | 19                 |
|                 | 2016 05 26                  | 3.0 - 3.5             | 5/8/10      | 18                 |
| BH16-113        | 2016 05 26                  | 0.2 - 0.6             | 20/23/27    | 50                 |
|                 | 2016 05 26                  | 1.5 - 2.0             | 22/22/13    | 35                 |
|                 | 2016 05 26                  | 2.3 - 2.7             | 12/20/16    | 36                 |
|                 | 2016 05 26                  | 3.0 - 3.5             | 8/7/6       | 13                 |
| BH16-114        | 2016 05 27                  | 0.2 - 0.6             | 12/9/8      | 17                 |
|                 | 2016 05 27                  | 1.5 - 2.0             | 8/10/11     | 21                 |
|                 | 2016 05 27                  | 2.3 - 2.7             | 20/13/9     | 22                 |
|                 | 2016 05 27                  | 3.0 - 3.5             | 2/6/8       | 14                 |
|                 | 2016 05 27                  | 5.9 - 6.4             | 7/11/16     | 27                 |
| BH16-115        | 2016 05 27                  | 0.6 - 0.9             | 10/21/16    | 37                 |
|                 | 2016 05 27                  | 1.5 - 2.0             | 10/10/18    | 28                 |
|                 | 2016 05 27                  | 2.3 - 2.7             | 20/12/8     | 20                 |
|                 | 2016 05 27                  | 3.0 - 3.5             | 7/7/7       | 14                 |
|                 | 2016 05 27                  | 5.9 - 6.4             | 13/8/8      | 16                 |
| BH16-135        | 2016 05 30                  | 0.5 - 0.9             | 11/12/9     | 21                 |
|                 | 2016 05 30                  | 1.5 - 2.0             | 10/15/14    | 29                 |
|                 | 2016 05 30                  | 2.3 - 2.7             | 21/38/18    | 56                 |
|                 | 2016 05 30                  | 3.0 - 3.5             | 7/8/8       | 16                 |
|                 | 2016 05 30                  | 6.1 - 6.6             | 8/16/20     | 36                 |



Client  
Public Works and Gov't Services Canada

Borehole No. : BH16-111

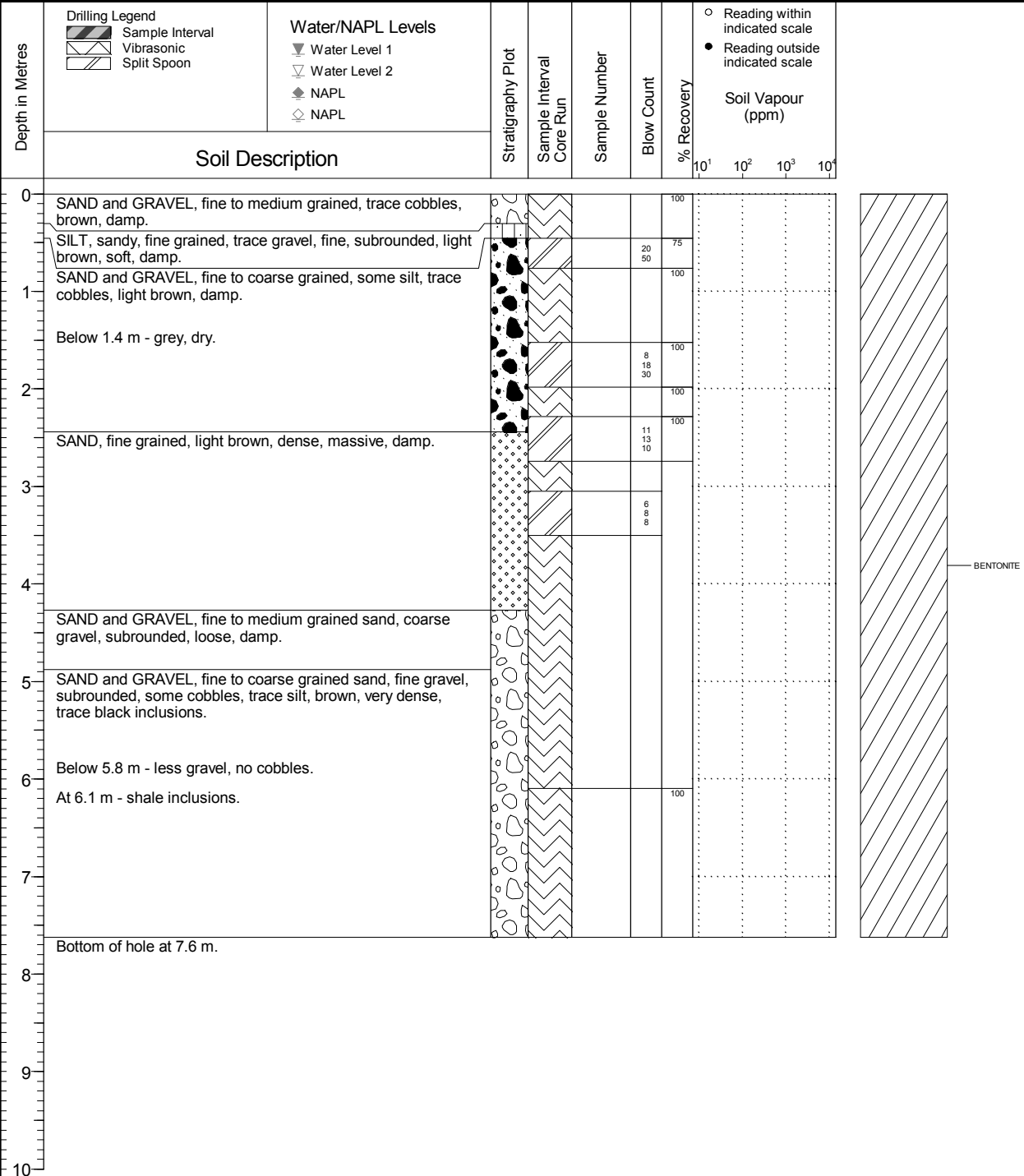
Location  
Toad River Maintenance Camp, BC

PAGE 1 OF 1

Drilling Contractor Geotech Drilling Services Ltd.  
Drilling Method Vibratory Sonic  
Borehole Dia. (m) 0.15  
Pipe/Slotted Pipe Dia. (m) none/none

Date Monitored n/a  
Ground Surface Elev. (m) 707.236  
Top of Casing Elev. (m) n/a  
Northing: 6525434.263 Easting: 371089.598

Project Number: 635734  
Borehole Logged By: SJWM  
Date Drilled: 2016 05 26  
Log Typed By: NDS



#### NOTES

Bolded sample denotes sample analyzed.



Client  
Public Works and Gov't Services Canada

Borehole No. : BH16-112

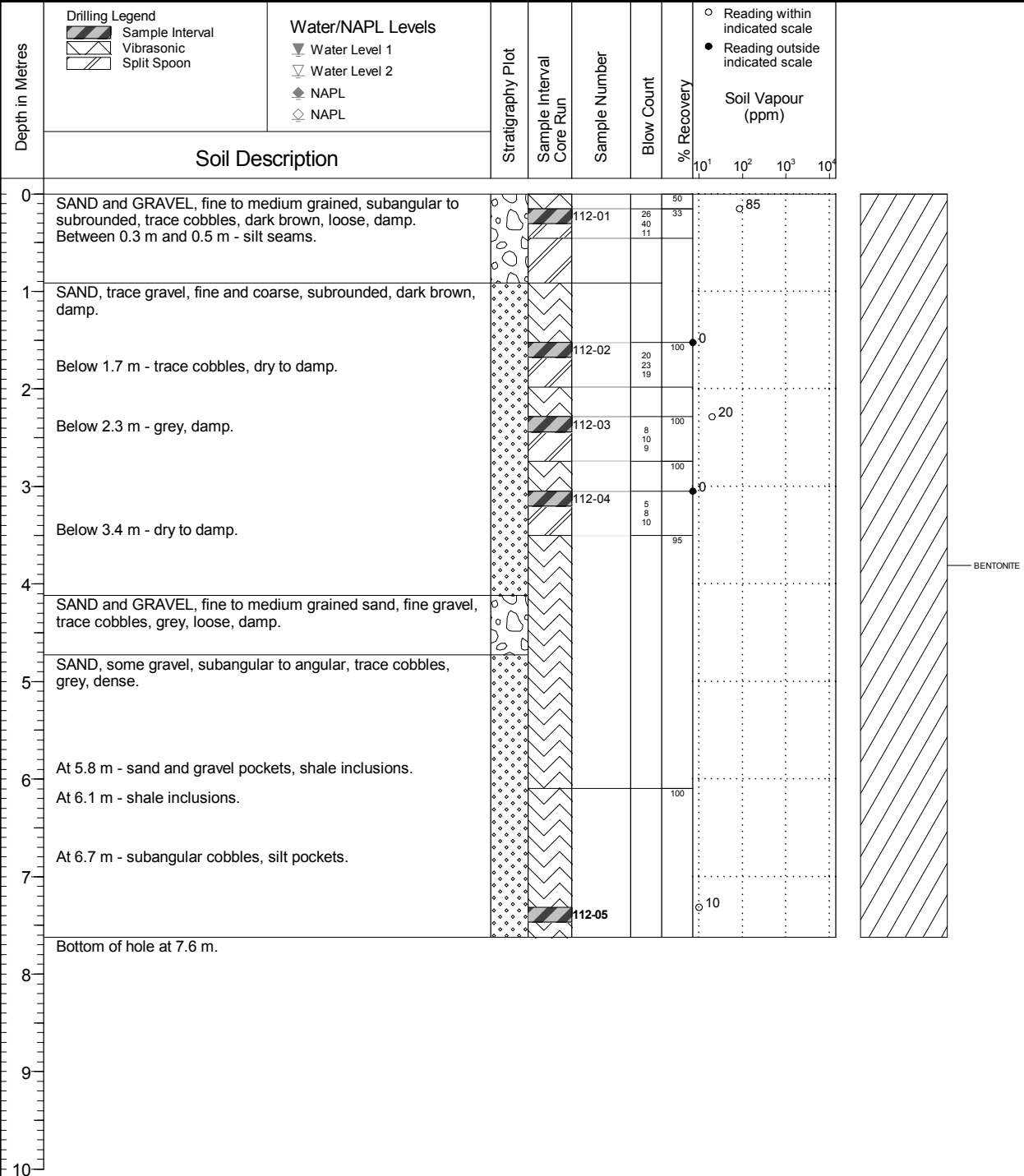
Location  
Toad River Maintenance Camp, BC

PAGE 1 OF 1

Drilling Contractor Geotech Drilling Services Ltd.  
Drilling Method Vibratory Sonic  
Borehole Dia. (m) 0.15  
Pipe/Slotted Pipe Dia. (m) none/none

Date Monitored n/a  
Ground Surface Elev. (m) 707.293  
Top of Casing Elev. (m) n/a  
Northing: 6525430.204 Easting: 371086.796

Project Number: 635734  
Borehole Logged By: SJWM/ST  
Date Drilled: 2016 05 26  
Log Typed By: NDS



NOTES

Bolded sample denotes sample analyzed.



Client  
Public Works and Gov't Services Canada

Location  
Toad River Maintenance Camp, BC

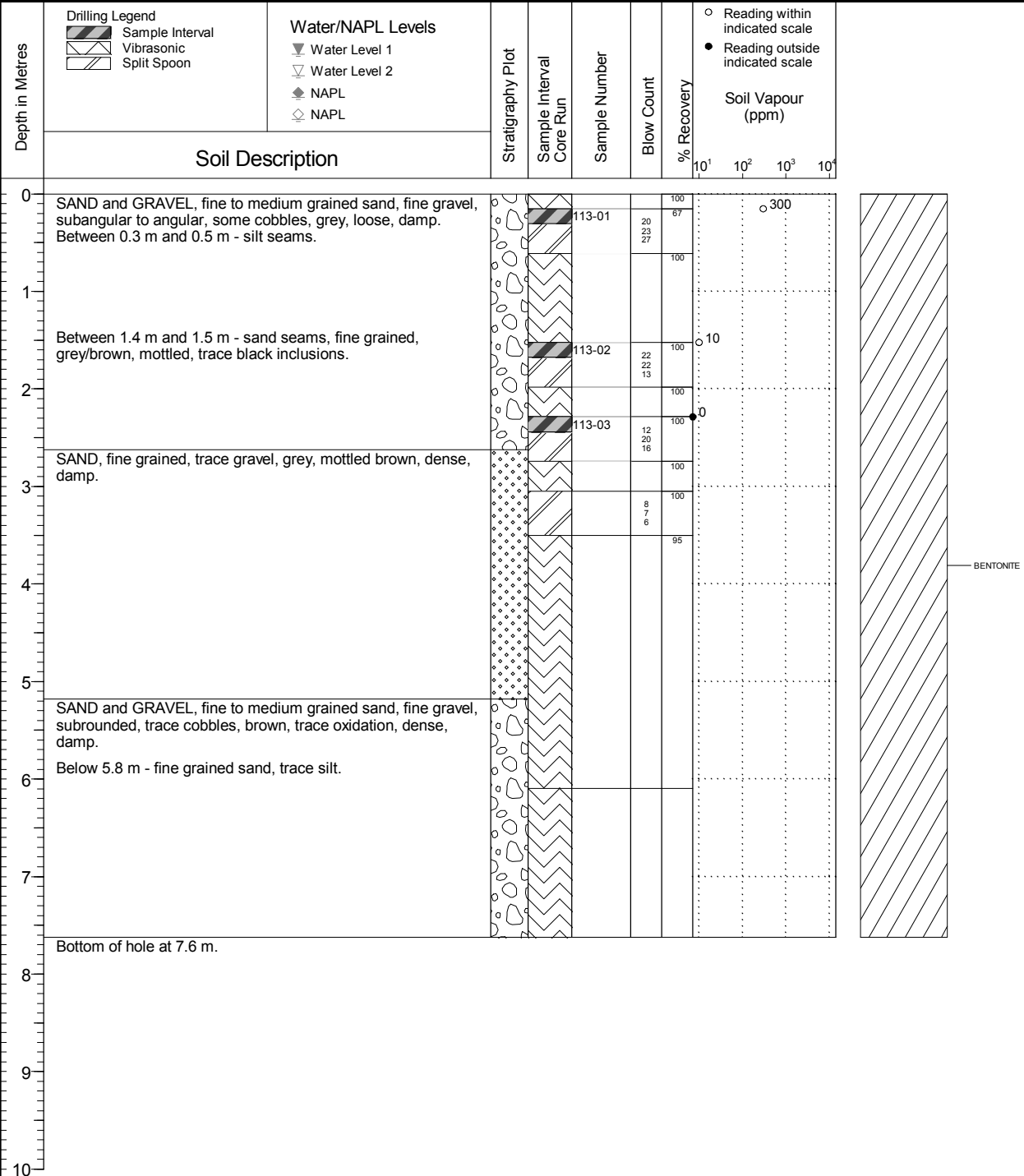
Borehole No. : BH16-113

PAGE 1 OF 1

Drilling Contractor Geotech Drilling Services Ltd.  
Drilling Method Vibratory Sonic  
Borehole Dia. (m) 0.15  
Pipe/Slotted Pipe Dia. (m) none/none

Date Monitored n/a  
Ground Surface Elev. (m) 707.345  
Top of Casing Elev. (m) n/a  
Northing: 6525426.882 Easting: 371084.867

Project Number: 635734  
Borehole Logged By: SJWM/ST  
Date Drilled: 2016 05 26  
Log Typed By: NDS



#### NOTES

Bolded sample denotes sample analyzed.



Client  
Public Works and Gov't Services Canada

Borehole No. : BH16-114

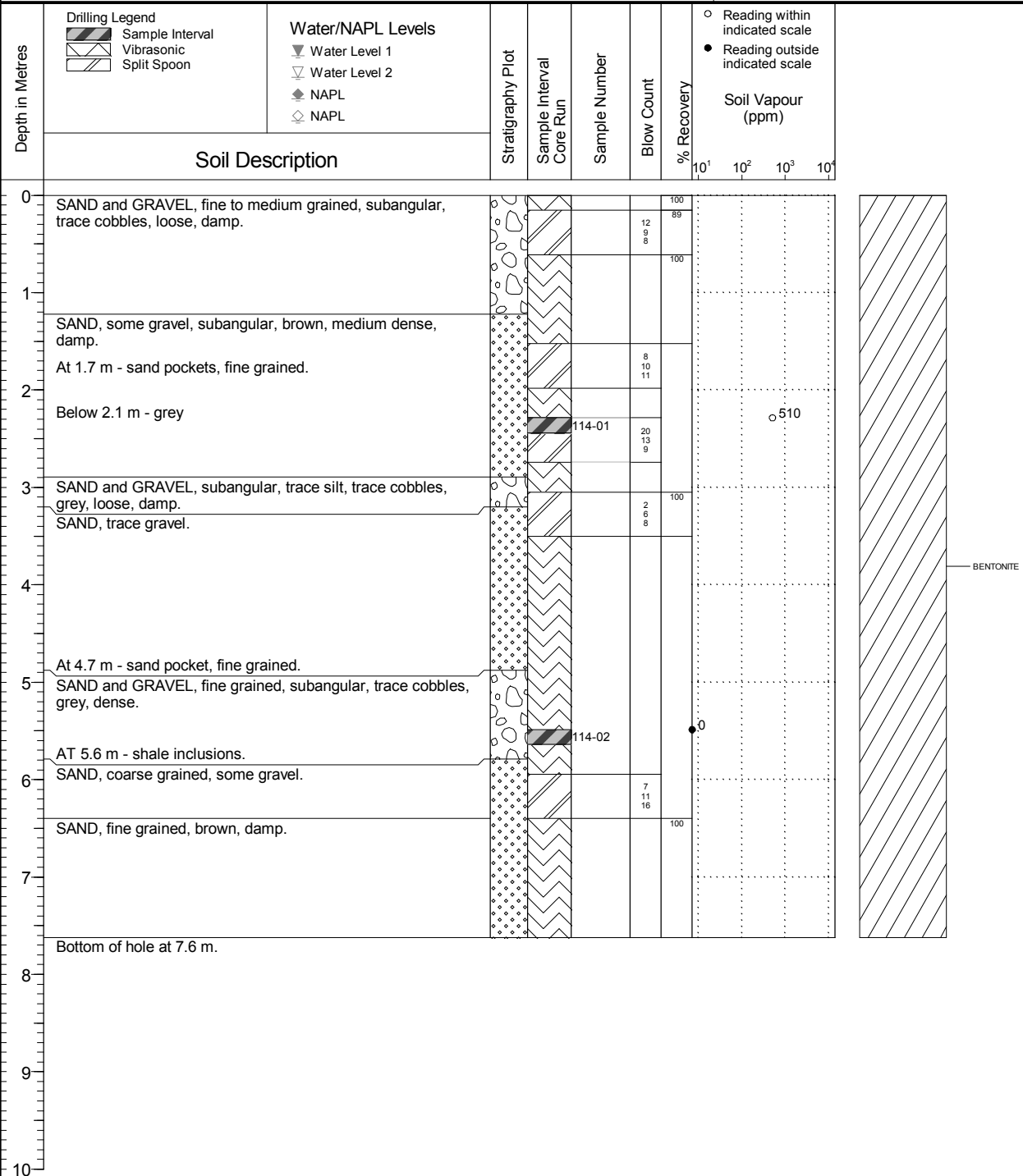
Location  
Toad River Maintenance Camp, BC

PAGE 1 OF 1

Drilling Contractor Geotech Drilling Services Ltd.  
Drilling Method Vibratory Sonic  
Borehole Dia. (m) 0.15  
Pipe/Slotted Pipe Dia. (m) none/none

Date Monitored n/a  
Ground Surface Elev. (m) 707.343  
Top of Casing Elev. (m) n/a  
Northing: 6525420.023 Easting: 371081.747

Project Number: 635734  
Borehole Logged By: SJWM/ST  
Date Drilled: 2016 05 27  
Log Typed By: NDS



#### NOTES

Bolded sample denotes sample analyzed.



Client  
Public Works and Gov't Services Canada

Borehole No. : BH16-115

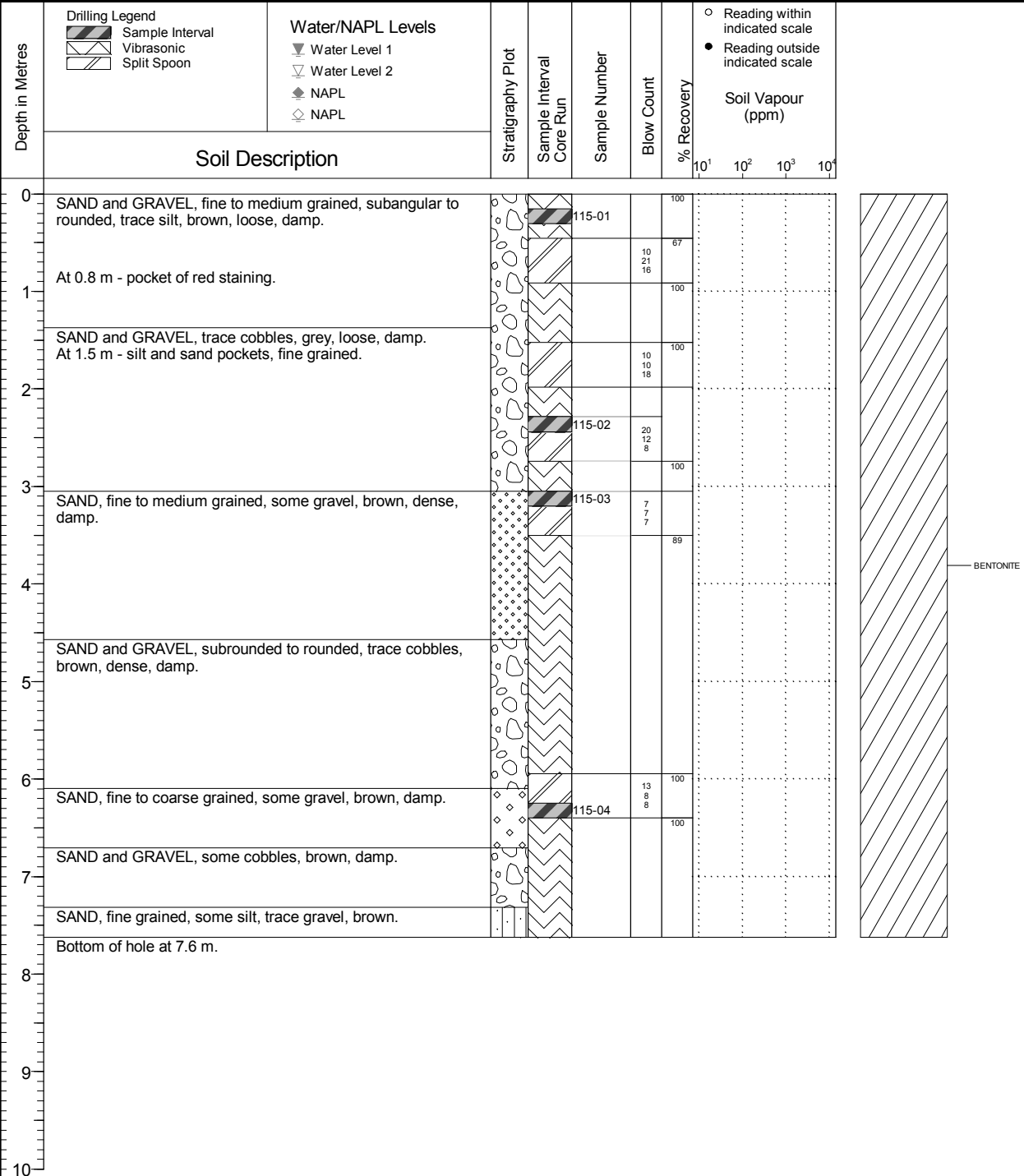
Location  
Toad River Maintenance Camp, BC

PAGE 1 OF 1

Drilling Contractor Geotech Drilling Services Ltd.  
Drilling Method Vibratory Sonic  
Borehole Dia. (m) 0.15  
Pipe/Slotted Pipe Dia. (m) none/none

Date Monitored n/a  
Ground Surface Elev. (m) 707.366  
Top of Casing Elev. (m) n/a  
Northing: 6525416.299 Easting: 371078.946

Project Number: 635734  
Borehole Logged By: SJWM/ST  
Date Drilled: 2016 05 27  
Log Typed By: NDS



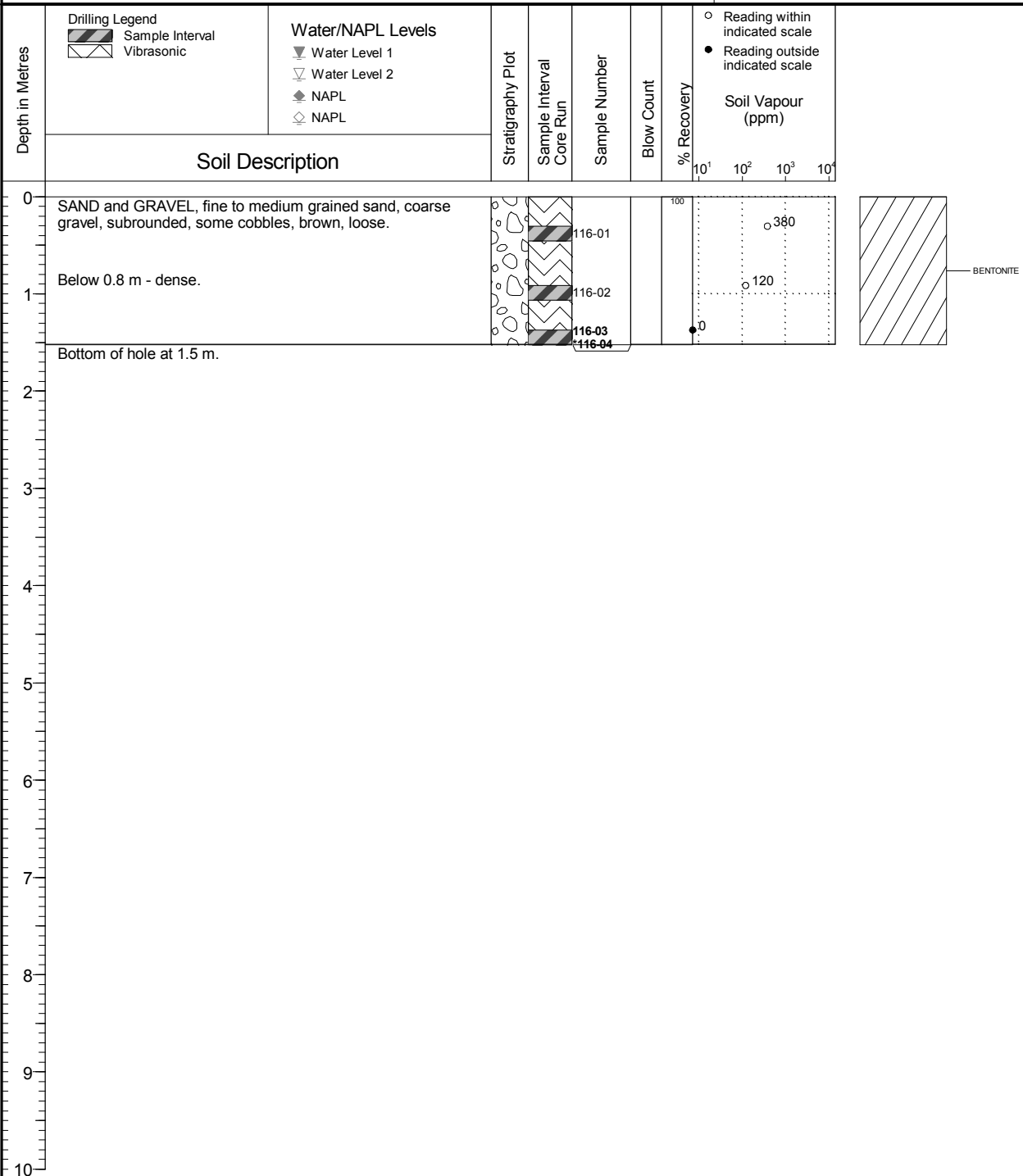
#### NOTES

Bolded sample denotes sample analyzed.

|                            |                                |
|----------------------------|--------------------------------|
| Drilling Contractor        | Geotech Drilling Services Ltd. |
| Drilling Method            | Vibratory Sonic                |
| Borehole Dia. (m)          | 0.10                           |
| Pipe/Slotted Pipe Dia. (m) | none/none                      |

|                          |                     |
|--------------------------|---------------------|
| Date Monitored           | n/a                 |
| Ground Surface Elev. (m) | 707.518             |
| Top of Casing Elev. (m)  | n/a                 |
| Northing: 6525411.100    | Easting: 371075.017 |

Project Number: 635734  
Borehole Logged By: SJWM/ST  
Date Drilled: 2016 05 28  
Log Typed By: NDS



## NOTES

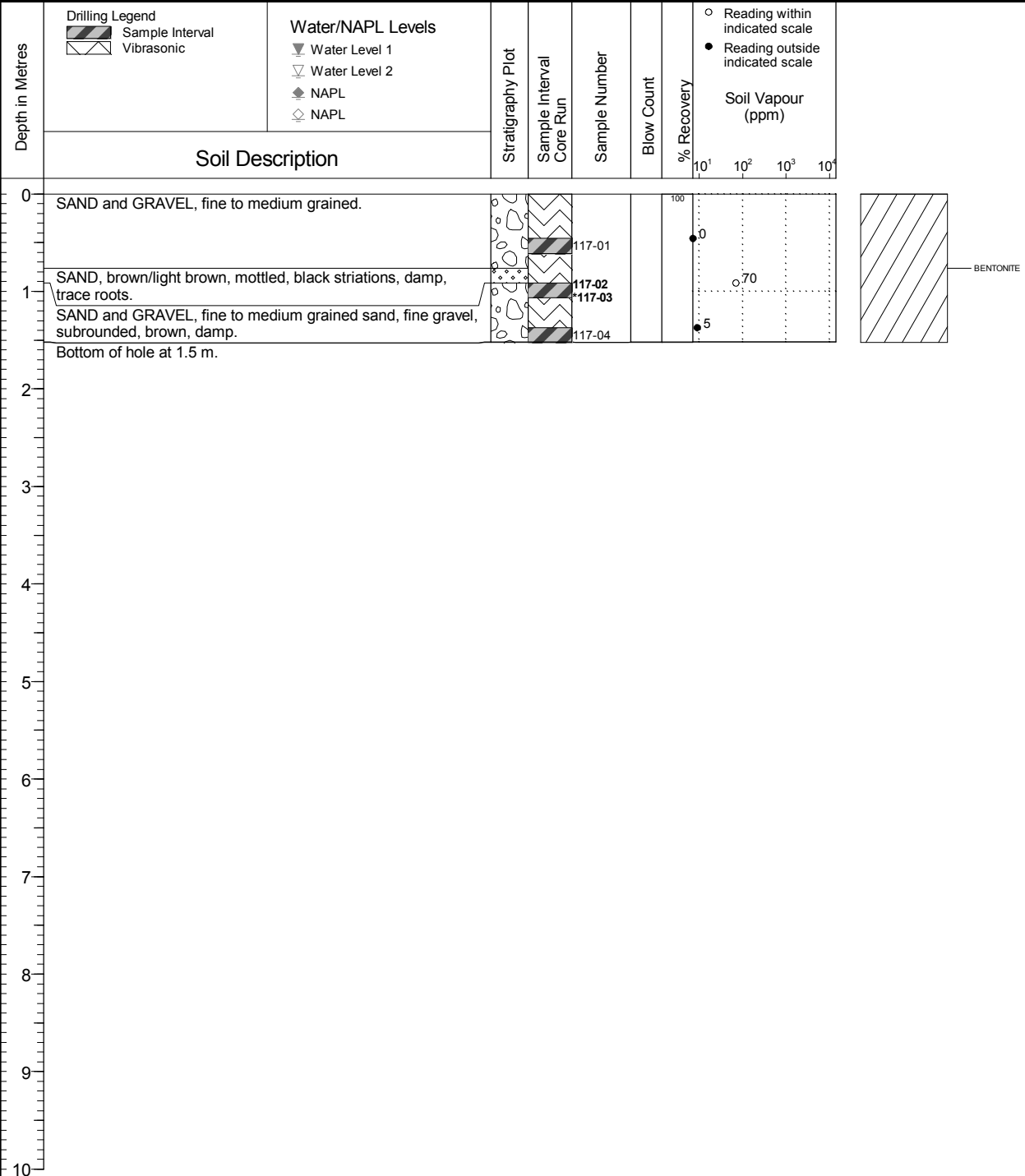
**NOTES**  
 Bolded sample denotes sample analyzed. \*denotes blind field duplicate.  
 116-04 is a blind field duplicate of 116-03.



Drilling Contractor: Geotech Drilling Services Ltd.  
Drilling Method: Vibratory Sonic  
Borehole Dia. (m): 0.10  
Pipe/Slotted Pipe Dia. (m): none/none

Date Monitored: n/a  
Ground Surface Elev. (m): 707.252  
Top of Casing Elev. (m): n/a  
Northing: 6525352.208  
Easting: 371096.697

Project Number: 635734  
Borehole Logged By: SJWM  
Date Drilled: 2016 05 28  
Log Typed By: NDS



#### NOTES

Bolded sample denotes sample analyzed. \*denotes blind field duplicate.  
117-03 is a blind field duplicate of 116-02.



Client  
Public Works and Gov't Services Canada

Borehole No. : BH16-118

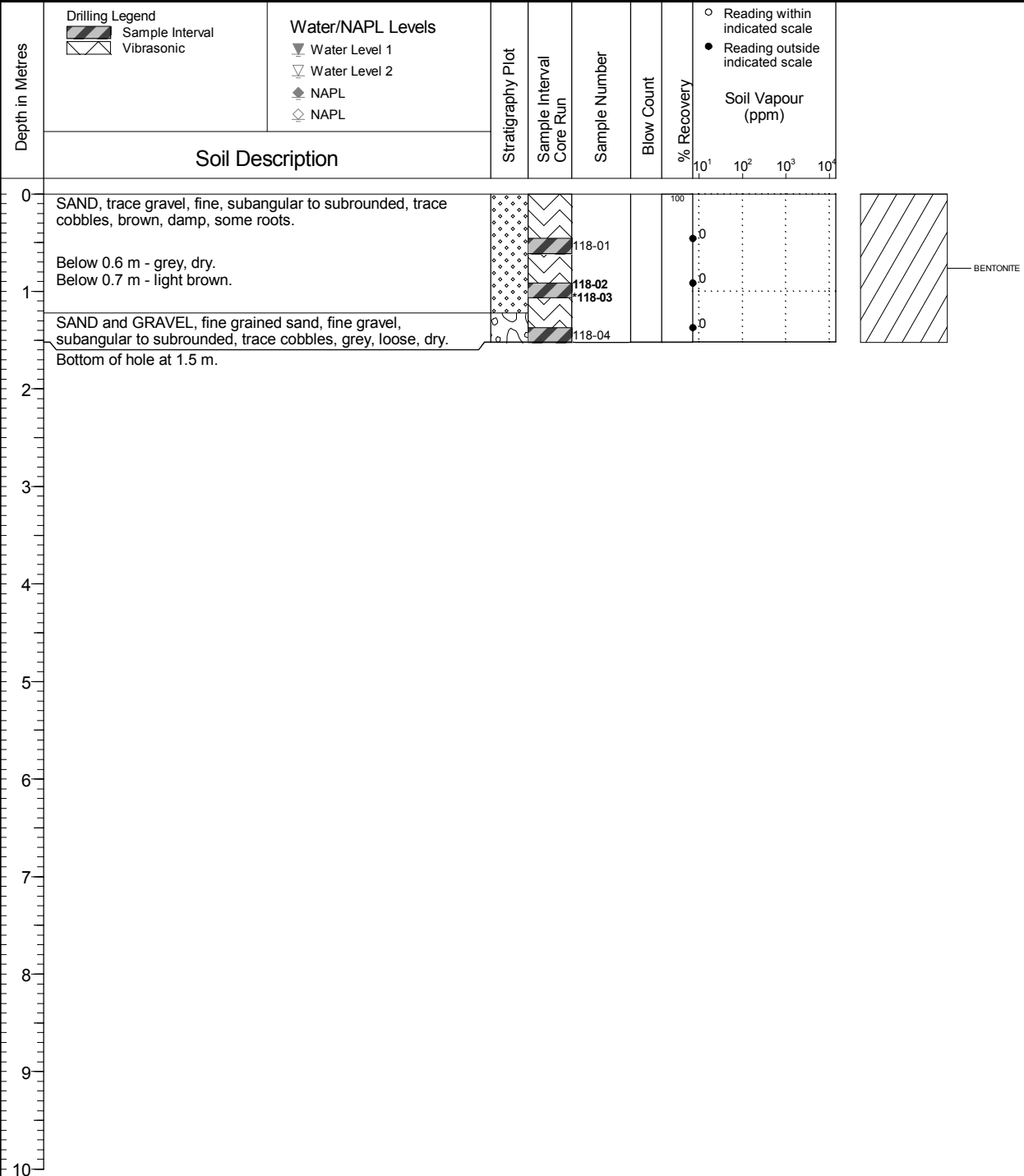
Location  
Toad River Maintenance Camp, BC

PAGE 1 OF 1

Drilling Contractor: Geotech Drilling Services Ltd.  
Drilling Method: Vibratory Sonic  
Borehole Dia. (m): 0.10  
Pipe/Slotted Pipe Dia. (m): none/none

Date Monitored: n/a  
Ground Surface Elev. (m): 708.001  
Top of Casing Elev. (m): n/a  
Northing: 6525350.853 Easting: 370972.893

Project Number: 635734  
Borehole Logged By: SJWM  
Date Drilled: 2016 05 28  
Log Typed By: NDS



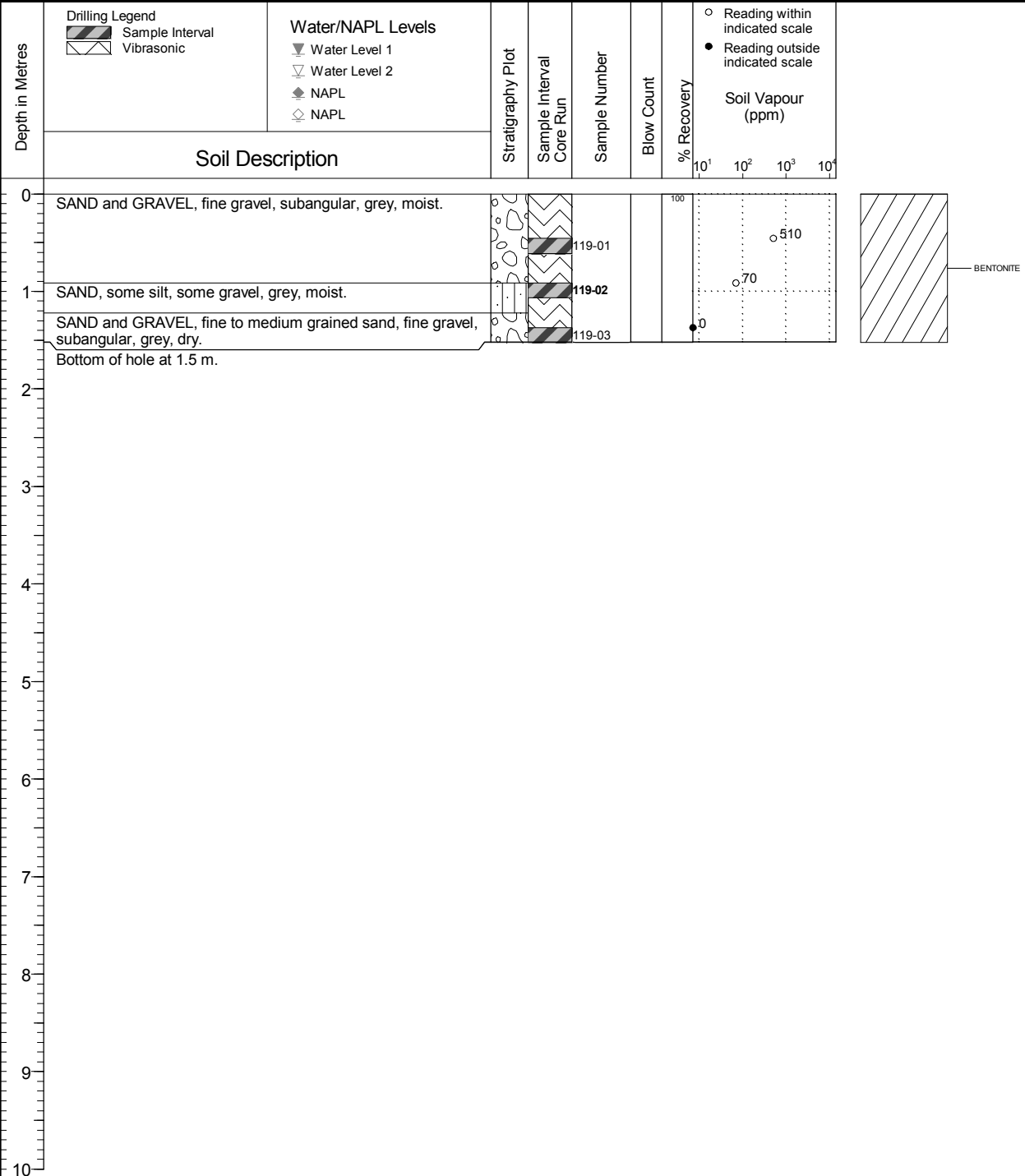
#### NOTES

Bolded sample denotes sample analyzed. \*denotes blind field duplicate.  
118-03 is a blind field duplicate of 118-02.

Drilling Contractor: Geotech Drilling Services Ltd.  
Drilling Method: Vibratory Sonic  
Borehole Dia. (m): 0.10  
Pipe/Slotted Pipe Dia. (m): none/none

Date Monitored: n/a  
Ground Surface Elev. (m): 707.922  
Top of Casing Elev. (m): n/a  
Northing: 6525419.151  
Easting: 370989.173

Project Number: 635734  
Borehole Logged By: SJWM  
Date Drilled: 2016 05 28  
Log Typed By: NDS



**NOTES**

Bolded sample denotes sample analyzed.



Client  
Public Works and Gov't Services Canada

Borehole No. : BH16-120

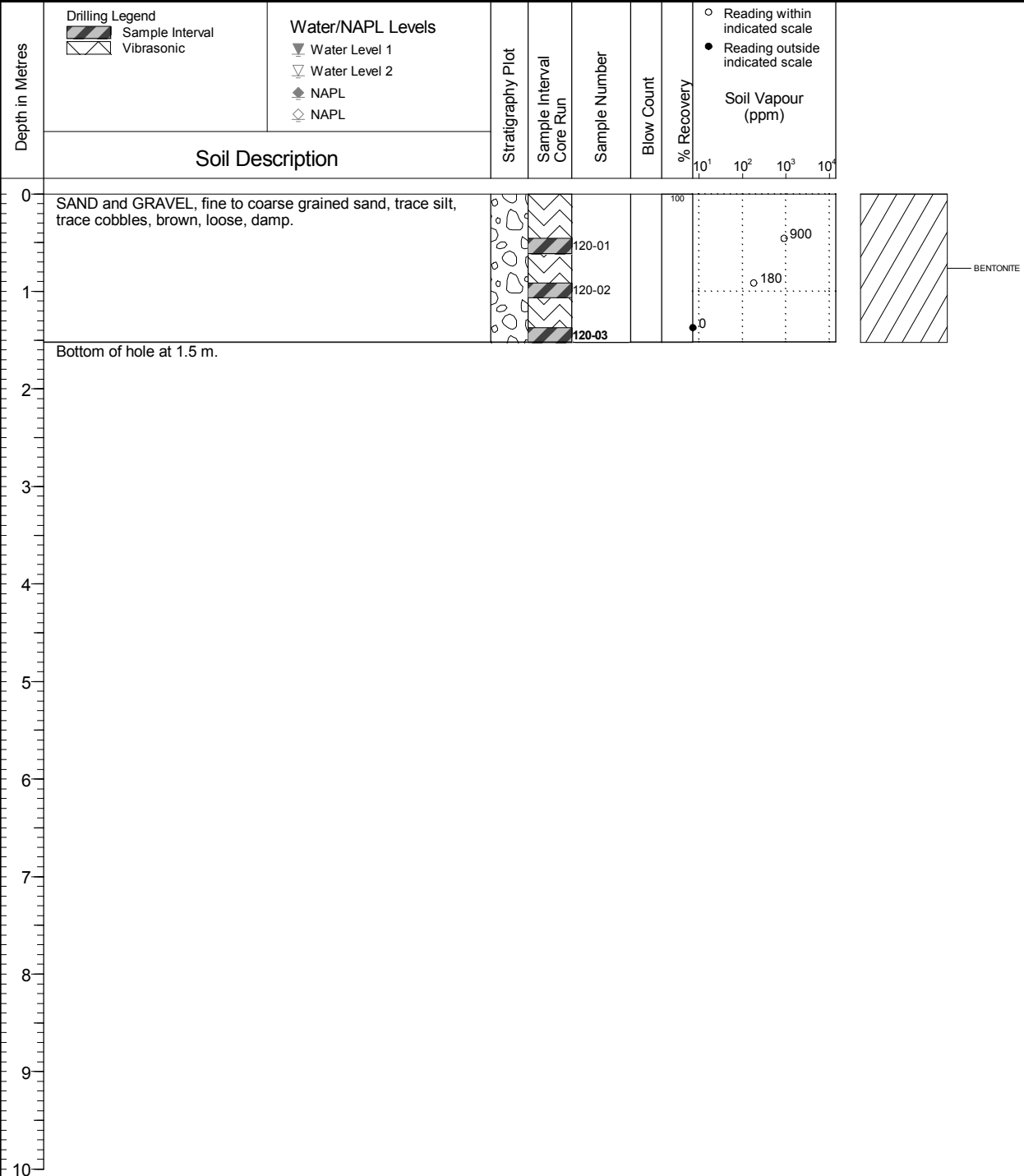
Location  
Toad River Maintenance Camp, BC

PAGE 1 OF 1

Drilling Contractor: Geotech Drilling Services Ltd.  
Drilling Method: Vibratory Sonic  
Borehole Dia. (m): 0.10  
Pipe/Slotted Pipe Dia. (m): none/none

Date Monitored: n/a  
Ground Surface Elev. (m): 710.435  
Top of Casing Elev. (m): n/a  
Northing: 6525472.285  
Easting: 370955.497

Project Number: 635734  
Borehole Logged By: SJWM/ST  
Date Drilled: 2016 05 28  
Log Typed By: NDS



#### NOTES

Bolded sample denotes sample analyzed.



Client  
Public Works and Gov't Services Canada

Borehole No. : BH16-121

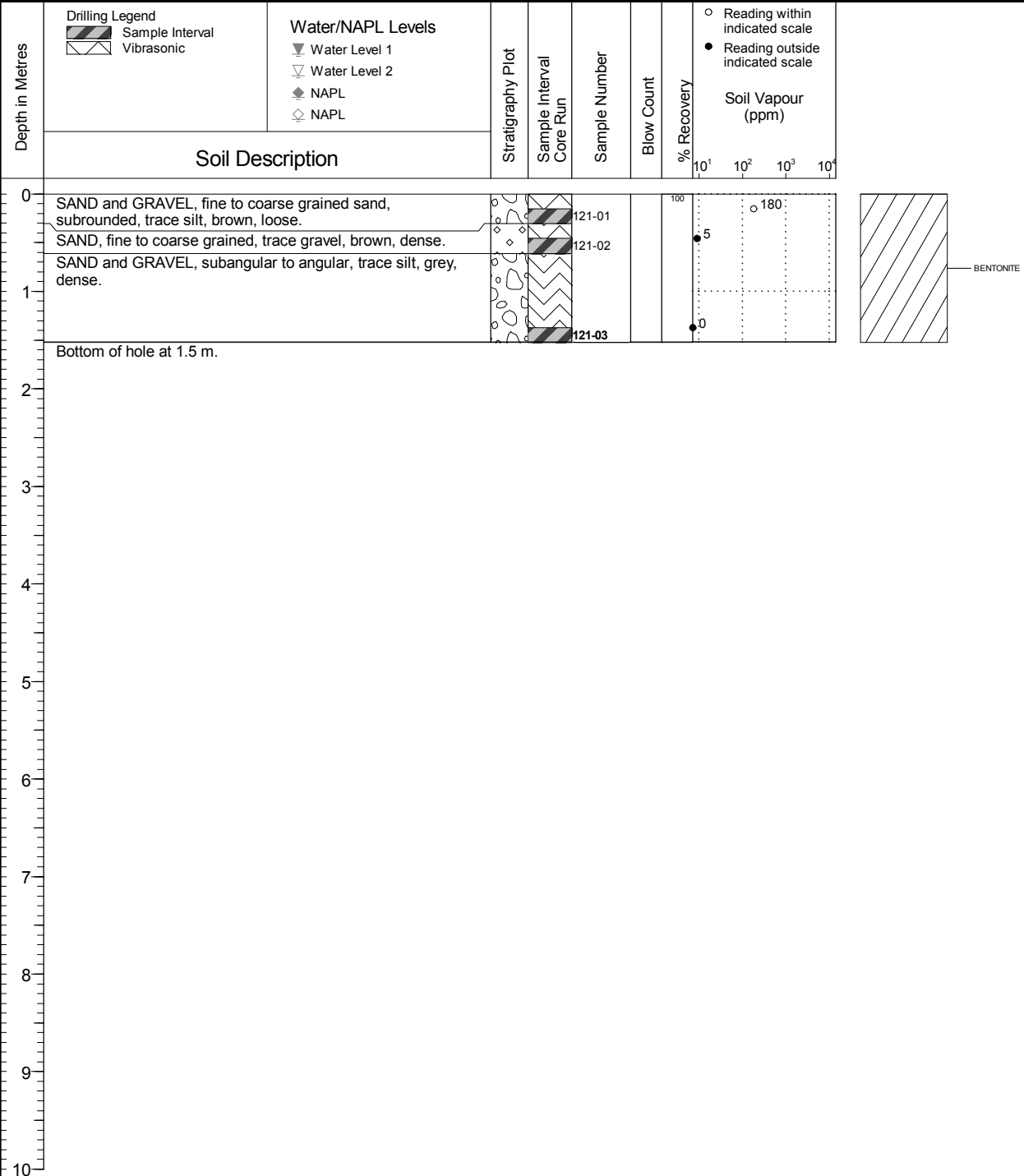
Location  
Toad River Maintenance Camp, BC

PAGE 1 OF 1

Drilling Contractor Geotech Drilling Services Ltd.  
Drilling Method Vibratory Sonic  
Borehole Dia. (m) 0.10  
Pipe/Slotted Pipe Dia. (m) none/none

Date Monitored n/a  
Ground Surface Elev. (m) 709.783  
Top of Casing Elev. (m) n/a  
Northing: 6525463.429 Easting: 370993.768

Project Number: 635734  
Borehole Logged By: SJWM/ST  
Date Drilled: 2016 05 28  
Log Typed By: NDS



NOTES

Bolded sample denotes sample analyzed.



Client  
Public Works and Gov't Services Canada

Location  
Toad River Maintenance Camp, BC

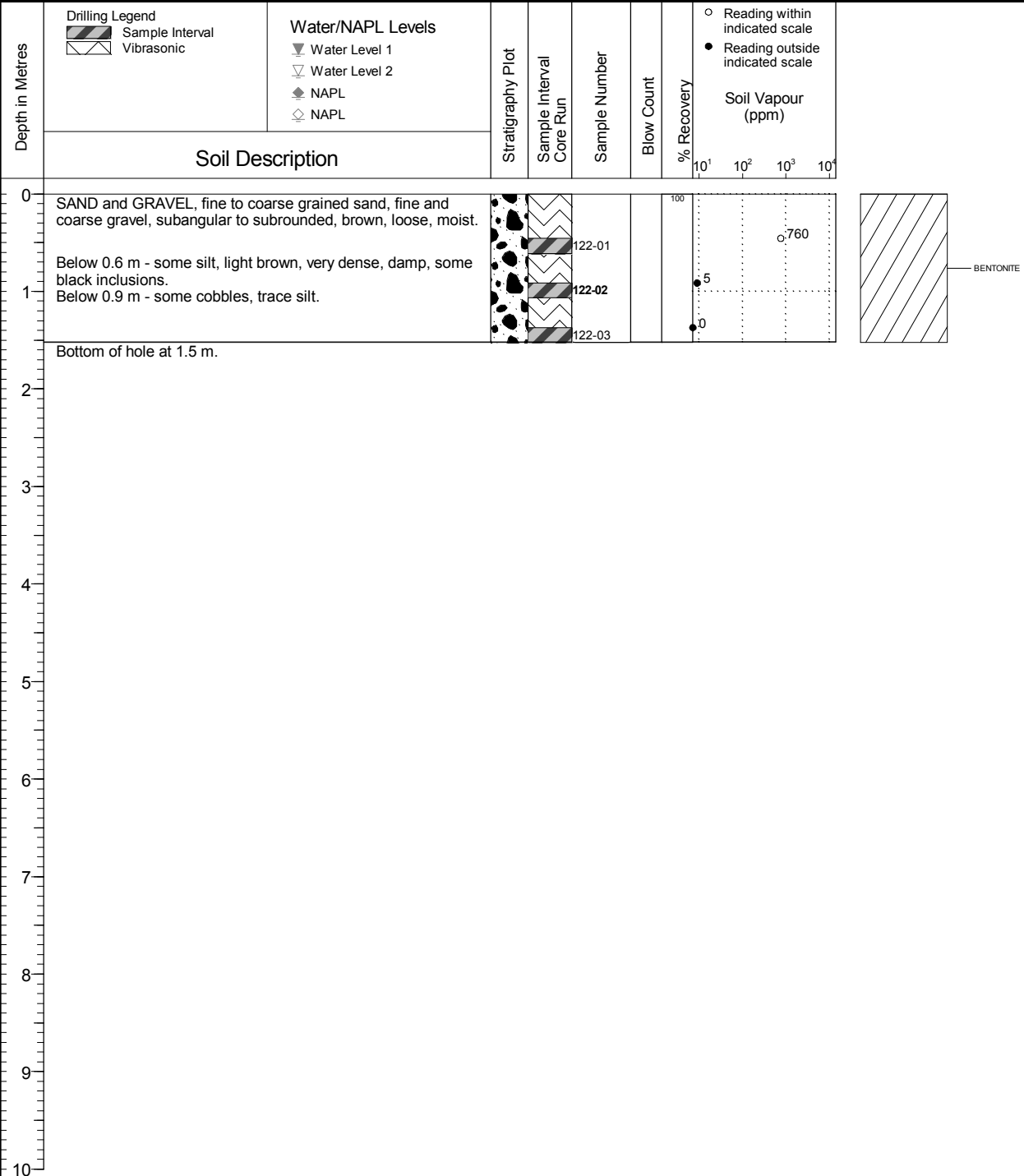
Borehole No. : BH16-122

PAGE 1 OF 1

Drilling Contractor Geotech Drilling Services Ltd.  
Drilling Method Vibratory Sonic  
Borehole Dia. (m) 0.10  
Pipe/Slotted Pipe Dia. (m) none/none

Date Monitored n/a  
Ground Surface Elev. (m) 707.339  
Top of Casing Elev. (m) n/a  
Northing: 6525427.436 Easting: 371058.777

Project Number: 635734  
Borehole Logged By: SJWM  
Date Drilled: 2016 05 28  
Log Typed By: NDS

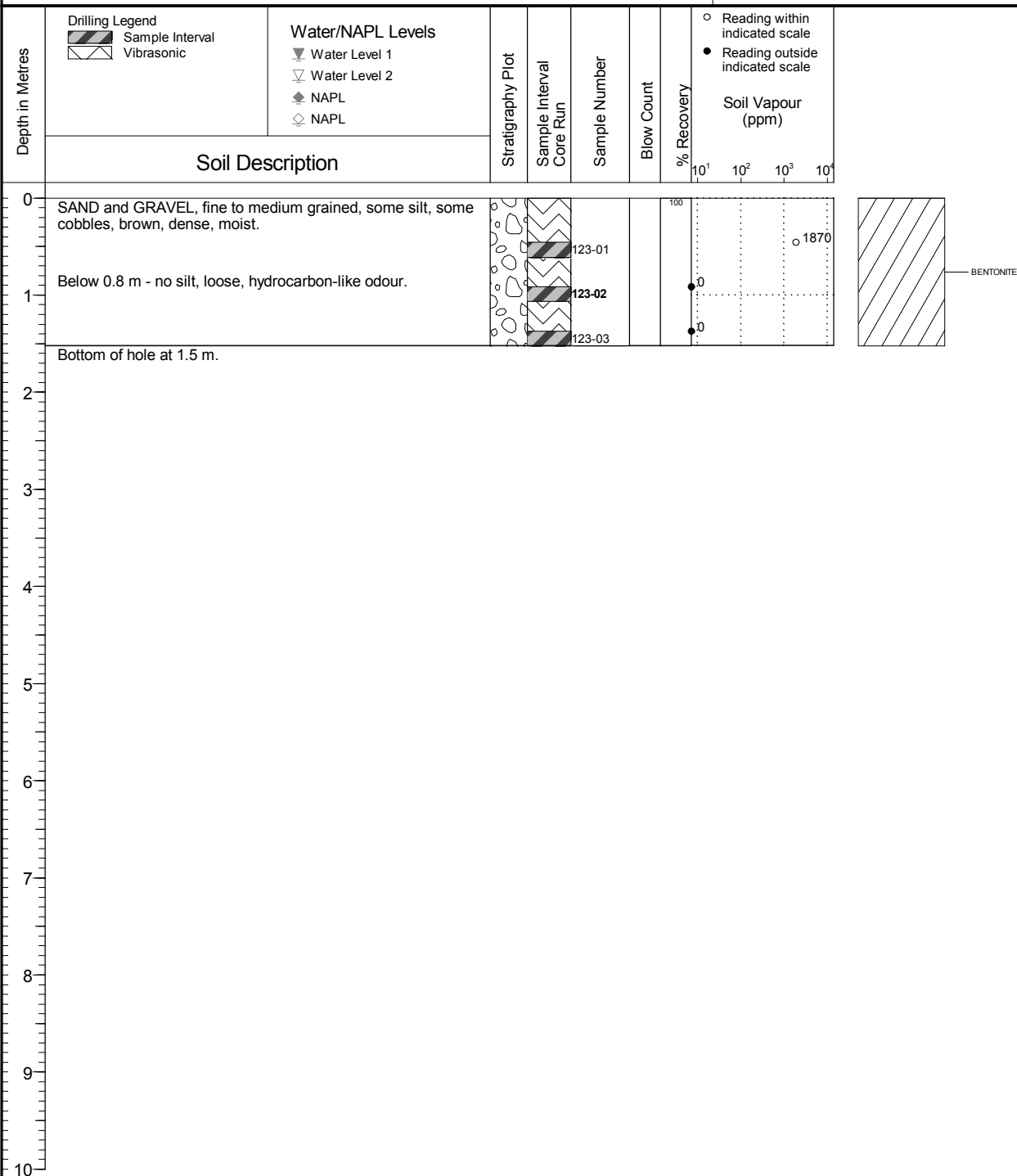


**NOTES**  
Bolded sample denotes sample analyzed.

Drilling Contractor: Geotech Drilling Services Ltd.  
Drilling Method: Vibratory Sonic  
Borehole Dia. (m): 0.10  
Pipe/Slotted Pipe Dia. (m): none/none

Date Monitored: n/a  
Ground Surface Elev. (m): 707.273  
Top of Casing Elev. (m): n/a  
Northing: 6525432.707 Easting: 371081.379

Project Number: 635734  
Borehole Logged By: SJWM  
Date Drilled: 2016 05 28  
Log Typed By: NDS



#### NOTES

Bolded sample denotes sample analyzed.



Client  
Public Works and Gov't Services Canada

Location  
Toad River Maintenance Camp, BC

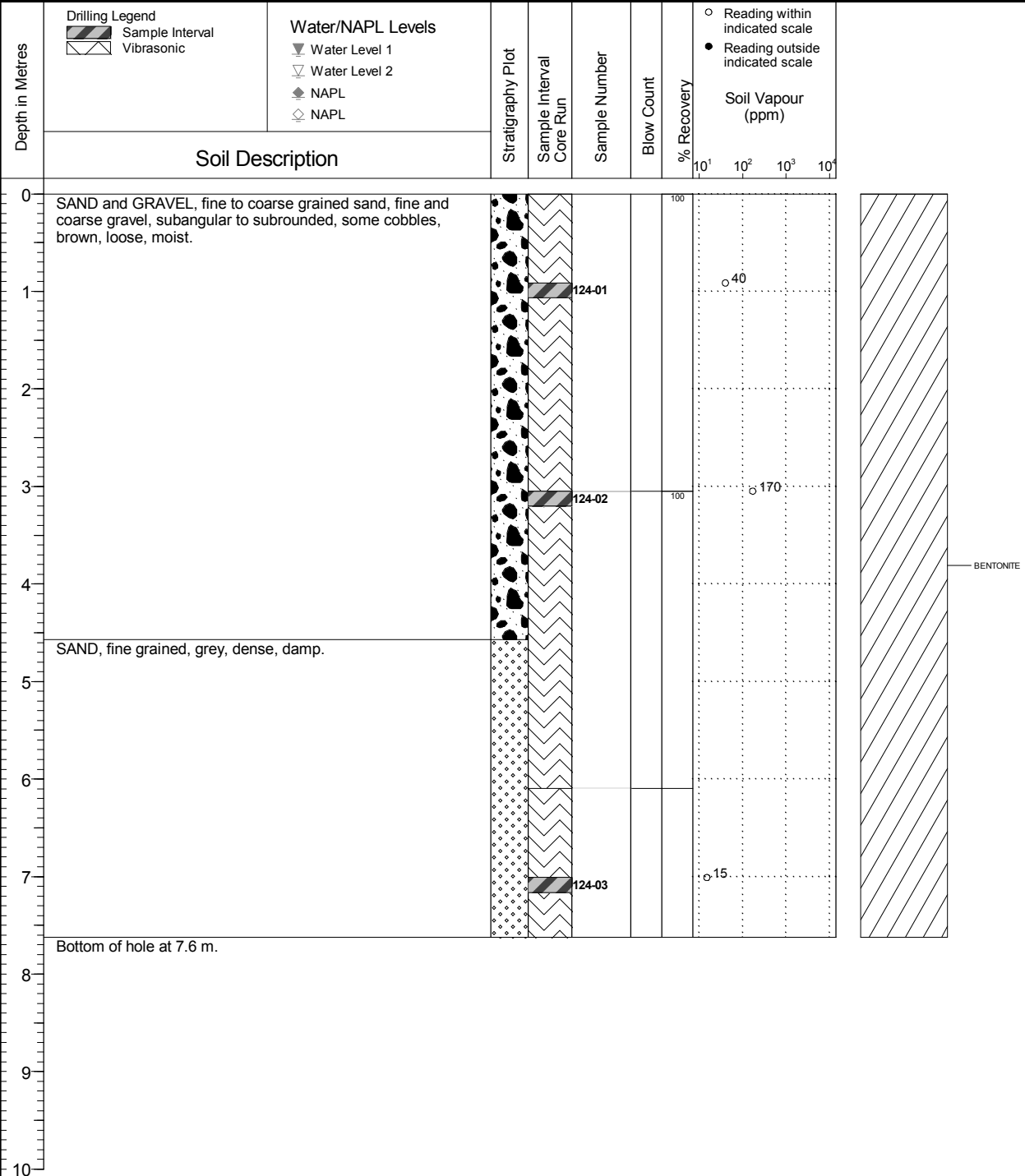
Borehole No. : BH16-124

PAGE 1 OF 1

Drilling Contractor Geotech Drilling Services Ltd.  
Drilling Method Vibratory Sonic  
Borehole Dia. (m) 0.10  
Pipe/Slotted Pipe Dia. (m) none/none

Date Monitored n/a  
Ground Surface Elev. (m) 709.229  
Top of Casing Elev. (m) n/a  
Northing: 6525466.661 Easting: 371066.576

Project Number: 635734  
Borehole Logged By: SJWM  
Date Drilled: 2016 05 28  
Log Typed By: NDS



#### NOTES

Bolded sample denotes sample analyzed.





Client  
Public Works and Gov't Services Canada

Location  
Toad River Maintenance Camp, BC

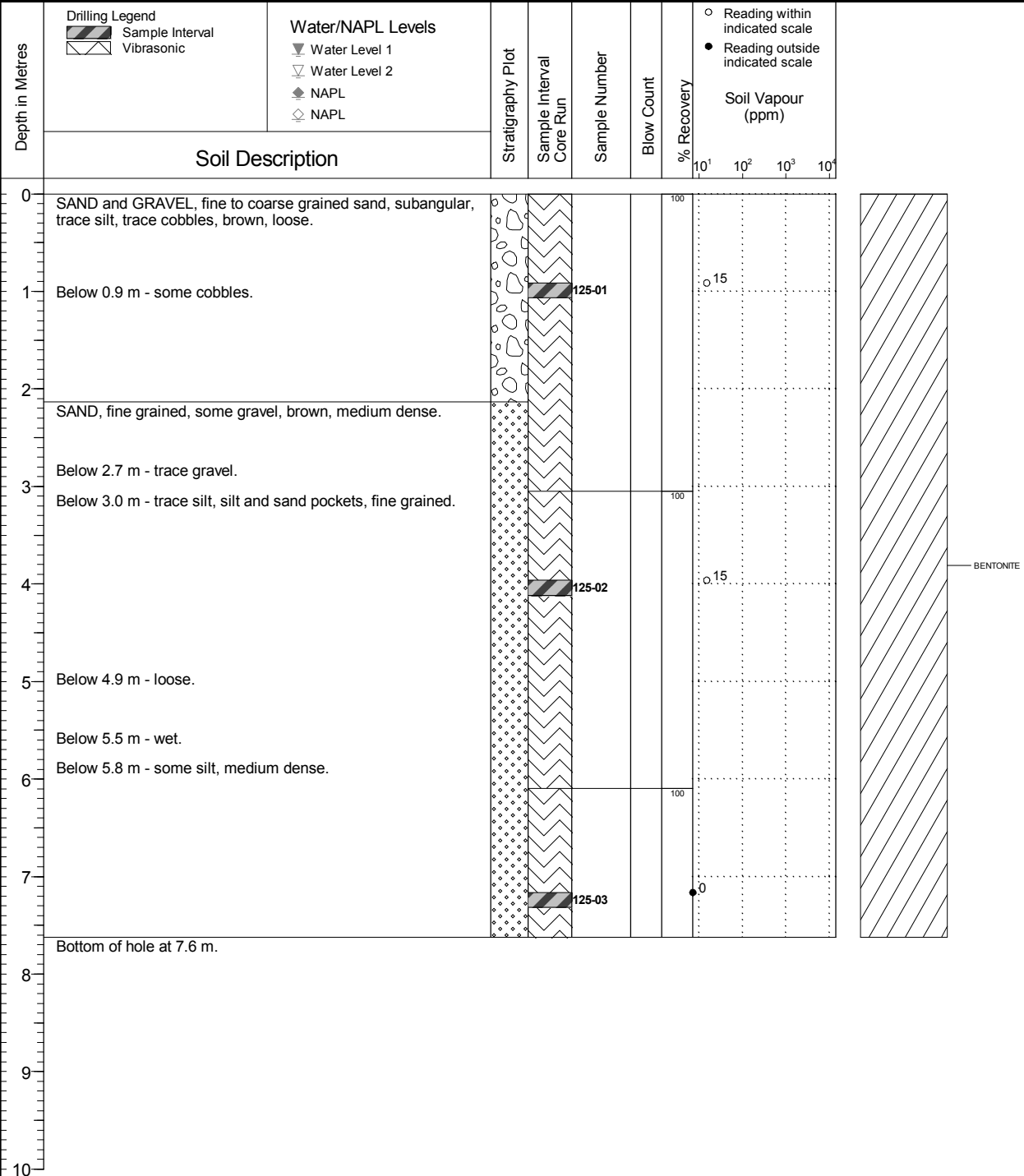
Borehole No. : BH16-125

PAGE 1 OF 1

Drilling Contractor Geotech Drilling Services Ltd.  
Drilling Method Vibratory Sonic  
Borehole Dia. (m) 0.10  
Pipe/Slotted Pipe Dia. (m) none/none

Date Monitored n/a  
Ground Surface Elev. (m) 708.224  
Top of Casing Elev. (m) n/a  
Northing: 6525456.326 Easting: 371065.740

Project Number: 635734  
Borehole Logged By: SJWM/ST  
Date Drilled: 2016 05 28  
Log Typed By: NDS



NOTES  
Bolded sample denotes sample analyzed.



Client  
Public Works and Gov't Services Canada

Borehole No. : BH16-126

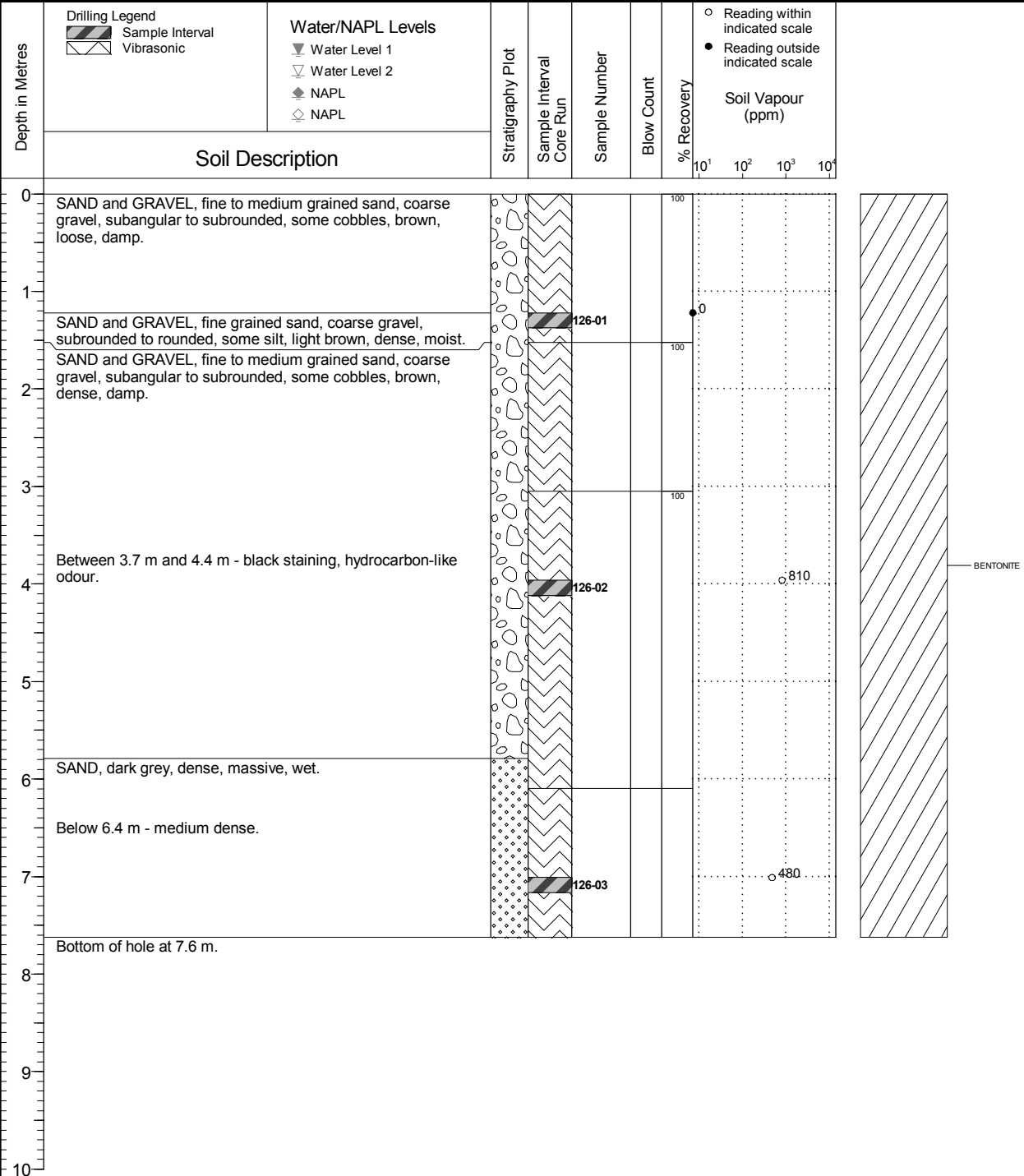
Location  
Toad River Maintenance Camp, BC

PAGE 1 OF 1

Drilling Contractor Geotech Drilling Services Ltd.  
Drilling Method Vibratory Sonic  
Borehole Dia. (m) 0.15  
Pipe/Slotted Pipe Dia. (m) none/none

Date Monitored n/a  
Ground Surface Elev. (m) 707.212  
Top of Casing Elev. (m) n/a  
Northing: 6525444.749 Easting: 371069.081

Project Number: 635734  
Borehole Logged By: SJWM  
Date Drilled: 2016 05 30  
Log Typed By: NDS



NOTES  
Bolded sample denotes sample analyzed.



Client  
Public Works and Gov't Services Canada

Location  
Toad River Maintenance Camp, BC

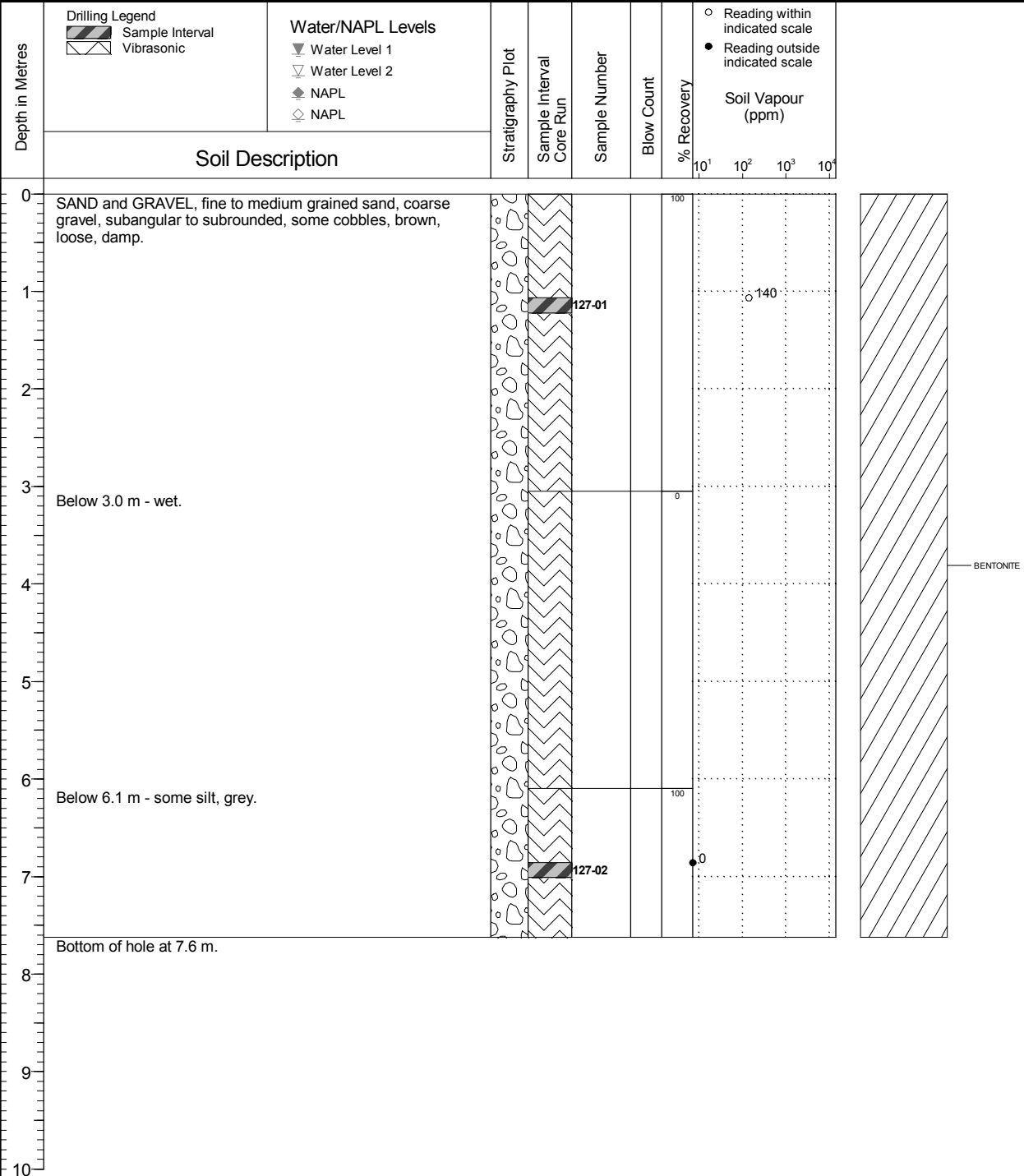
Borehole No. : BH16-127

PAGE 1 OF 1

Drilling Contractor Geotech Drilling Services Ltd.  
Drilling Method Vibratory Sonic  
Borehole Dia. (m) 0.15  
Pipe/Slotted Pipe Dia. (m) none/none

Date Monitored n/a  
Ground Surface Elev. (m) 707.186  
Top of Casing Elev. (m) n/a  
Northing: 6525456.705 Easting: 371077.099

Project Number: 635734  
Borehole Logged By: SJWM  
Date Drilled: 2016 05 30  
Log Typed By: NDS



NOTES

Bolded sample denotes sample analyzed.



Client  
Public Works and Gov't Services Canada

Borehole No. : BH16-128

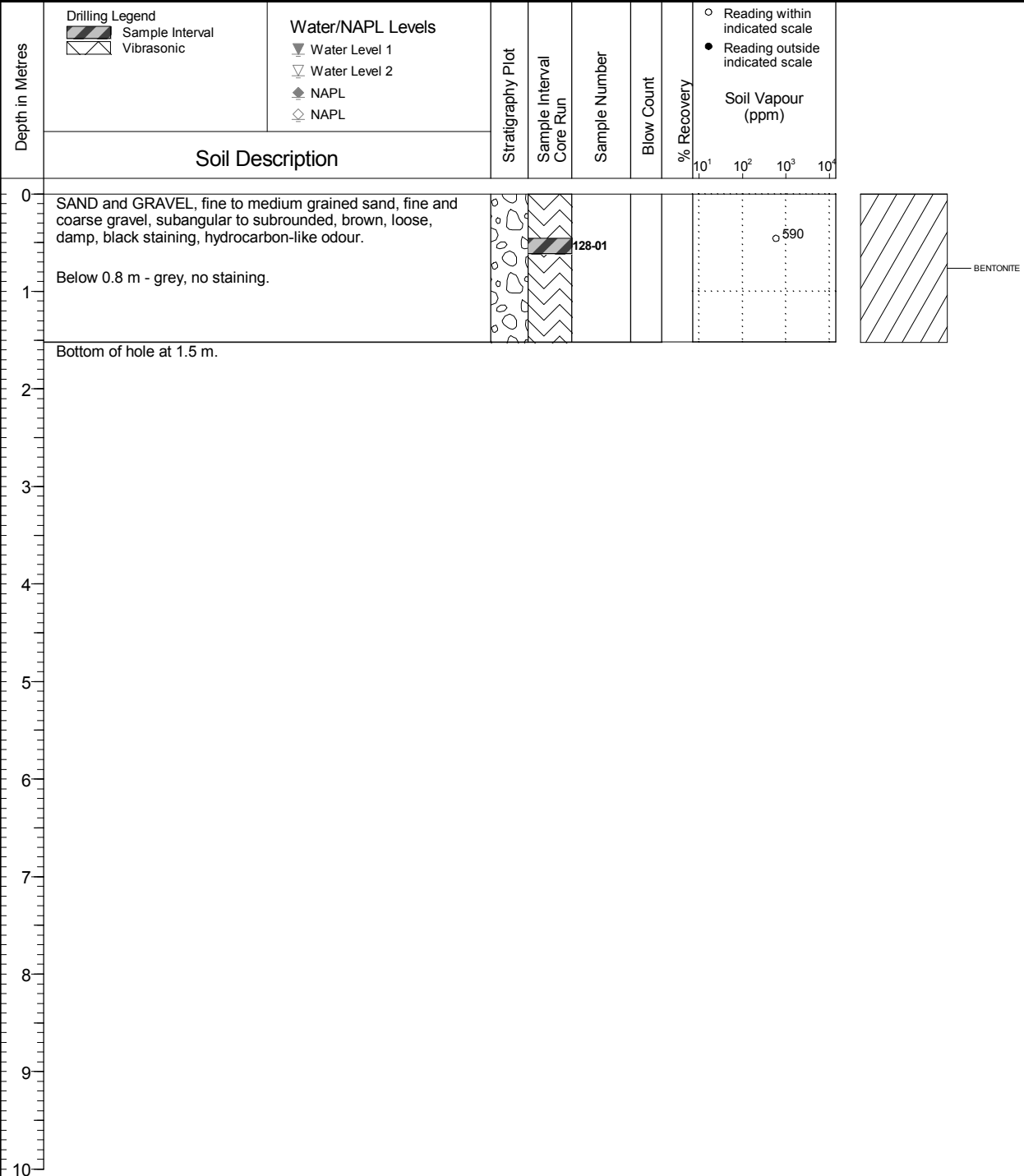
Location  
Toad River Maintenance Camp, BC

PAGE 1 OF 1

Drilling Contractor: Geotech Drilling Services Ltd.  
Drilling Method: Vibratory Sonic  
Borehole Dia. (m): 0.10  
Pipe/Slotted Pipe Dia. (m): none/none

Date Monitored: n/a  
Ground Surface Elev. (m): 707.068  
Top of Casing Elev. (m): n/a  
Northing: 6525448.186  
Easting: 371112.542

Project Number: 635734  
Borehole Logged By: SJWM  
Date Drilled: 2016 05 30  
Log Typed By: NDS





Client  
Public Works and Gov't Services Canada

Location  
Toad River Maintenance Camp, BC

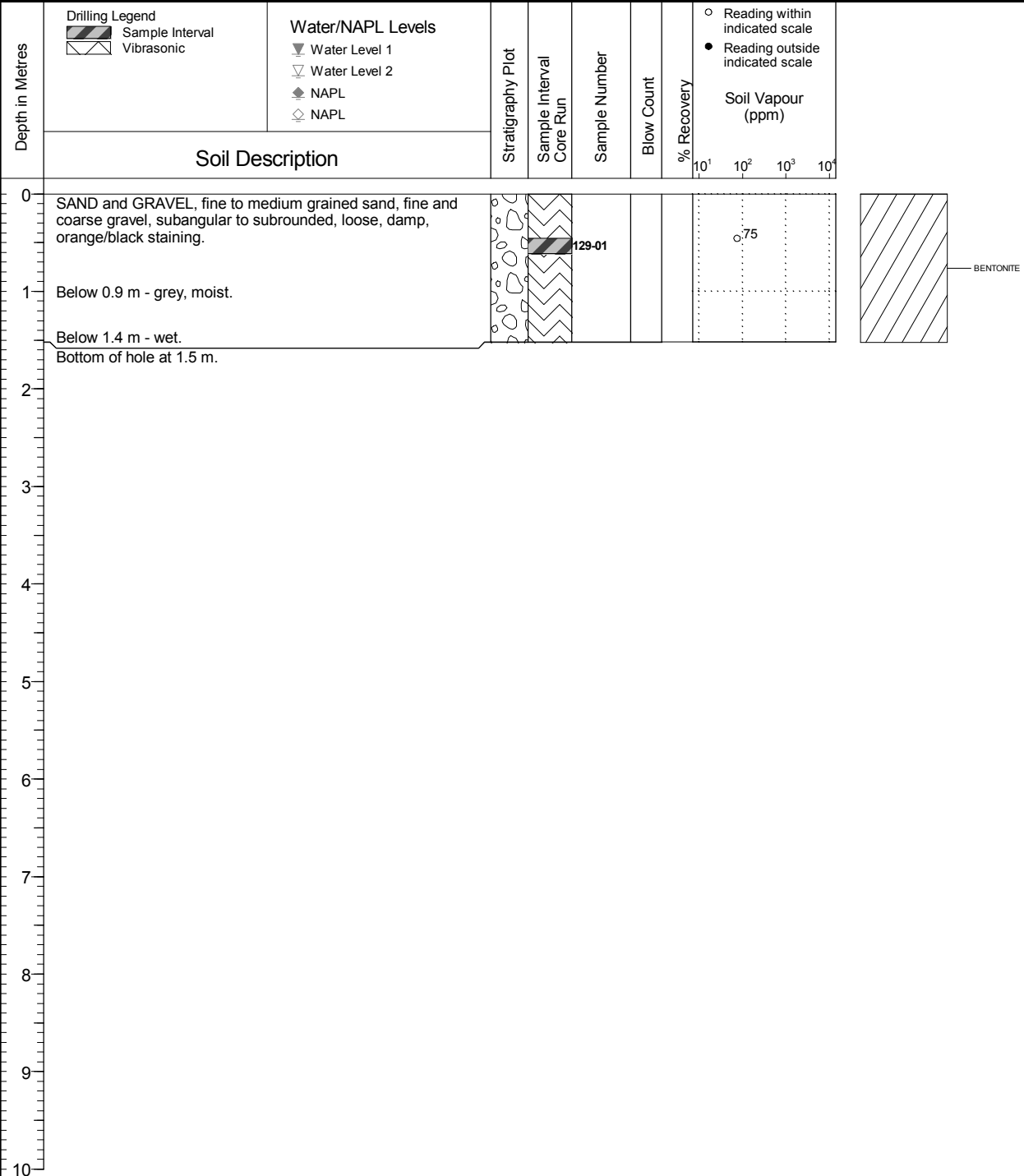
Borehole No. : BH16-129

PAGE 1 OF 1

Drilling Contractor: Geotech Drilling Services Ltd.  
Drilling Method: Vibratory Sonic  
Borehole Dia. (m): 0.10  
Pipe/Slotted Pipe Dia. (m): none/none

Date Monitored: n/a  
Ground Surface Elev. (m): 707.045  
Top of Casing Elev. (m): n/a  
Northing: 6525450.930  
Easting: 371107.202

Project Number: 635734  
Borehole Logged By: SJWM  
Date Drilled: 2016 05 30  
Log Typed By: NDS



**NOTES**

Bolded sample denotes sample analyzed.



Client  
Public Works and Gov't Services Canada

Location  
Toad River Maintenance Camp, BC

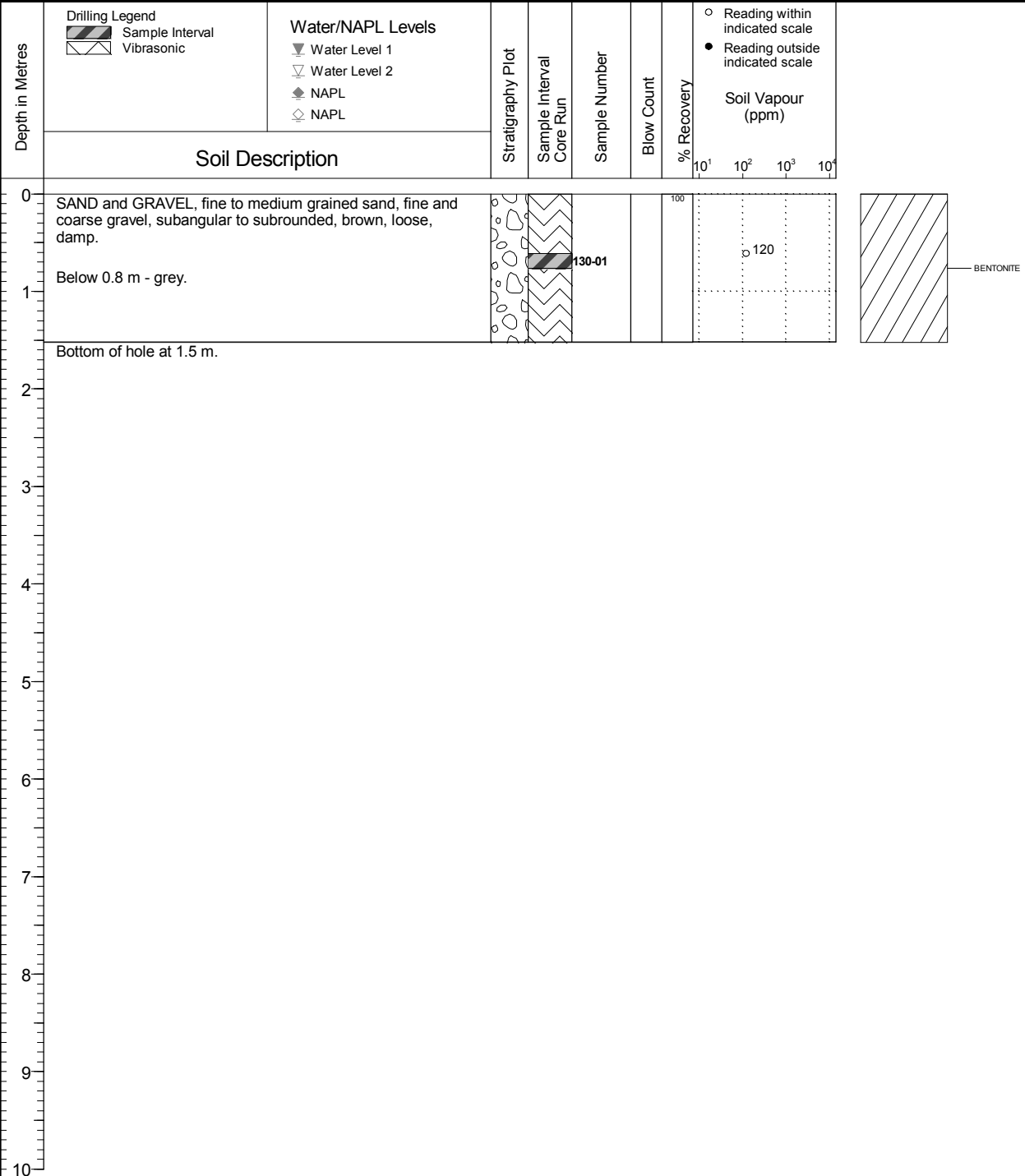
Borehole No. : BH16-130

PAGE 1 OF 1

Drilling Contractor: Geotech Drilling Services Ltd.  
Drilling Method: Vibratory Sonic  
Borehole Dia. (m): 0.10  
Pipe/Slotted Pipe Dia. (m): none/none

Date Monitored: n/a  
Ground Surface Elev. (m): 707.319  
Top of Casing Elev. (m): n/a  
Northing: 6525457.162 Easting: 371101.099

Project Number: 635734  
Borehole Logged By: SJWM  
Date Drilled: 2016 05 30  
Log Typed By: NDS



NOTES

Bolded sample denotes sample analyzed.



Client  
Public Works and Gov't Services Canada

Borehole No. : BH16-131

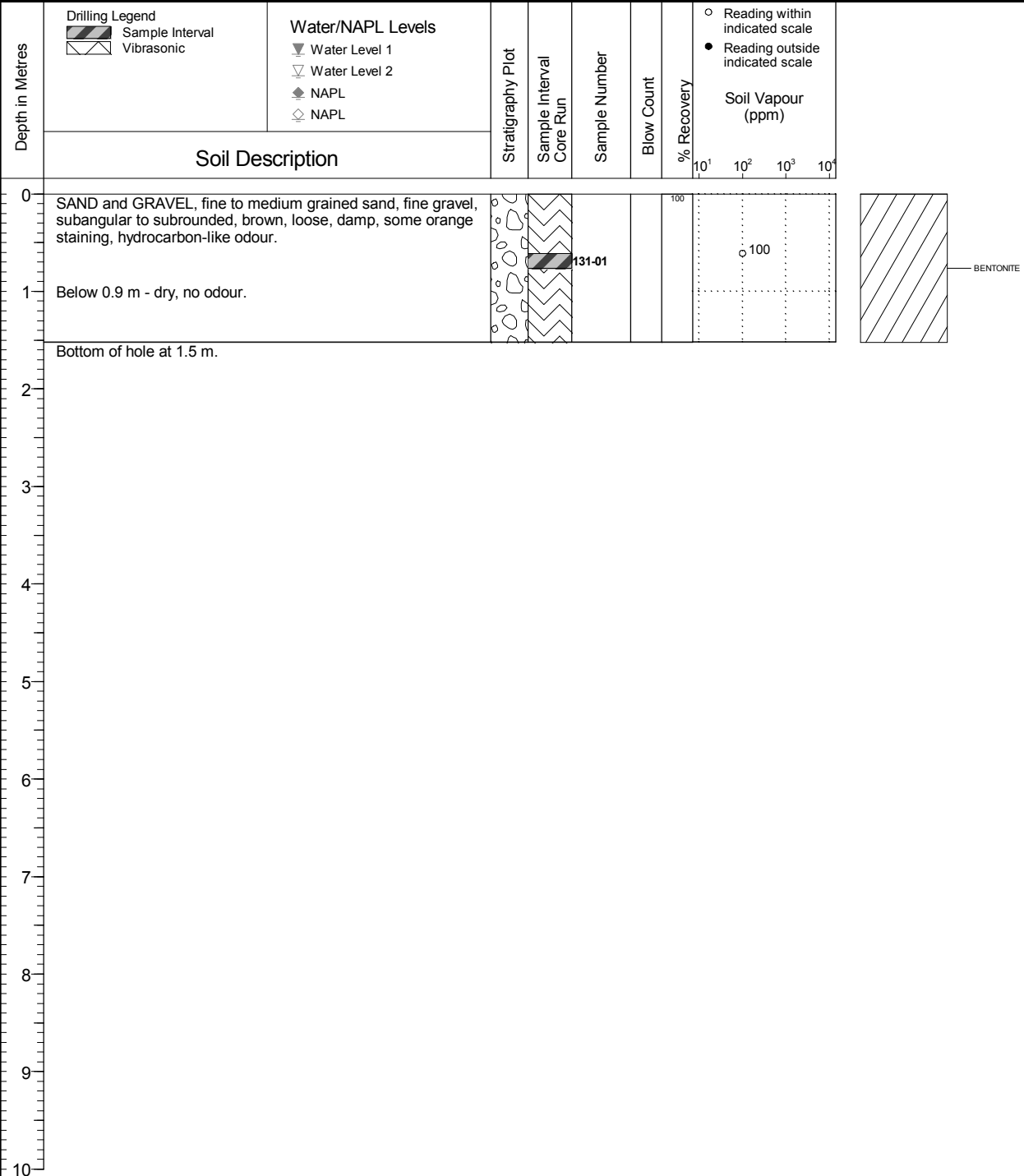
Location  
Toad River Maintenance Camp, BC

PAGE 1 OF 1

Drilling Contractor: Geotech Drilling Services Ltd.  
Drilling Method: Vibratory Sonic  
Borehole Dia. (m): 0.10  
Pipe/Slotted Pipe Dia. (m): none/none

Date Monitored: n/a  
Ground Surface Elev. (m): 707.784  
Top of Casing Elev. (m): n/a  
Northing: 6525370.844  
Easting: 371037.879

Project Number: 635734  
Borehole Logged By: SJWM  
Date Drilled: 2016 05 30  
Log Typed By: NDS



NOTES

Bolded sample denotes sample analyzed.



Client  
Public Works and Gov't Services Canada

Borehole No. : BH16-132

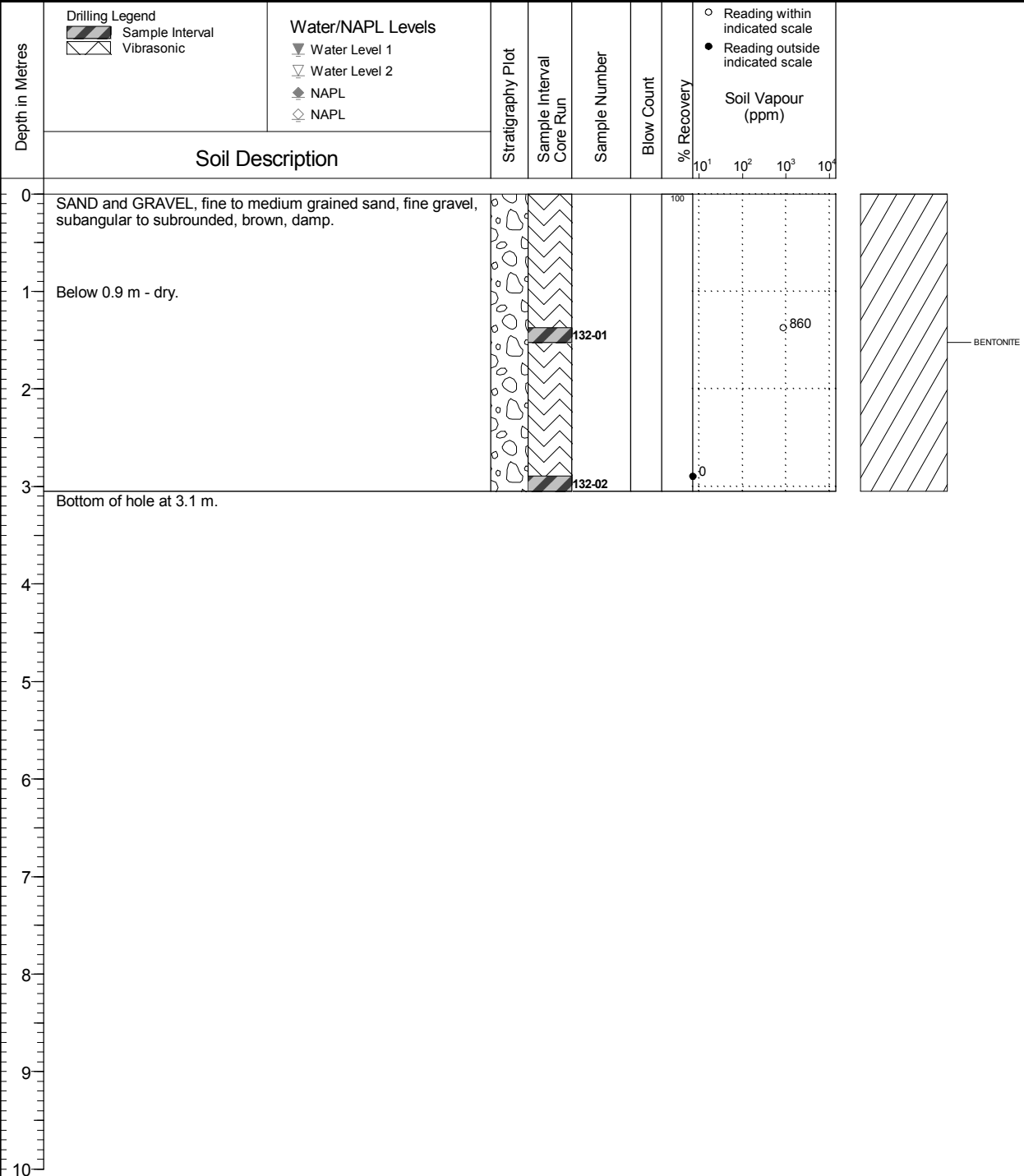
Location  
Toad River Maintenance Camp, BC

PAGE 1 OF 1

Drilling Contractor: Geotech Drilling Services Ltd.  
Drilling Method: Vibratory Sonic  
Borehole Dia. (m): 0.10  
Pipe/Slotted Pipe Dia. (m): none/none

Date Monitored: n/a  
Ground Surface Elev. (m): 707.665  
Top of Casing Elev. (m): n/a  
Northing: 6525366.202  
Easting: 371037.476

Project Number: 635734  
Borehole Logged By: SJWM  
Date Drilled: 2016 05 30  
Log Typed By: NDS



NOTES

Bolded sample denotes sample analyzed.





Client  
Public Works and Gov't Services Canada

Location  
Toad River Maintenance Camp, BC

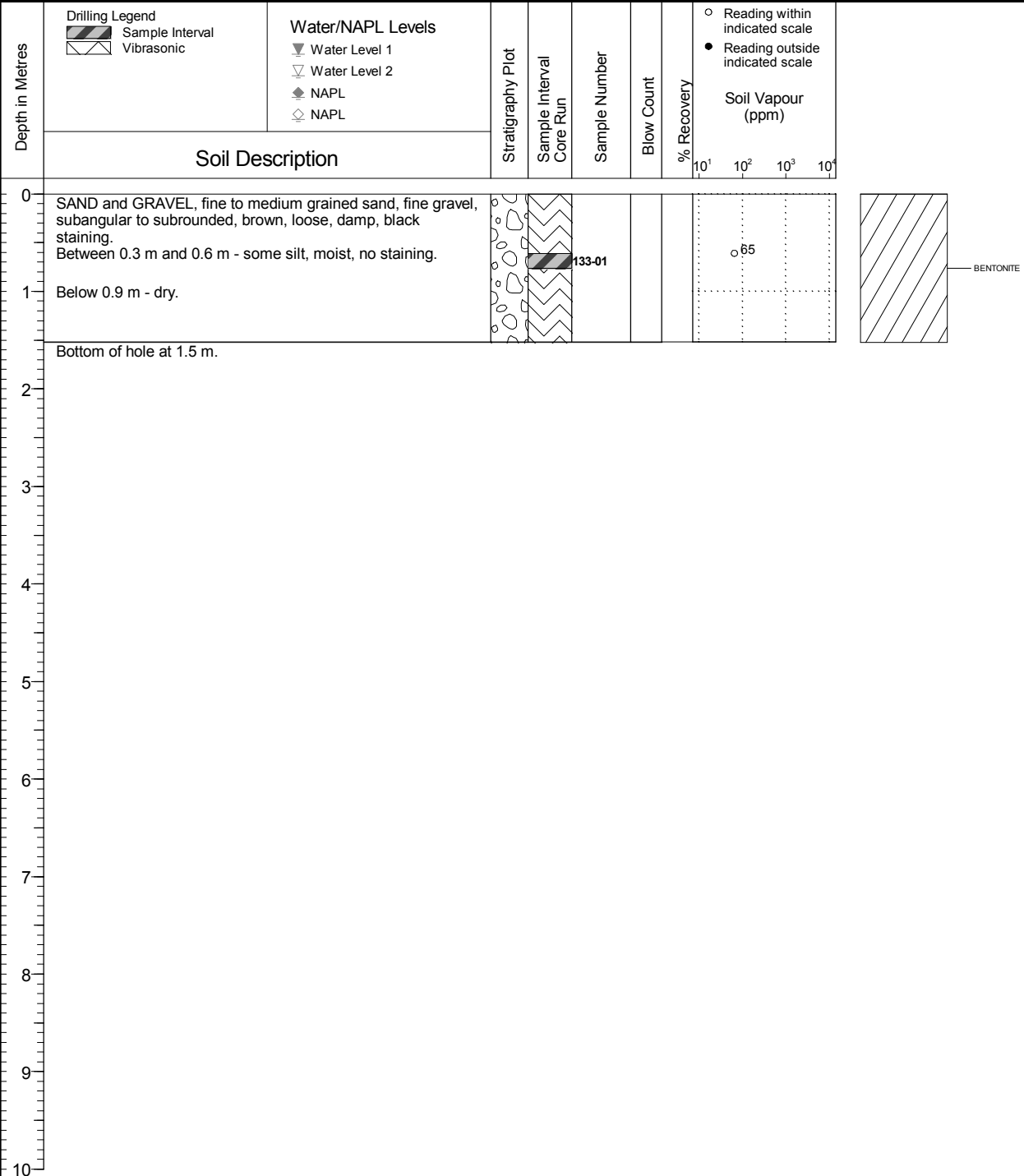
Borehole No. : BH16-133

PAGE 1 OF 1

Drilling Contractor Geotech Drilling Services Ltd.  
Drilling Method Vibratory Sonic  
Borehole Dia. (m) 0.10  
Pipe/Slotted Pipe Dia. (m) none/none

Date Monitored n/a  
Ground Surface Elev. (m) 707.616  
Top of Casing Elev. (m) n/a  
Northing: 6525364.215 Easting: 371032.964

Project Number: 635734  
Borehole Logged By: SJWM  
Date Drilled: 2016 05 30  
Log Typed By: NDS



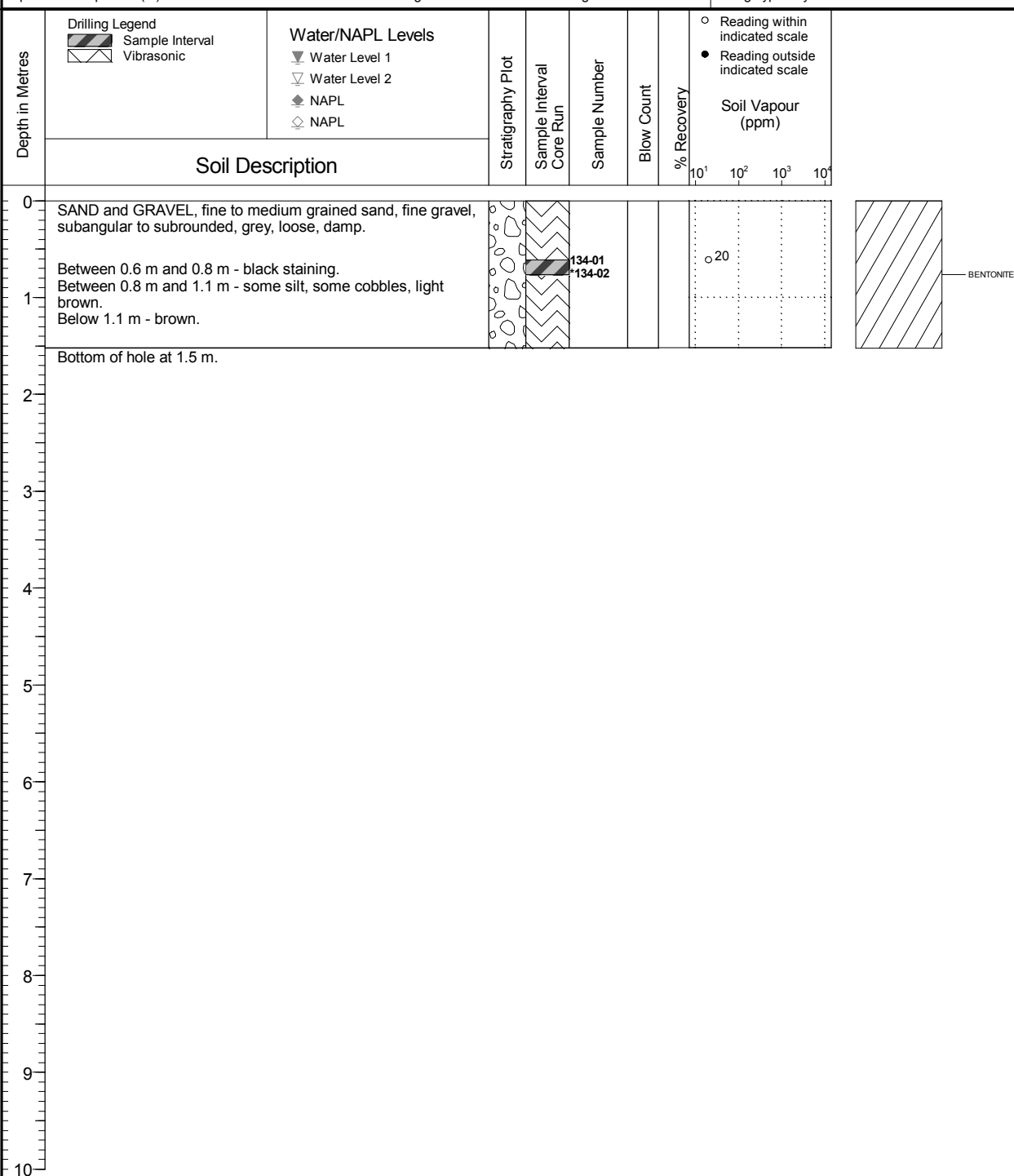
**NOTES**

Bolded sample denotes sample analyzed.

|                            |                                |
|----------------------------|--------------------------------|
| Drilling Contractor        | Geotech Drilling Services Ltd. |
| Drilling Method            | Vibratory Sonic                |
| Borehole Dia. (m)          | 0.10                           |
| Pipe/Slotted Pipe Dia. (m) | none/none                      |

|                          |                     |
|--------------------------|---------------------|
| Date Monitored           | n/a                 |
| Ground Surface Elev. (m) | 707.611             |
| Top of Casing Elev. (m)  | n/a                 |
| Northing: 6525363.276    | Easting: 371041.953 |

Project Number: 635734  
Borehole Logged By: SJWM  
Date Drilled: 2016 05 30  
Log Typed By: NDS



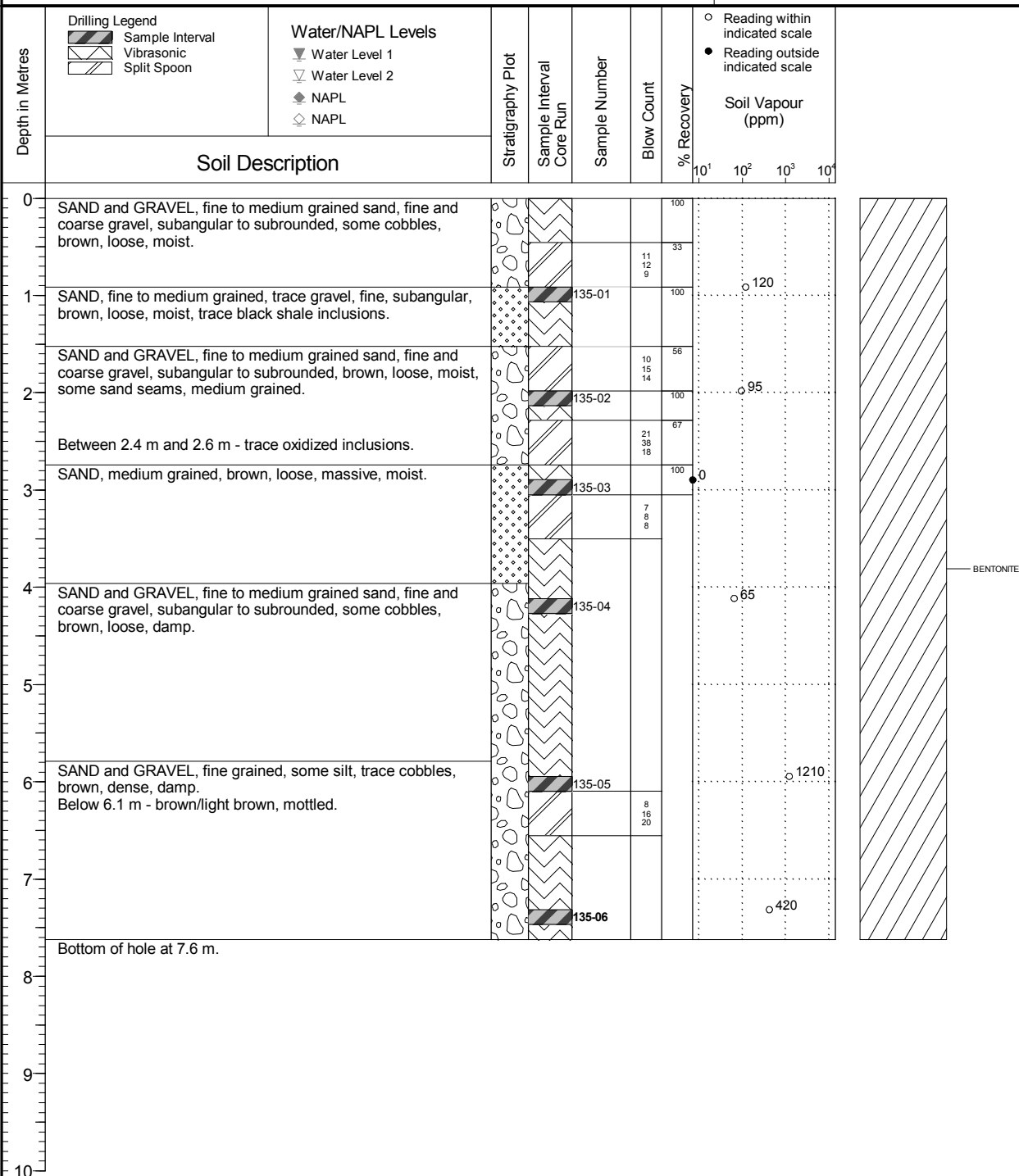
## NOTES

Bolded sample denotes sample analyzed. \*denotes blind field duplicate.  
134-02 is a blind field duplicate of 134-01.

Drilling Contractor Geotech Drilling Services Ltd.  
Drilling Method Vibratory Sonic  
Borehole Dia. (m) 0.15  
Pipe/Slotted Pipe Dia. (m) none/none

Date Monitored n/a  
Ground Surface Elev. (m) 707.285  
Top of Casing Elev. (m) n/a  
Northing: 6525423.970 Easting: 371083.585

Project Number: 635734  
Borehole Logged By: SJWM  
Date Drilled: 2016 05 30  
Log Typed By: NDS



#### NOTES

Bolded sample denotes sample analyzed.



929 Mattick's Wood Lane, Victoria, BC V8Y 3H6  
www.westrekgeotech.com

March 29, 2014  
Our File: 014-012

**Franz Environmental Inc.**  
308-1080 Mainland St  
Vancouver, BC  
V6B 2T4

Attention: Richard Wells, P.Eng., CSAP

Dear Sir,

**Re: Proposed Excavation Shoring Conceptual design  
Toad River Maintenance Camp  
Km 648.7 Alaska Highway, British Columbia**

---

## 1 Introduction

Subsurface contamination has been identified at the Toad River Maintenance Camp along the Alaska Highway and the proposed excavation will extend close to the existing maintenance building. At the request of Franz Environmental Inc. on behalf of Public Works and Government Services Canada (PWGSC), Westrek Geotechnical Services Ltd. (Westrek) completed a geotechnical investigation of the subsurface conditions adjacent to the existing maintenance building and assessed conceptual design options for shoring the proposed excavation.

The scope of this project is detailed in Westrek's "Proposed Scope and Budget Estimate" dated \_\_\_\_\_, 2014 and approved by \_\_\_\_\_.

## 2 Work Completed

### 2.1 Field Work

## 2.2 Conceptual Design

Based on the subsurface soil and groundwater conditions, various shoring options were assessed with respect to their suitability for the existing conditions. Detailed design work was not conducted at this stage because of the limited information regarding the building foundation and the general assumptions regarding the level of excavation.

## 2.3 Design Assumptions

The contaminated soils are located on the northwest side of the maintenance building. For the purpose of excavation design, Westrek was instructed by Franz to assume that the excavation will be 4 m deep and extend to 0.5 m from the outside edge of the maintenance building.

The building is a clear-span, steel frame, steel clad structure with a cast-in-place concrete slab-on-grade. The building is approximately 30 m long by 12.5 m wide. No information was available regarding the building's foundation and the frozen ground prevented Westrek from excavating alongside the building to determine the type of foundation. Photos provided by the client show round column footings on both sides of the equipment bay doorway, bearing directly on granular soils at about 0.3 m depth. At least one other steel column appears to bear on a small pad footing with minimal burial but the corner columns appear to be poorly supported at grade. The remainder of the steel cladding appears to rest on timber sills in direct contact with the granular soils, which has caused extensive decay.

## 2.4 Site Conditions

Based on the drilling results, the subsurface conditions along the northwest side of the building consist of loose to compact sand. The frozen ground hindered sampling and determination of the soil density in the upper 1.4 m but the upper 1.5 to 2.4 m appears to be gravelly sand overlying more uniform sand with just a trace of gravel. The deposit appears to be clean with less than 10% fines (silt and clay). Although Standard Penetration Test (SPT) results were variable, the upper 4 m appears to be mostly loose.

The sand deposit overlies compact to dense silty fine sand at 5.5 and 4.8 m depth in boreholes BH14-105 and W18-WGS-1, respectively. This denser, finer-grained deposit is assumed to be till. However, boreholes BH14-104 and W18-WGS-2 failed to encounter till and found bedrock at 5.0 and 6.2 m depth, respectively. Regardless, more competent bearing conditions are assumed to be between roughly 5 and 6 m depth.

Piezometers were not installed in any of these four boreholes but groundwater measurements in other boreholes on this property found water levels between 6 and 7 m depth in early March. The sand deposit is highly permeable and creates an unconfined aquifer perched on top of the till or bedrock. The groundwater level is assumed to be relatively consistent or level across this site; therefore, the seasonal water level is assumed to be below 5 m depth at present. The groundwater level is expected to rise during spring freshet and could affect the 4 m deep excavation.

## 3 Shoring Design Options

Several options for shoring were considered. The following options are potentially viable. Costing will depend on the contractors operating in Northeast BC and their available equipment.

These options are all based on the assumption that the excavation maintains at least a 0.5 m setback from the outside of the northwest edge of the building and extends no deeper than 4 m. Some options

allow the excavation to be deepened if necessary but none of the options allow for excavation closer to the building.

### **3.1 Tangent Pile Wall**

Tangent pile or contiguous caisson walls involve drilling large diameter holes, in the order of 900 mm wide, and filling them with low-strength concrete. The holes are drilled in stages and ultimately overlap approximately 150 mm to create a continuous wall. Given the loose granular soils at this site, the holes may have to be cased but the casing should be pulled as the concrete is poured. The caissons should be drilled to the top of the till or bedrock and could also serve as underpinning for the building foundation. With the caissons drilled through the entire thickness of the sand deposit, basal stability should not be a problem.

Considering the wall diameter and rigidity, only one row of soil anchors should be required for the 4 m deep excavation. Alternatively, the wall could be braced by rakers installed inside the excavation. If the excavation needs to be deepened to the top of the till layer, another row of anchors or rakers may be needed but the caissons will already be deep enough. The wall is constructed prior to excavation, then localized excavations are made to install the soil anchors or rakers prior to the bulk excavation.

The large diameter piles need to be structurally designed but typically require some internal reinforcement and walers (external horizontal member) that tie the anchors or rakers together.

The large diameter piles form a rigid wall and, because they are installed prior to excavation, cause minimal ground deformation beneath the building. Excess deformation occurs only if the excavation advances too far before installing the soil anchors or rakers.

### **3.2 Sheetpile Wall**

Sheetpiles are driven ahead of the excavation and should bear on the till or bedrock, similar to the caisson option. The excavation then proceeds in stages with soil anchors installed at the appropriate depth as the excavation proceeds. Like the caisson option, basal stability should not be a problem because the sheetpiles bear on till or rock, and the excavation can be deepened if needed if an additional row of soil anchors is installed.

Unlike the caisson option, sheetpiles are much more flexible and some lateral deformation should be anticipated, causing settlement behind the wall. The building will require separate underpinning prior to shoring. The underpinning will support the building foundation but settlement could still cause cracking of the slab-on-grade.

Installation of the sheetpiles just 0.5 m away from the building could be problematic. Ground vibrations could damage to foundations and the pile driving head may require greater offset.

### **3.3 H-Piles & Lagging**

H-piles are driven to refusal, which should be slightly into the till or bedrock. Spacing can range from 1.5 to 2.5 m depending on design loads and the size of the H-piles. The H-piles are usually restrained laterally by diagonal supports or rakers. The rakers themselves must also be supported by either large footings or possibly helical piles. Another option is to laterally support the H-piles using soil anchors drilled beneath the building.

After the H-piles are installed, the excavation proceeds in shallow lifts and the lagging is installed after each lift. The depths of each lift should be quite shallow because the loose sand will tend to ravel

considerably, causing lateral movement and the loss of soil beneath the building. The voids behind the lagging must be filled after construction. The void beneath the slab-on-grade will likely have to be filled by low-pressure grouting.

The building should be underpinned prior to the excavation or the H-piles can be designed (and supported laterally) to support the building loads. However, lateral movement in loose sand can be significant and could damage the building. Failures often occur within the loose sand between the H-piles.

Toe support at the base of the H-piles is critical. If the excavation must be deepened to the surface of the till or bedrock, toe support could be compromised, requiring another row of rakers anchored into the bedrock.

Like the sheetpile option, installation of H-piles 0.5 m off back from the building could be problematic with respect to vibrations and the space required by the equipment.

### **3.4 Shotcrete & Anchors**

The excavation could be supported by shotcrete and anchors; however, loose sand can be difficult to support. The excavation would have to proceed in small stages, perhaps less than 2 m wide by 1 m deep. Each stage would have to be supported with shotcrete and anchors prior to excavating the adjacent section. This process can be time-consuming because of the small sections or panels required in loose sand. Any small failure that occurs prior to shotcreting compromises the stability of the building.

The shotcrete should be reinforced with wire-mesh and sleeves cast-in-place where the anchors are to be installed. The capacity of grouted soil anchors in loose sand is limited and the anchors must strain to develop the required resistance, causing lateral movement behind the shotcrete. The capacity of tremie-grouted anchors is quite low in the loose sand and requires a very tight spacing (in the range of 1 m o/c). Pressure-grouted anchors can create much greater capacity in the loose sand but often require multiple stages of grouting. Meanwhile, the shotcrete remains under-supported until the anchors are installed and tensioned; therefore, adjacent panels cannot proceed in a timely manner. Given the wide variation in anchor pullout resistance, a high frequency of pullout tests is recommended.

Helical anchors or expanding plate anchors (i.e. Manta-Ray) can provide much greater resistance and can be tensioned and locked off to reduce the amount of strain immediately after installation. Capacities depend on the length of the anchor and the size of the head or helix. These anchors are more expensive than typical soil anchors but cause much less delays during construction.

The shotcrete cannot extend below the base of the excavation; therefore, basal failures could be a significant hazard if the groundwater level is close to the base of the excavation. Dewatering below the base of the excavation may be required.

This option is likely the most problematic given the soil conditions at this site.

## **4 Lateral Earth Pressures**

Lateral earth pressures will vary for each of the design options above, depending on the rigidity of the system, the location and number of supports (i.e. anchors, rakers, or lateral bracing), the wall thickness, and the amount of movement permitted. Earth pressures must be determined during detailed design for the selected method of shoring.

## 5 Underpinning

Depending on the shoring design option and the acceptable level of both lateral and vertical displacement, the building's foundation may have to be underpinned to the till or bedrock layer prior to shoring. The concrete tangent pile wall and the H-piles can be designed to support the building loads directly; however, the shotcrete and anchor option, and possibly also the sheetpile option, require separate underpinning.

Underpinning requires that the building loads extend down to below at least 5 m depth. Micropiles, consisting of a Gewi-pile (by Dywidag) or other similar steel anchor system, could be drilled into the bedrock and then grouted. Another option would be screw piles or helical piles drilled to the base of the sand deposit. However, given the depth to bedrock, micro-piles drilled into bedrock are expected to be more cost-effective than helical piles.

Design of the underpinning requires more information regarding the existing foundations. Unless specific design information is available, further investigation is warranted once the ground has thawed. Test pits should be excavated alongside the existing foundation to determine the depth of bearing and the height and thickness of the existing footings. However, available photos show undersized footings (or possibly a lack of footings) with inadequate burial. The existing foundations do not appear to meet current design standards.

If the existing foundation were adequate, underpinning would involve installing micropiles at each building column, as close as possible to the existing footing. A small pile cap would then be formed and tied into the existing footing or directly beneath the footing. Lateral support for the underpinning should be provided by the shoring design (i.e. by incorporating soil anchors or rakers at each column). However, based on the apparent lack of a proper foundation, the pile caps will have to be enlarged and used to directly support the steel columns. A grade beam may also be required to run the length of the building to tie together all of the column footings.

## 6 Conclusions

The loose sand creates unfavourable conditions for shoring, particularly if groundwater levels are higher at the time of excavation. Uncertainties normally associated with contaminant excavations and the apparent inadequacies of the existing building foundation compound the unfavourable conditions at this site. Given these conditions, a tangent pile wall is the preferred shoring option because it is a more rigid system than the others. The large diameter piles could also be incorporated into the building underpinning. Further investigation is required for detailed design. Detailed design will also require a structural engineer to design the internal reinforcement.

Given the costs and challenges associated with shoring and underpinning at this remote site, coupled with the apparent lack of a proper building foundation, consideration should be given to moving the building. The building could be dismantled and reconstructed after soil remediation is completed or reconstructed elsewhere on site. Reconstruction would allow the apparent problems with the foundation to be remedied. This option is particularly attractive if there is a possibility that the contaminated soils may extend beneath the building.

## 7 Limitations

This study is intended for use by Franz Environmental Inc. and PWGSC. **No other party may rely upon this report without the expressed written permission of Westrek.** The services provided by Westrek



are subject to the terms and conditions contained in the attached Interpretation and Use of Study and Report & Limitations of Liability document.

If there are any questions please contact the undersigned.


Yours truly,

**Westrek Geotechnical Services Ltd.**

Eric McQuarrie, P.Eng.  
*Senior Geotechnical Engineer*

Timothy Smith, P.Geo., Eng.L  
*Senior Engineering Geologist*

Enc:     Appendix A: Interpretation and Use of Study and Report & Limitations of Liability  
          Appendix B: Borehole Logs and Figures.

|                     |       |                         | <b>DRAFT LOG OF BOREHOLE No. W18-WGS-1</b>                            |  |   |
|---|-------|-------------------------|---|--|---|
|   |       |                         | Toad River Maintenance Camp km 648.7 Alaska Highway<br>Toad River, BC |  |   |
| LOGGED:   | Jpsio | DRAWN:                  | Jpsio   | Project No. 014-012  |   |
| <b>TEST RESULTS</b><br>● - SPT (N-value) ▲ - DCPT (60° cone)<br>◆-◇◇ PL - WN - LL (water content %) |       | DEPTH<br>(m)<br>(Elev.) | SOIL SYMBOL   | Drilling Type: Odex  | CONDITION<br>TYPE<br>Corrected N<br>WATER LEVEL<br>OTHER TESTS<br>DEPTH SCALE |
|   |       |                         |   | Co-ordinate: See site map  |   |
|   |       |                         |   | Elevation (m): 9.8 Datum: Floor slab (10m)   |   |
|   |       |                         |   | <b>SOIL DESCRIPTION</b>  |   |
| 0 50 100  |       |                         |   | <b>SAND</b> , medium to coarse grained, subangular; and gravel, fine grained, subrounded to subangular; trace fines; max. size = 15 mm; compact; light brown; possible fill. |   |
| 0.0   |       |                         |   | ...frozen to at least 1.4 m.   |   |
| 1.0   |       |                         | <b>SW</b>   | Refusal (frozen)   | 1   |
| 2.0   |       |                         |   |  | 2   |
| 2.4 (7.4)   |       |                         |   |  |   |
| 3.0   |       |                         | <b>SP</b>   | D SS 9   | 3   |
| 4.0   |       |                         |   |  | 4   |
| 4.1 (5.7)   |       |                         |   |  |   |
| 4.8 (5.0)   |       |                         | <b>SW</b>   | D SS 18  | 5   |
| 5.0   |       |                         |   |  | 6   |
| 6.0   |       |                         |   |  | 7   |
| 7.0   |       |                         | <b>SM</b>   | D SS 32  | 8   |
| 8.0   |       |                         |   |  | 9   |
| 8.8 (1.0)   |       |                         |   |  |   |
| 9.0   |       |                         |   |  |   |
| 10.0  |       |                         |   |  |   |
| <b>NOTES:</b> Water table at 6.5 m, based on soil observations.                                     |       |                         |   |  | SHEET 1 of 10   |



# DRAFT LOG OF BOREHOLE No. BH14-105

Toad River Maintenance Camp km 648.7 Alaska Highway

Toad River, BC

|   |  |               |                         |   |   |                     |           |      |             |             |             |             |   |
|---|--|---------------|-------------------------|---|---|---------------------|-----------|------|-------------|-------------|-------------|-------------|---|
| LOGGED: Jpisio  |  | DRAWN: Jpisio |                         | Drilling Date: 06-Mar-14  |   | Project No. 014-012 |           |      |             |             |             |             |   |
| <b>TEST RESULTS</b><br>● - SPT (N-value) ▲ - DCPT (60° cone)<br>◆-◇◇ PL - WN - LL (water content %)   |  |               | DEPTH<br>(m)<br>(Elev.) | SOIL SYMBOL   | Drilling Type: Odex   |                     | CONDITION | TYPE | Corrected N | WATER LEVEL | OTHER TESTS | DEPTH SCALE |   |
|   |  |               |                         |   | Co-ordinate:  |                     |           |      |             |             |             |             |   |
|   |  |               |                         |   | Elevation (m): 9.9 Datum: Floor slab (10m)  |                     |           |      |             |             |             |             |   |
|   |  |               |                         |   | <b>SOIL DESCRIPTION</b>   |                     |           |      |             |             |             |             |   |
| <div>0 50 100</div> <div>0.0</div> <div>1.0</div> <div>2.0</div> <div>3.0</div> <div>4.0</div> <div>5.0</div> <div>6.0</div> <div>7.0</div> <div>8.0</div> <div>9.0</div> <div>10.0</div> |  |               | SW                      | SAND, medium to coarse grained, subangular; and gravel, fine grained, subangular; trace fines; max. size = 10 mm; light brown; frozen; likely fill.   |   |                     |           |      |             |             |             | 1           |   |
|   |  |               |                         | SAND, medium grained, subangular to angular, sand; loose to compact; brown; frozen; 0.1 m thick silty fine sand lense at 1.6 m. ...moist below 2.3 m. |   | (frozen)            |           |      |             |             |             | 2           |   |
|   |  |               |                         |   |   | D                   | SS        | 16   |             |             |             |             |   |
|   |  |               |                         |   |   | D                   | SS        | 7    |             |             |             |             |   |
|   |  |               |                         | SP  | SAND, subangular to angular; some gravel, subrounded to subangular; trace fines; compact; brown; moist.   |                     | D         | SS   | 16          |             |             |             | 4 |
|   |  |               |                         |   | TILL, silty fine sand; some gravel, fine grained, sub-rounded to subangular; max. size = 15 mm; compact to dense; low plasticity; brown; moist. ...trace fine gravel below 6.0 m; max. size = 5 mm. |                     | D         | SS   | 17          |             |             |             | 5 |
|   |  |               |                         |   |   |                     | D         | SS   | 22          |             |             |             | 6 |
|   |  |               |                         | SM  | ...wet below 7.1 m.   |                     | D         | SS   | 22          |             |             |             | 7 |
|   |  |               |                         |   |   |                     | D         | SS   | 17          |             |             |             |   |
|   |  |               |                         |   | Borehole terminated at 8.2 m in TILL.   |                     | D         | SS   | 41          |             |             |             | 8 |
|   |  |               |                         |   |   |                     |           |      | 9           |             |             |             |   |

NOTES: Water table at 7.1 m, based on soil observations.



**DRAFT LOG OF BOREHOLE No. W18-WGS-2**

Toad River Maintenance Camp km 648.7 Alaska Highway

Toad River, BC

|   |              |   |   |                     |           |      |             |             |             |             |   |
|---|--------------|---|---|---------------------|-----------|------|-------------|-------------|-------------|-------------|---|
| LOGGED: Jpiso   | DRAWN: Jpiso | Drilling Date: 07-Mar-14                  | Project No. 014-012   |                     |           |      |             |             |             |             |   |
| <b>TEST RESULTS</b><br>● - SPT (N-value) ▲ - DCPT (60° cone)<br>◆-◇◇ PL - WN - LL (water content %)   |              | DEPTH (m) (Elev.)                         | SOIL SYMBOL   | Drilling Type: Odex | CONDITION | TYPE | Corrected N | WATER LEVEL | OTHER TESTS | DEPTH SCALE |   |
|   |              | Co-ordinate:                              |   |                     |           |      |             |             |             |             |   |
|   |              | Elevation (m): 10 Datum: Floor slab (10m) |   |                     |           |      |             |             |             |             |   |
|   |              | <b>SOIL DESCRIPTION</b>                   |   |                     |           |      |             |             |             |             |   |
| <div>0 50 100</div> <div>0.0<br/>1.0<br/>2.0<br/>2.4 (7.6)<br/>3.0<br/>4.0<br/>4.1 (5.9)<br/>5.0<br/>5.8 (4.2)<br/>6.0<br/>6.2 (3.8)<br/>7.0<br/>8.0<br/>9.0<br/>10.0</div> |              | SW  | <b>SAND</b> , medium to coarse grained, subangular; gravelly, fine grained, subangular to subrounded; trace fines; max. size = 15 mm; brown.<br><br>...at least 0.2 m layer of silty sand at 1.4 m.<br>...frozen to at least 1.5 m. |                     |           |      |             |             | 1           |             |   |
|   |              |   |   |                     |           |      |             |             |             | 2           |   |
|   |              |   |   |                     |           |      |             |             |             |             | 3 |
|   |              |   |   |                     |           |      |             |             |             |             | 4 |
|   |              |   |   |                     |           |      |             |             |             |             | 5 |
|   |              |   |   |                     |           |      |             |             |             |             | 6 |
|   |              |   |   |                     |           |      |             |             |             |             | 7 |
|   |              |   |   |                     |           |      |             |             |             |             | 8 |
|   |              |   |   |                     |           |      |             |             |             |             | 9 |
|   |              |   |   |                     |           |      |             |             |             |             |   |
| NOTES:  |              | SHEET 1 of 10                             |   |                     |           |      |             |             |             |             |   |

## Appendix E

### **Sieve Analysis Reports**



**McElhanney**

Report of:

Client: Franz Enviromental Inc.

## Grain Size Analysis

Project No: 2211-80037-9

Project: Alaska Highway

Sample Date: 11-Oct-08

Sample By: Client

Test Date: 21-Oct-08

Tested By: ME

### SAMPLE INFORMATION:

Material Type: Gravelly SAND; some silt

Source: Stockpile - Bucket 1 of 3

Specification: N/A

Sample Location: Toad River

Sample No: 5

Moisture Content: 7.1%

Fracture: N/A

Washed Sieve: ☒

Dry Sieve: ☐

| Sieve Analysis |           |           |            |
|----------------|-----------|-----------|------------|
| Sieve (mm)     | % Passing | Low Spec. | High Spec. |
| 100.0          |           |           |            |
| 75.0           |           |           |            |
| 50.0           | 100.0     |           |            |
| 37.5           | 98.5      |           |            |
| 25.0           | 95.5      |           |            |
| 19.0           | 91.8      |           |            |
| 12.5           | 80.7      |           |            |
| 9.50           | 73.0      |           |            |
| 4.75           | 60.7      |           |            |
| 2.00           | 50.3      |           |            |
| 0.850          | 42.8      |           |            |
| 0.425          | 35.3      |           |            |
| 0.180          | 26.8      |           |            |
| 0.075          | 20.0      |           |            |

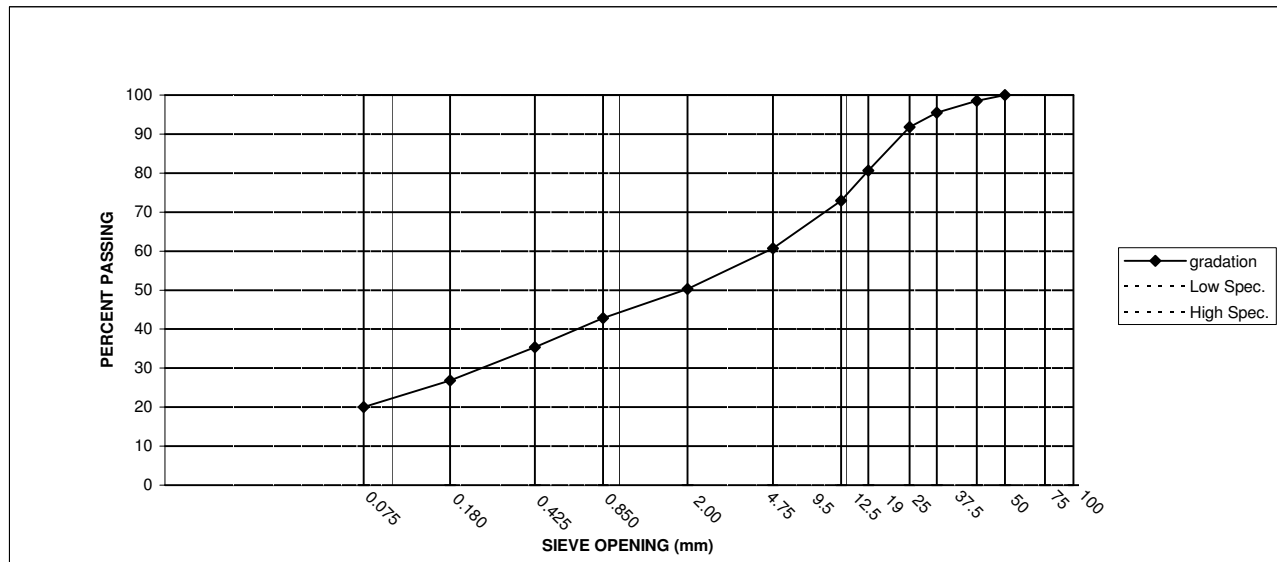
### Sample Properties

Gravel (+4.75 mm): 39.3 %

Sand (+0.075 to -4.75 mm): 40.7 %

Silt and / or Clay (-0.075 mm): 20.0 %

### AGGREGATE GRADATION:



### Comments:

per: Kerry Barth, ASCT

This report represents a testing service only.  
No engineering interpretation opinion is expressed or implied.  
Engineering review and interpretation can be provided on written request.



Report of: \_\_\_\_\_

Client: Franz Enviromental Inc.

## Grain Size Analysis

Project No: 2211-80037-9

Project: Alaska Highway

Sample Date: 11-Oct-08

Sample By: Client

Test Date: 21-Oct-08

Tested By: ME

### SAMPLE INFORMATION:

Material Type: SAND & GRAVEL; some silt

Source: Stockpile - Bucket 2 of 3

Specification: N/A

Sample Location: Toad River

Sample No: 6

Moisture Content: 5.5%

Fracture: N/A

Washed Sieve: ☒

Dry Sieve: ☐

| Sieve Analysis |           |           |            |
|----------------|-----------|-----------|------------|
| Sieve (mm)     | % Passing | Low Spec. | High Spec. |
| 100.0          |           |           |            |
| 75.0           |           |           |            |
| 50.0           |           |           |            |
| 37.5           | 100.0     |           |            |
| 25.0           | 97.6      |           |            |
| 19.0           | 94.6      |           |            |
| 12.5           | 81.4      |           |            |
| 9.50           | 73.3      |           |            |
| 4.75           | 55.7      |           |            |
| 2.00           | 43.9      |           |            |
| 0.850          | 35.7      |           |            |
| 0.425          | 28.3      |           |            |
| 0.180          | 20.4      |           |            |
| 0.075          | 15.2      |           |            |

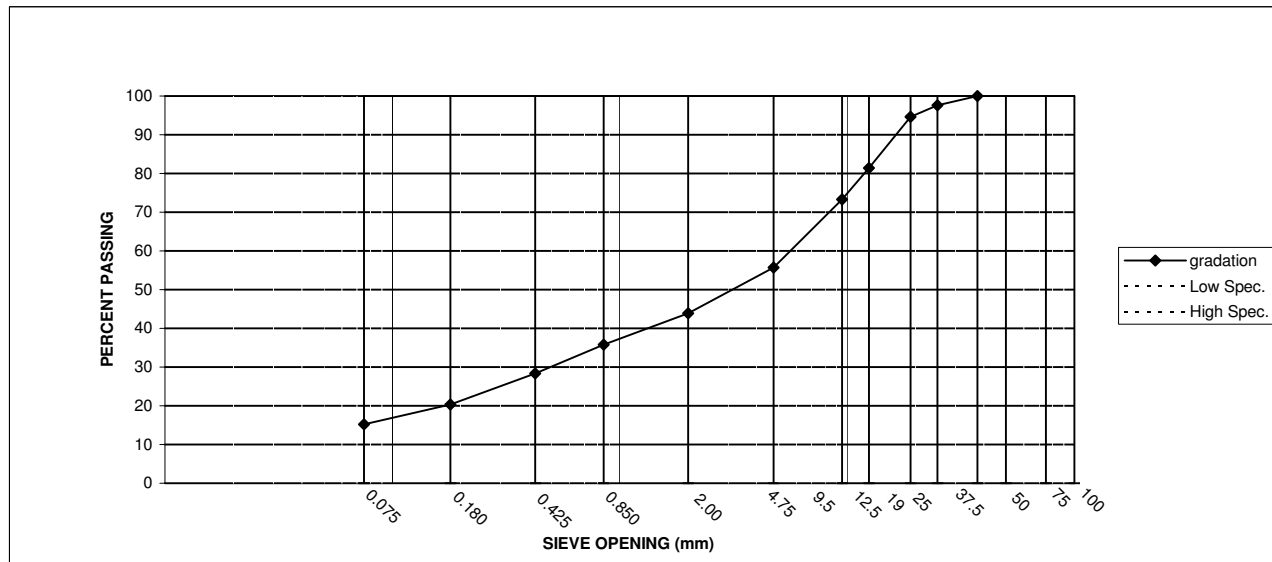
### Sample Properties

Gravel (+4.75 mm): 44.3 %

Sand (+0.075 to -4.75 mm): 40.5 %

Silt and / or Clay (-0.075 mm): 15.2 %

### AGGREGATE GRADATION:



### Comments:

per: \_\_\_\_\_  
Kerry Barth, ASCT

This report represents a testing service only.  
No engineering interpretation opinion is expressed or implied.  
Engineering review and interpretation can be provided on written request.





**McElhanney**

Report of: \_\_\_\_\_

Client: Franz Enviromental Inc.

## Grain Size Analysis

Project No: 2211-80037-9

Project: Alaska Highway

Sample Date: 11-Oct-08

Sample By: Client

Test Date: 21-Oct-08

Tested By: ME

### SAMPLE INFORMATION:

Material Type: SAND & GRAVEL; some silt

Source: Stockpile - Bucket 3 of 3

Specification: N/A

Sample Location: Toad River

Sample No: 7

Moisture Content: 4.9%

Fracture: N/A

Washed Sieve: ☒

Dry Sieve: ☐

| Sieve Analysis |           |           |            |
|----------------|-----------|-----------|------------|
| Sieve (mm)     | % Passing | Low Spec. | High Spec. |
| 100.0          |           |           |            |
| 75.0           |           |           |            |
| 50.0           | 100.0     |           |            |
| 37.5           | 99.0      |           |            |
| 25.0           | 96.4      |           |            |
| 19.0           | 94.2      |           |            |
| 12.5           | 80.6      |           |            |
| 9.50           | 72.0      |           |            |
| 4.75           | 57.1      |           |            |
| 2.00           | 46.2      |           |            |
| 0.850          | 38.0      |           |            |
| 0.425          | 30.0      |           |            |
| 0.180          | 21.1      |           |            |
| 0.075          | 15.6      |           |            |

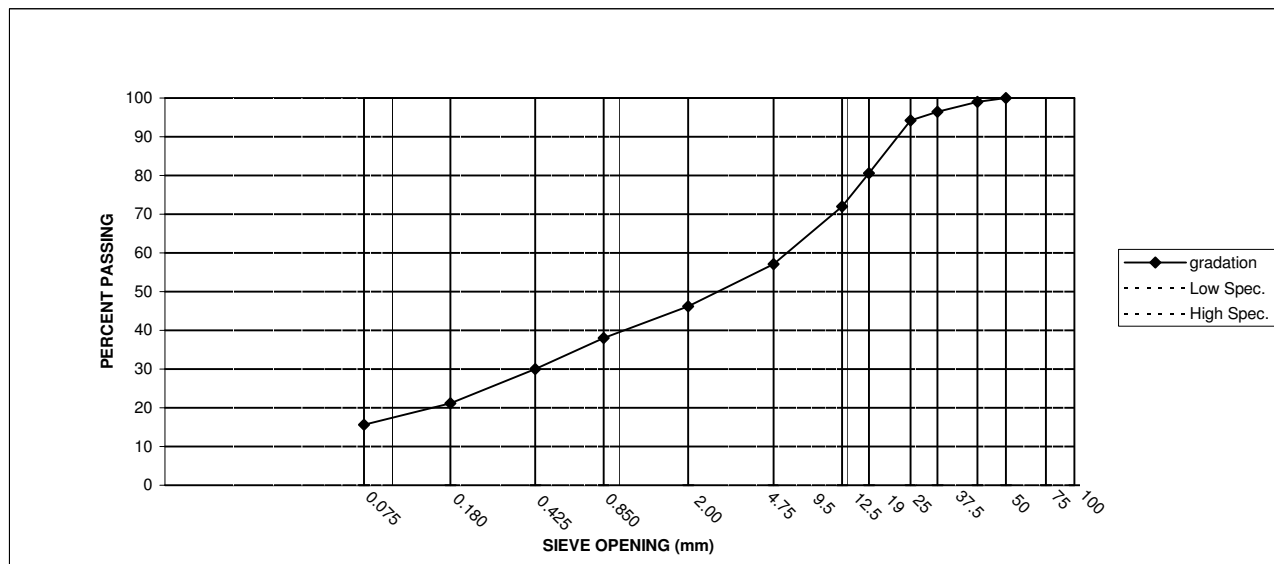
### Sample Properties

Gravel (+4.75 mm): 42.9 %

Sand (+0.075 to -4.75 mm): 41.5 %

Silt and / or Clay (-0.075 mm): 15.6 %

### AGGREGATE GRADATION:



### Comments:

per: \_\_\_\_\_  
Kerry Barth, ASCT

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No engineering interpretation opinion is expressed or implied.  
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