

## **Appendix B**

### **Cone Penetration Testing Results**

Part of: The Use of Waste Rock Inclusions to Control the Effects  
of Liquefaction in Tailings Impoundments

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### Classification of the Soil Based on Cone Penetration Test Results

Robertson (2000) provides the following method for the classification of soils based on the measured tip resistance,  $q_c$ , and skin friction,  $f_s$ , from cone penetration testing:

Calculate the normalized cone resistance,  $Q$ :

$$Q = \left[ \frac{(q_c - \sigma_{vo})}{P_a} \right] \left[ \frac{P_a}{\sigma'_{vo}} \right]^n$$

where:  $q_c$  is the measured tip resistance;

$\sigma_{vo}$  is the total vertical stress;

$\sigma'_{vo}$  is the effective vertical stress;

$P_a$  is atmospheric pressure; and

$n$  is an exponent varying from 0.5 for clean sands, to 1.0 for clays, with intermediate values for silts and sandy silts.

Calculate the normalized friction ratio,  $F$ :

$$F = \left[ \frac{f_s}{(q_c - \sigma_{vo})} \right] \cdot 100\%$$

where:  $f_s$  is the measured skin friction.

Calculate the soil behavior type index,  $I_c$ :

$$I_c = [(3.47 - \log Q)^2 + (1.22 + \log F)^2]^{0.5}$$

The soil type can then be estimated from Figure **Error! No text of specified style in document.**-1.

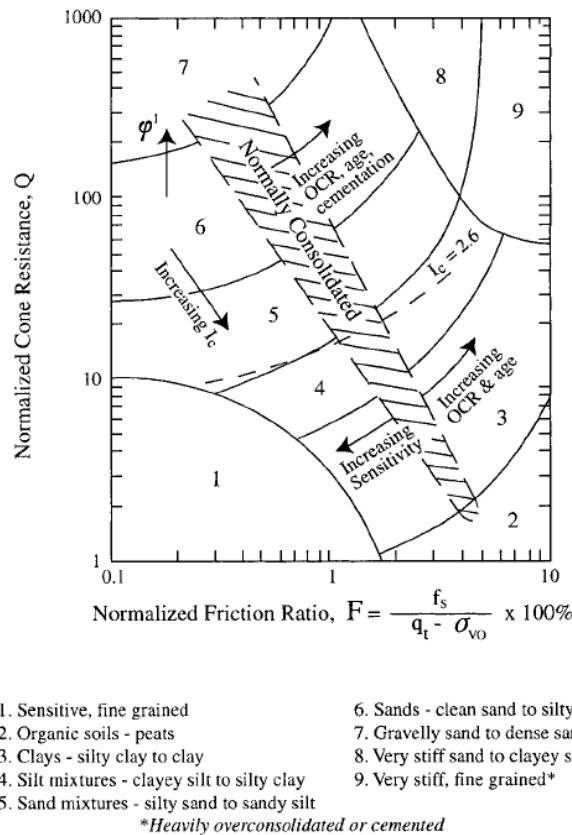


Figure Error! No text of specified style in document.-1 – Soil behavior type chart by Robertson (2000).

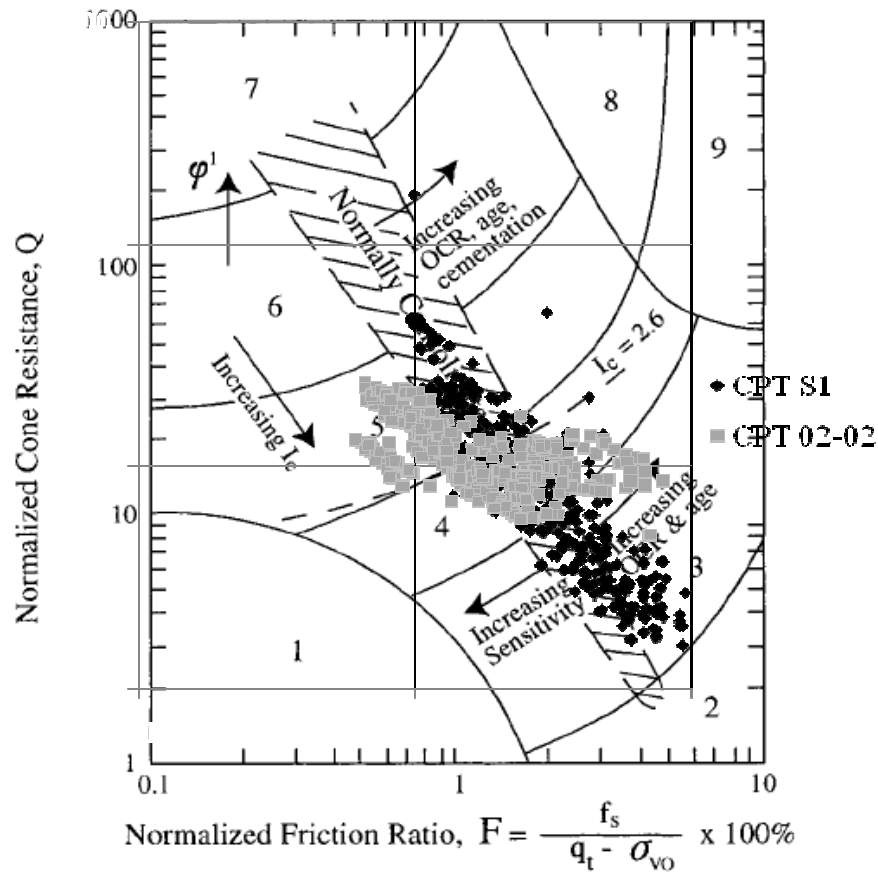
The normalized parameters  $Q$  and  $F$  and the associated soil behavior type indices,  $I_c$ , for all of the cone penetration testing completed on the site are shown on the logs of cone penetration testing presented later in this appendix. A value of 0.5 was used for the exponent,  $n$ , based on the findings of the Ulrich and Hughes (1994) that the tip resistance in active hard rock tailings impoundment is similar to that of coarse sands and the relatively high friction angle obtained from direct shear testing.

Figure Error! No text of specified style in document.-2 is the soil behavior type chart of Figure Error! No text of specified style in document.-1 with the normalized

parameters from CPT S1 and CPT 02-02 overlain on the chart. The data from these CPT logs is typical of 14 CPT logs from the site. Based on the chart, the soil types vary from organic soils (peat) to sand mixtures (silty sand to sandy silt). However, as the chart was developed for normally consolidated to over-consolidated soils and the tailings at the time of the field exploration were under consolidated, the application of the soil behavior type chart appears to be inapplicable to the active tailings impoundments.

Table **Error! No text of specified style in document.-1** – List of CPT.

| CPT Designation           | Surface Elevation (m) | Depth (m) |
|---------------------------|-----------------------|-----------|
| Polytechnique/INRS (2004) |                       |           |
| S1                        | 342.2                 | 8.95      |
| S2                        | 342.4                 | 7.51      |
| S3                        | 342.2                 | 7.55      |
| S4                        | 342.3                 | 6.47      |
| S5                        | 342.4                 | 7.21      |
| S6                        | 342.2                 | 7.81      |
| S7                        | 342.4                 | 4.63      |
| S8                        | 342.6                 | 2.42      |
| S9                        | 342.6                 | 5.22      |
| S10                       | 342.0                 | 5.14      |
| S11                       | 342.1                 | 7.71      |
| Golder Associés (2002)    |                       |           |
| 02-02                     | 338.5                 | 13.65     |
| 02-03                     | 338.6                 | 11.63     |
| 02-04                     | 339.1                 | 10.55     |



- |                                              |                                     |
|----------------------------------------------|-------------------------------------|
| 1. Sensitive, fine grained                   | 6. Sands - clean sand to silty sand |
| 2. Organic soils - peats                     | 7. Gravelly sand to dense sand      |
| 3. Clays - silty clay to clay                | 8. Very stiff sand to clayey sand*  |
| 4. Silt mixtures - clayey silt to silty clay | 9. Very stiff, fine grained*        |
| 5. Sand mixtures - silty sand to sandy silt  |                                     |
- \*Heavily overconsolidated or cemented*

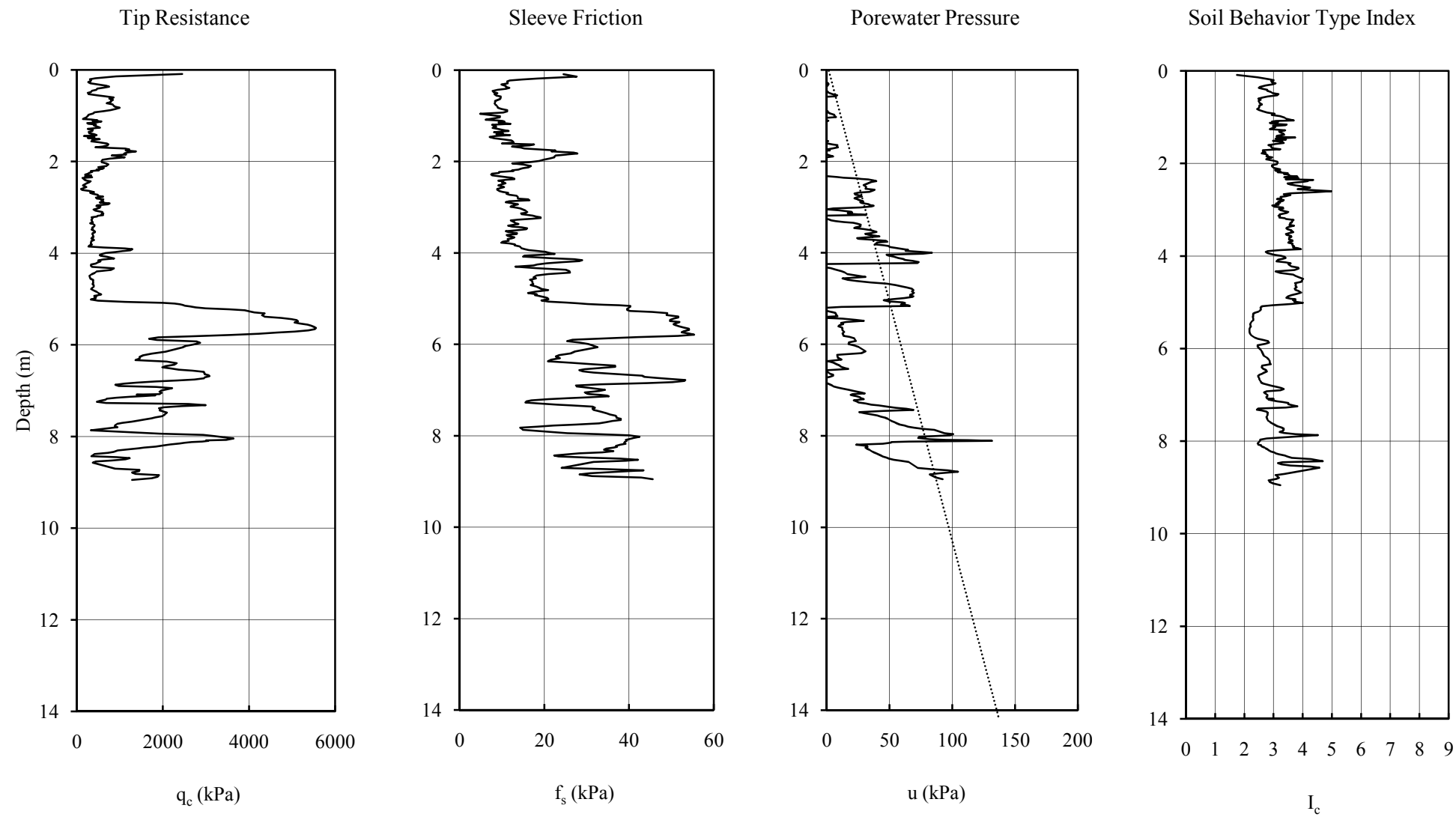
Figure Error! No text of specified style in document.-2 – Robertson (1990) soil behavior type chart with results from CPT S1 and CPT 02-02.

### **Logs of Cone Penetration Testing**

The logs of cone penetration testing conducted for this study for the previous study by Golder (2002) follow. Each log consists of profiles of the measured tip resistance,  $q_c$ , skin friction,  $f_s$ , and porewater pressure, PWP, and of the calculated soil behavior type index,  $I_c$ . The methods and equipment used in the CPT program are presented in Section 3.4.3 and the locations of the CPTs are shown on Drawing No. 3 of Appendix I.

Tailings Impoundment at Dike No. 1  
Laronde Mine - Pressiac, Quebec

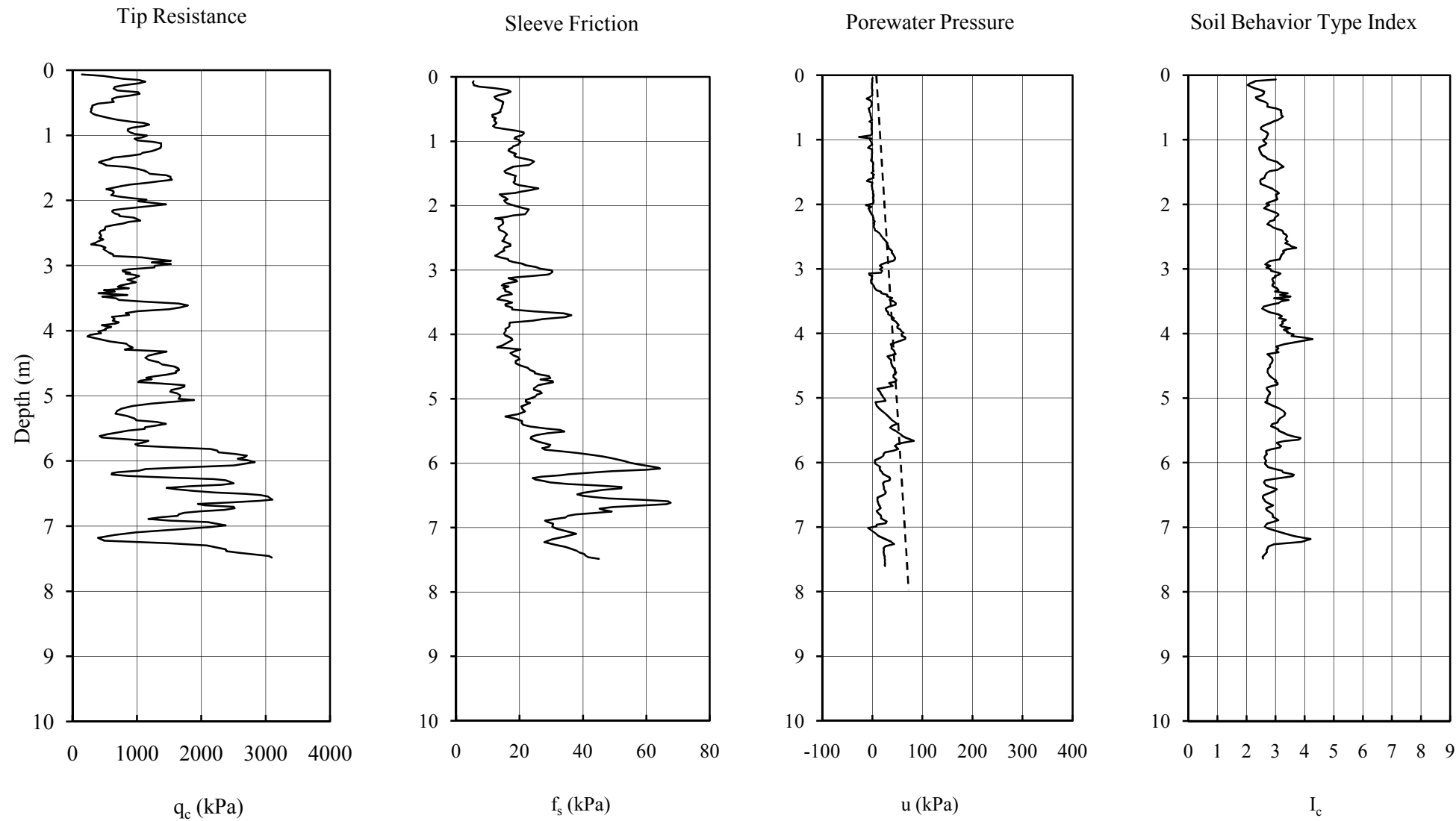
|         |    |
|---------|----|
| CPT NO. | S1 |
|---------|----|



Tailings Impoundment at Dike No. 1  
Laronde Mine - Pressiac, Quebec

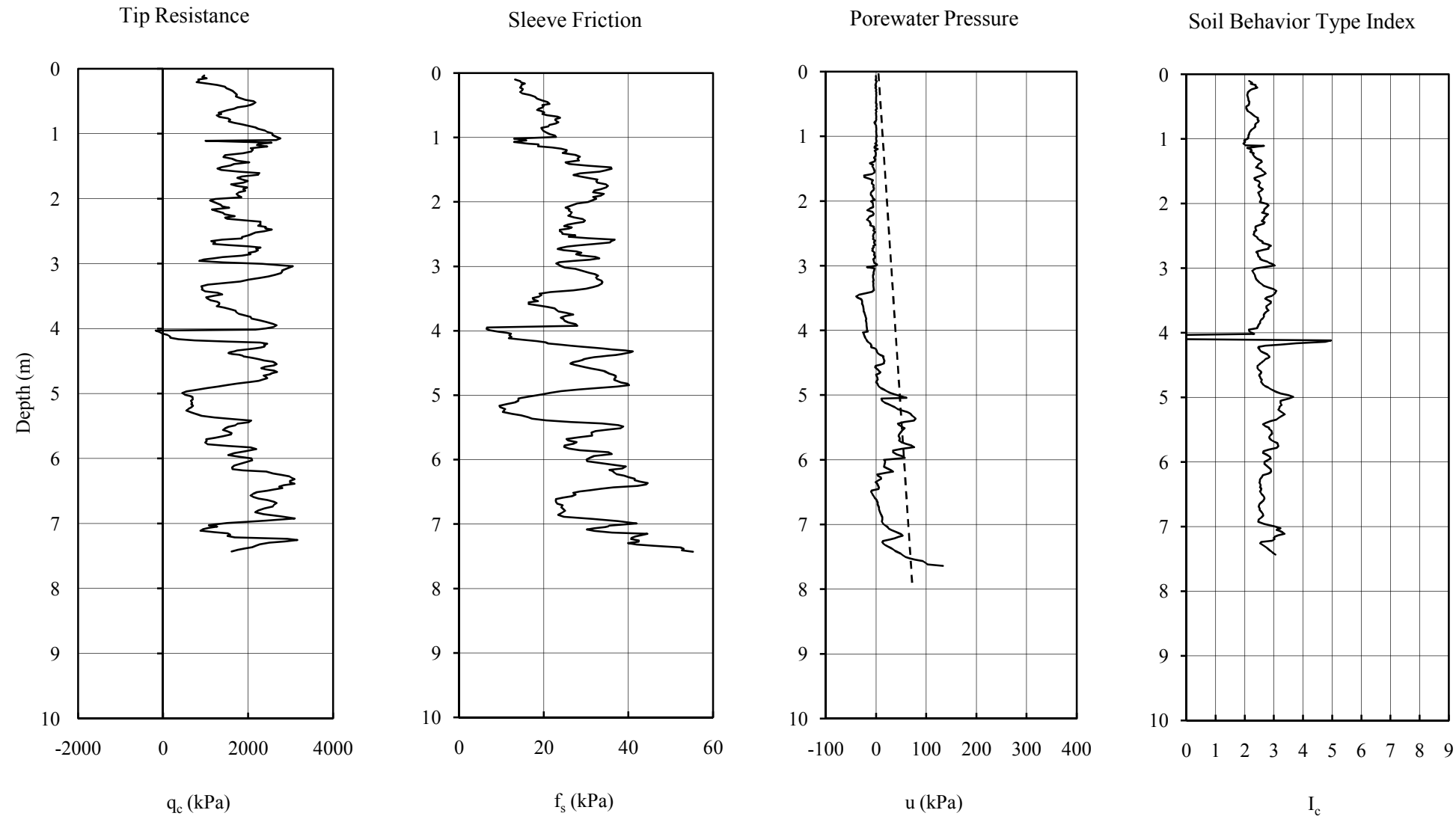
CPT NO.

S2



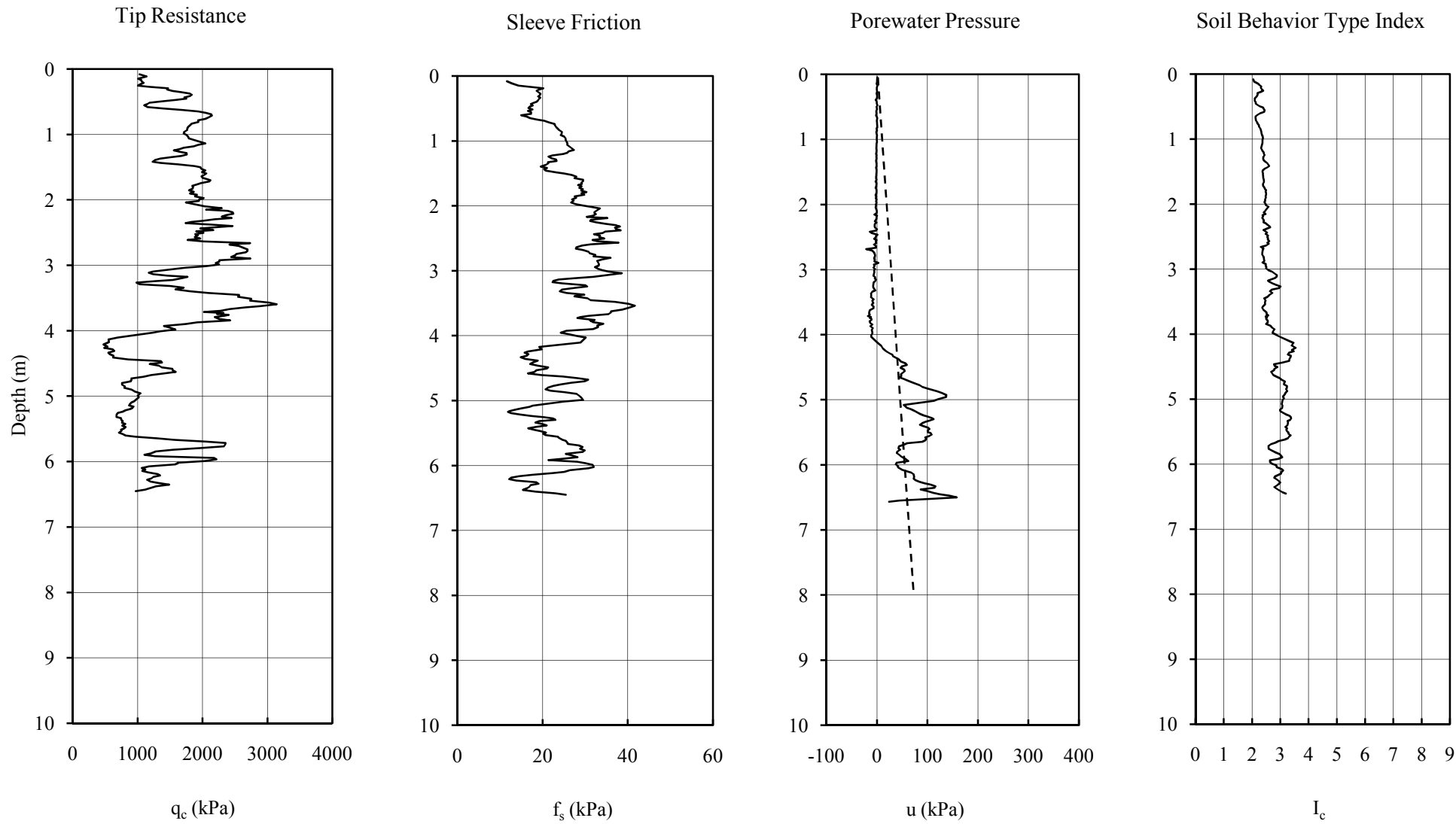
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Laronde Mine - Pressiac, Quebec

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| CPT NO. | S3 |
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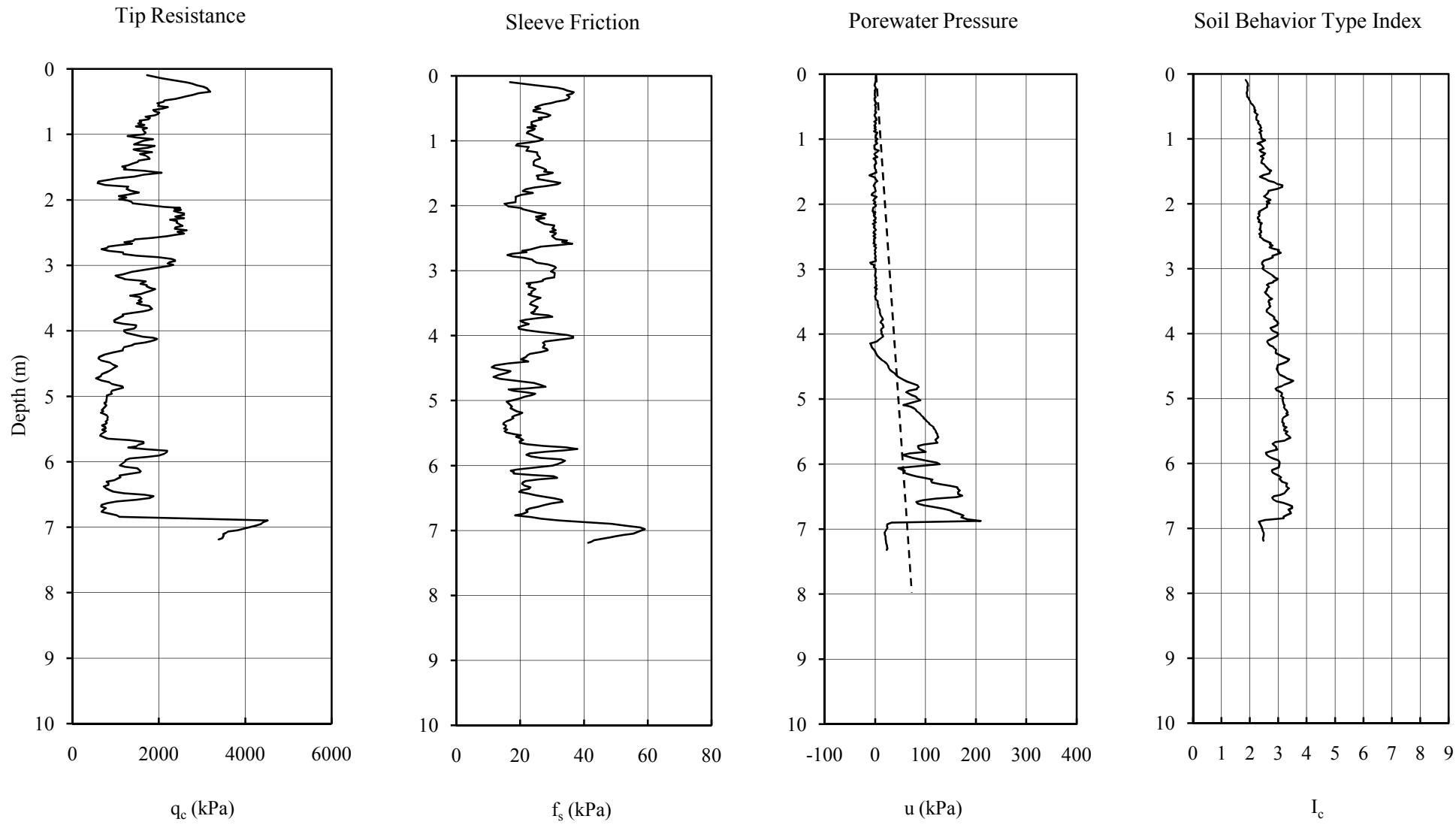
Failings Impoundment at Dike No. 1  
Laronde Mine - Pressiac, Quebec

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| CPT NO. | S4 |
|---------|----|



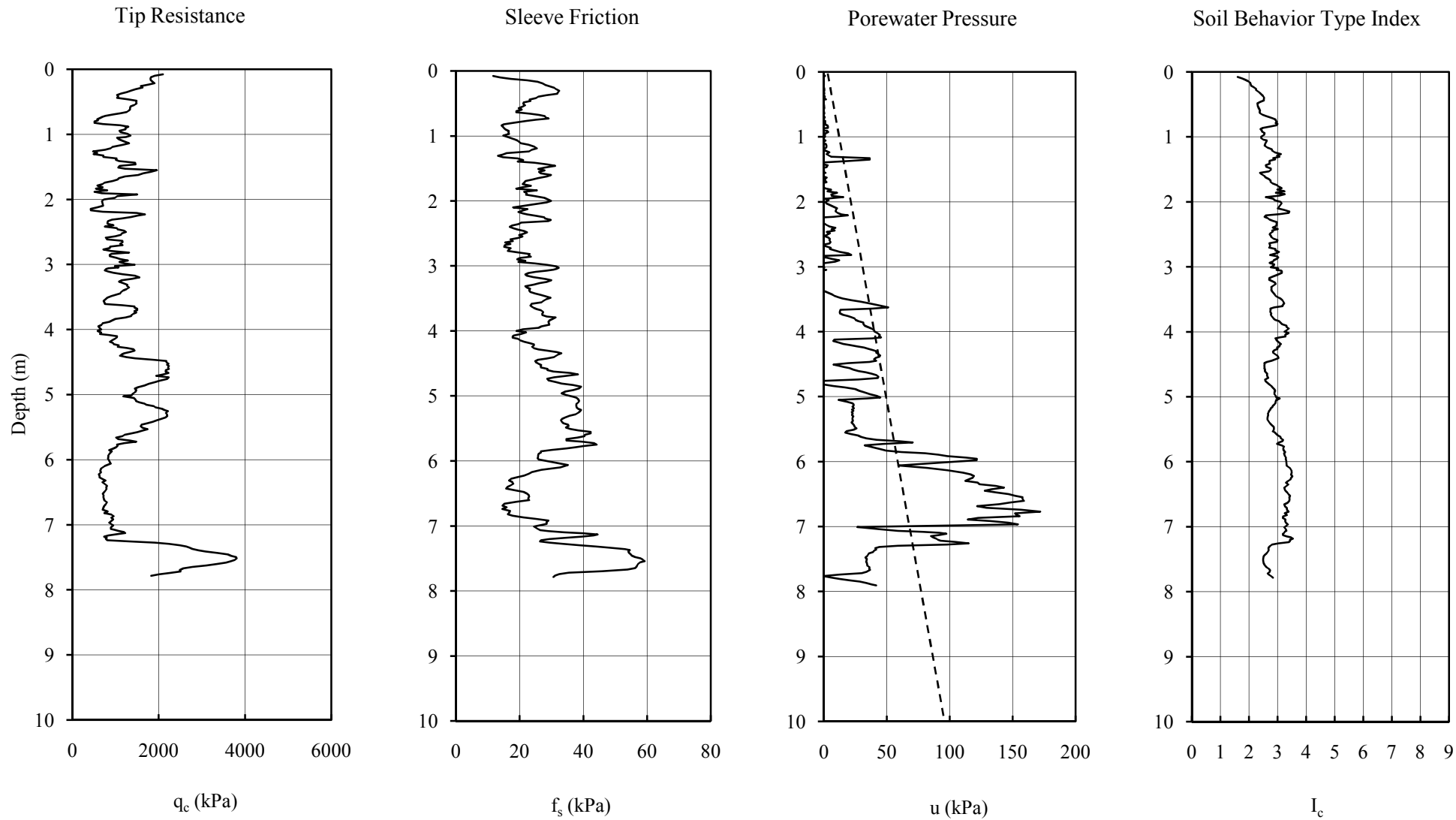
Failings Impoundment at Dike No. 1  
Laronde Mine - Pressiac, Quebec

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| CPT NO. | S5 |
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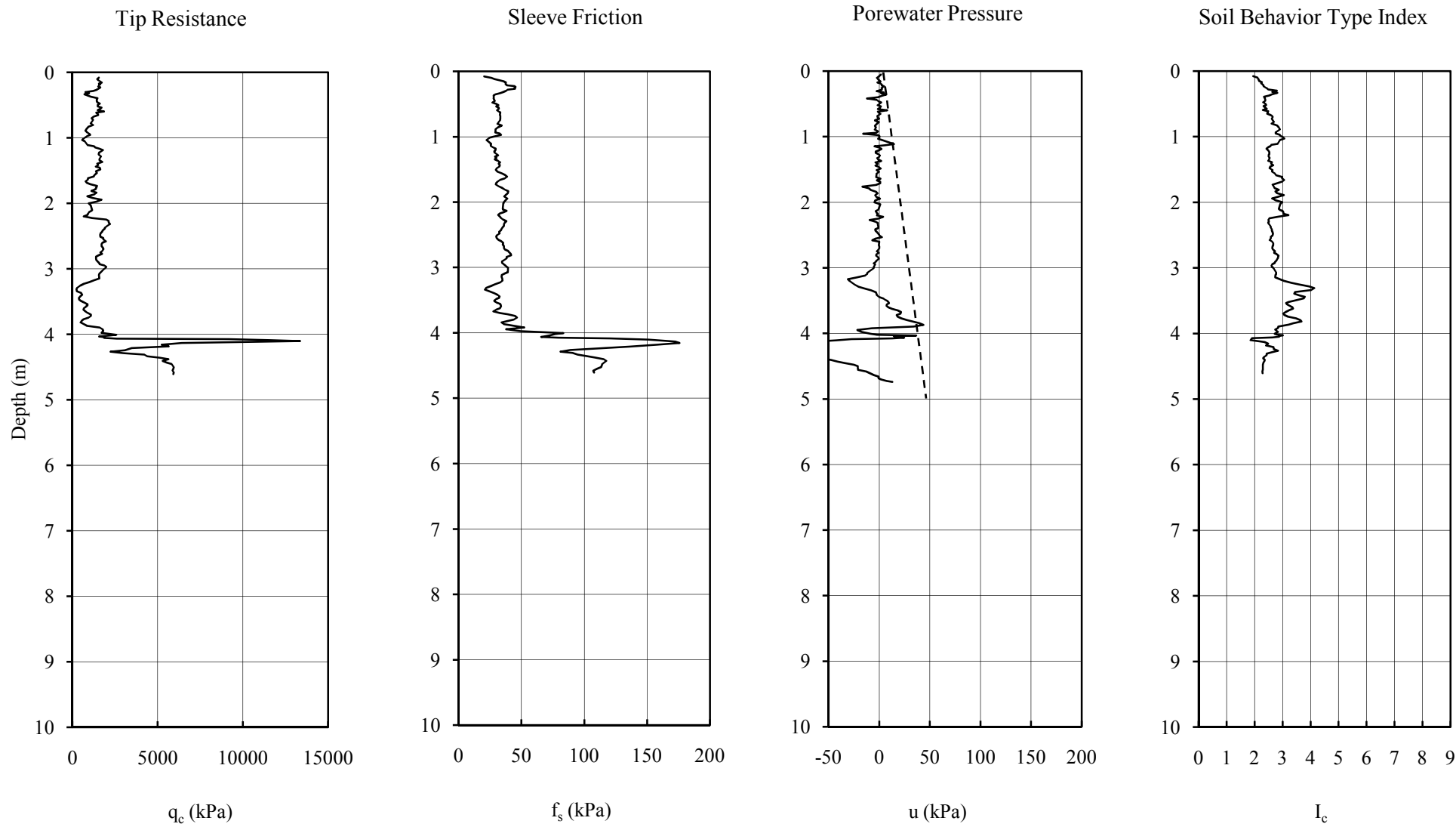
Failings Impoundment at Dike No. 1  
Laronde Mine - Pressiac, Quebec

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| CPT NO. | S6 |
|---------|----|



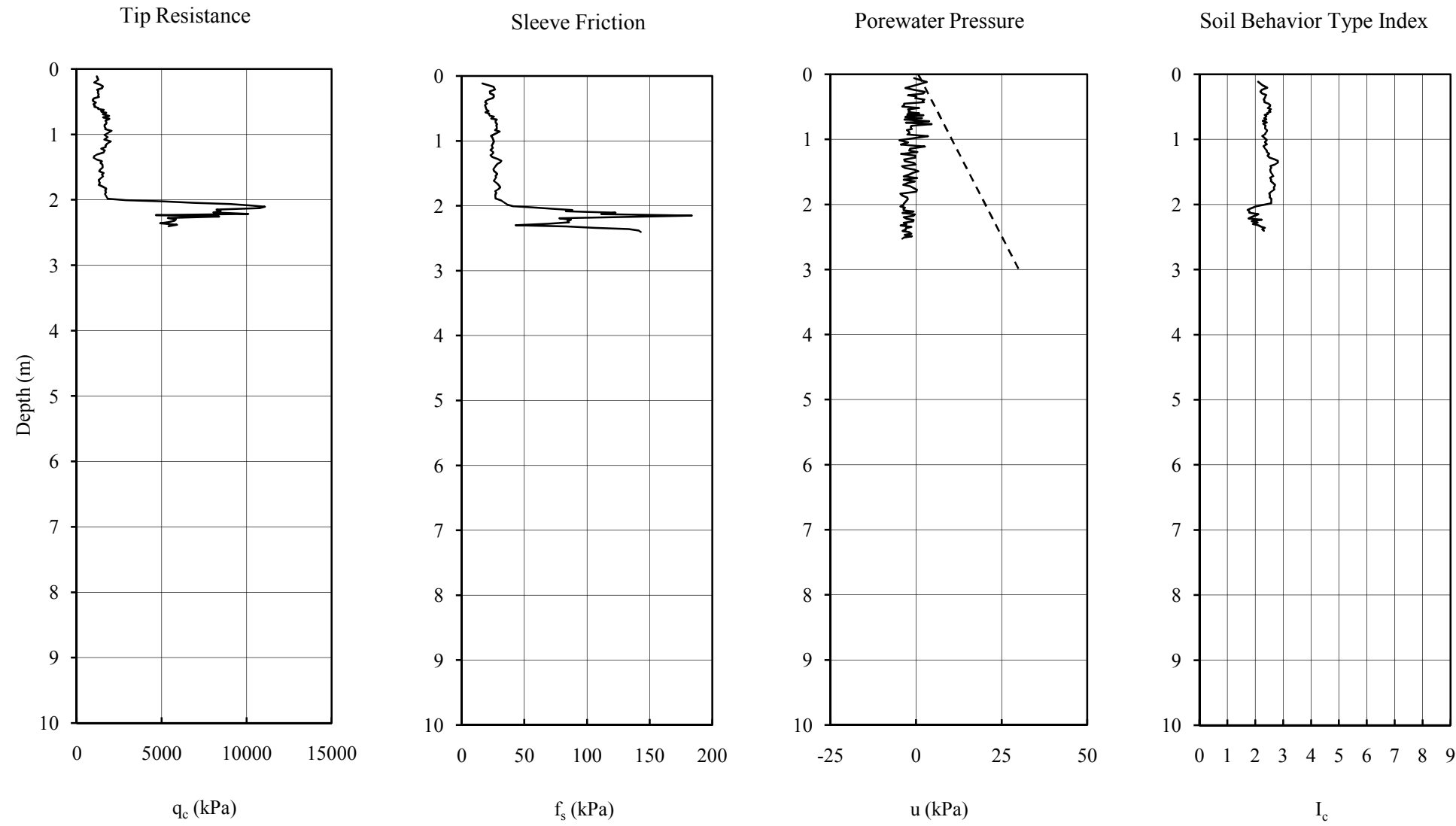
Failings Impoundment at Dike No. 1  
Laronde Mine - Pressiac, Quebec

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| CPT NO. | S7 |
|---------|----|



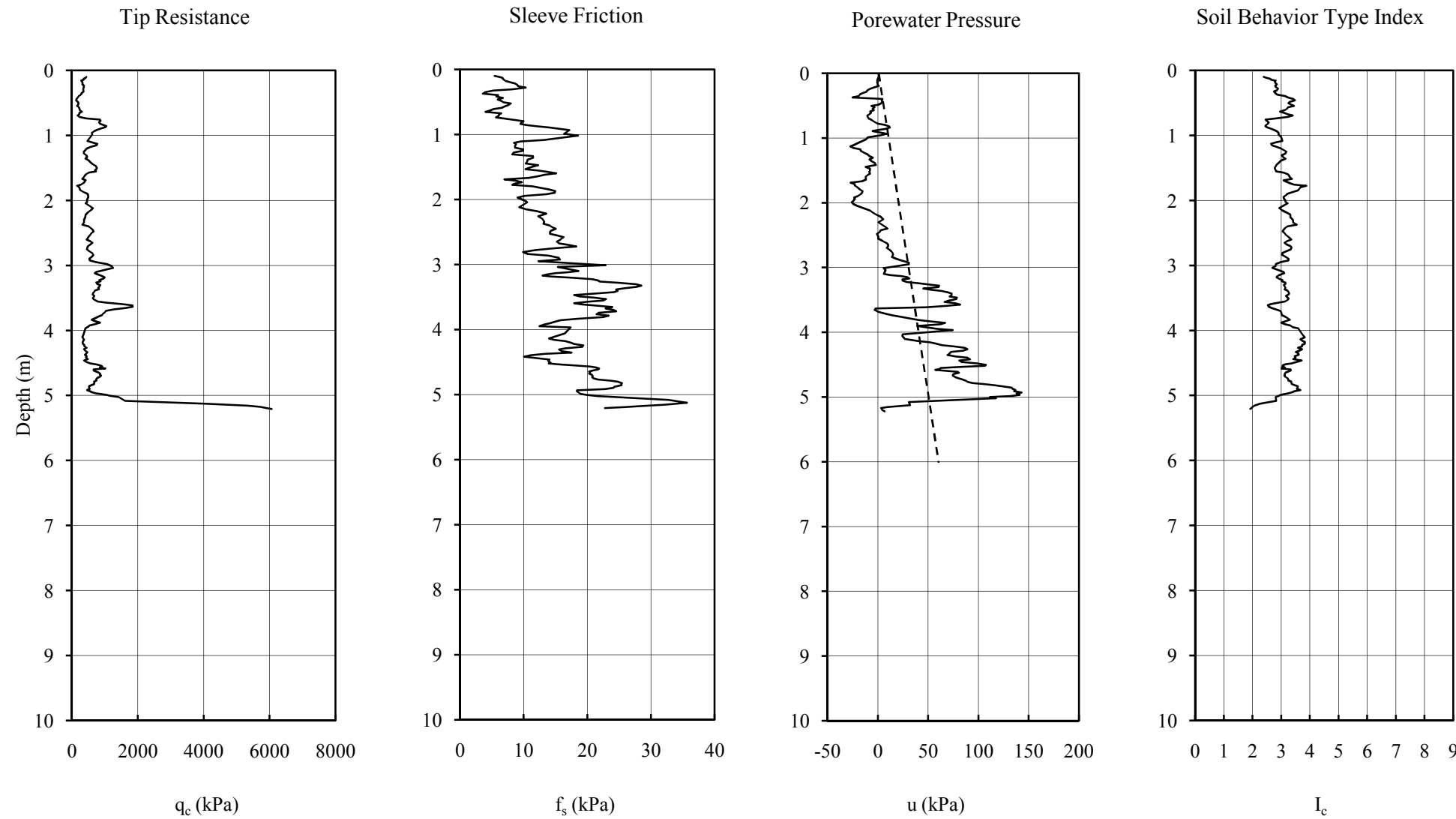
Tailings Impoundment at Dike No. 1  
Laronde Mine - Pressiac, Quebec

|         |    |
|---------|----|
| CPT NO. | S8 |
|---------|----|



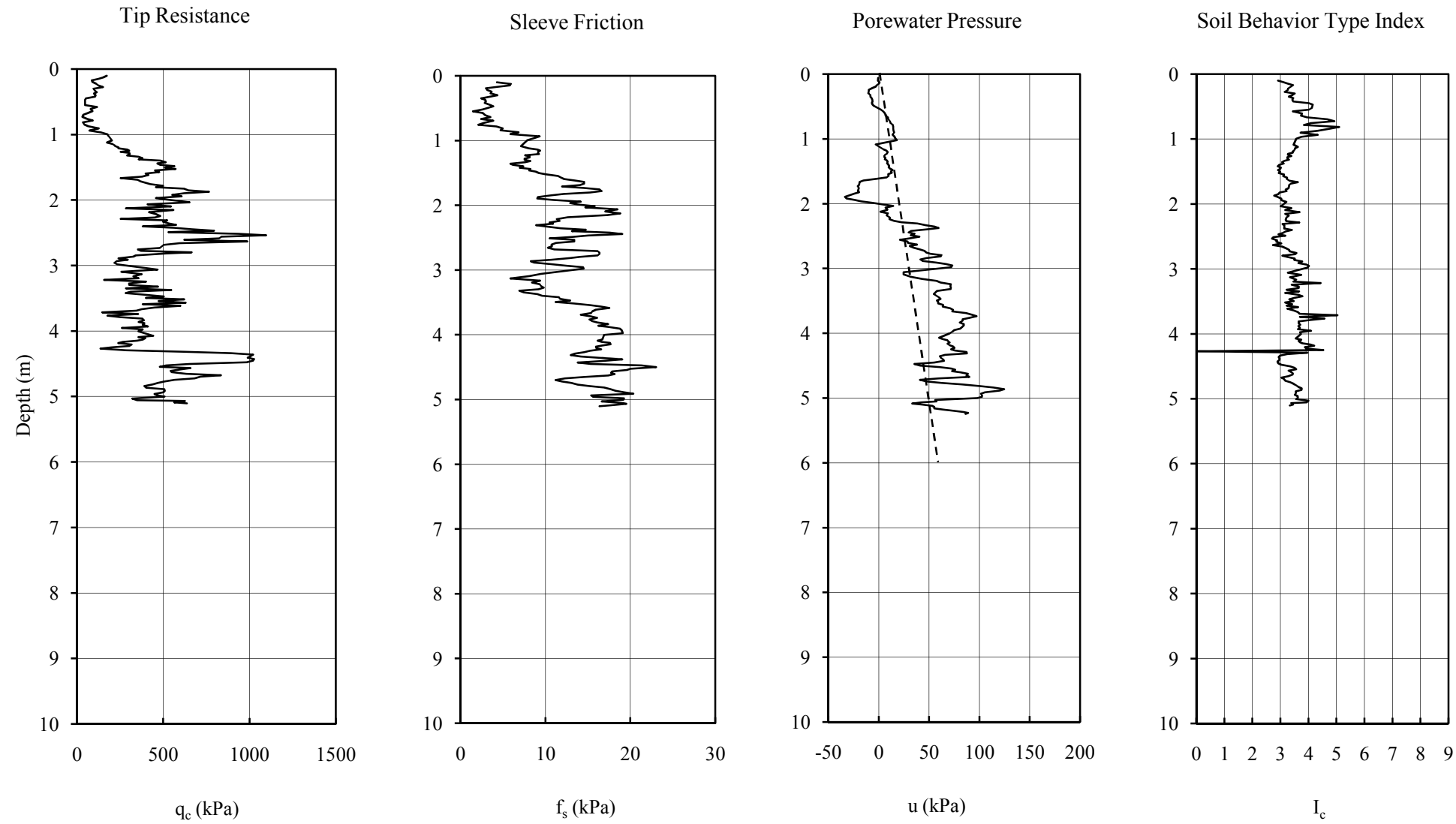
Tailings Impoundment at Dike No. 1  
Laronde Mine - Pressiac, Qeubec

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| CPT NO. | S9 |
|---------|----|



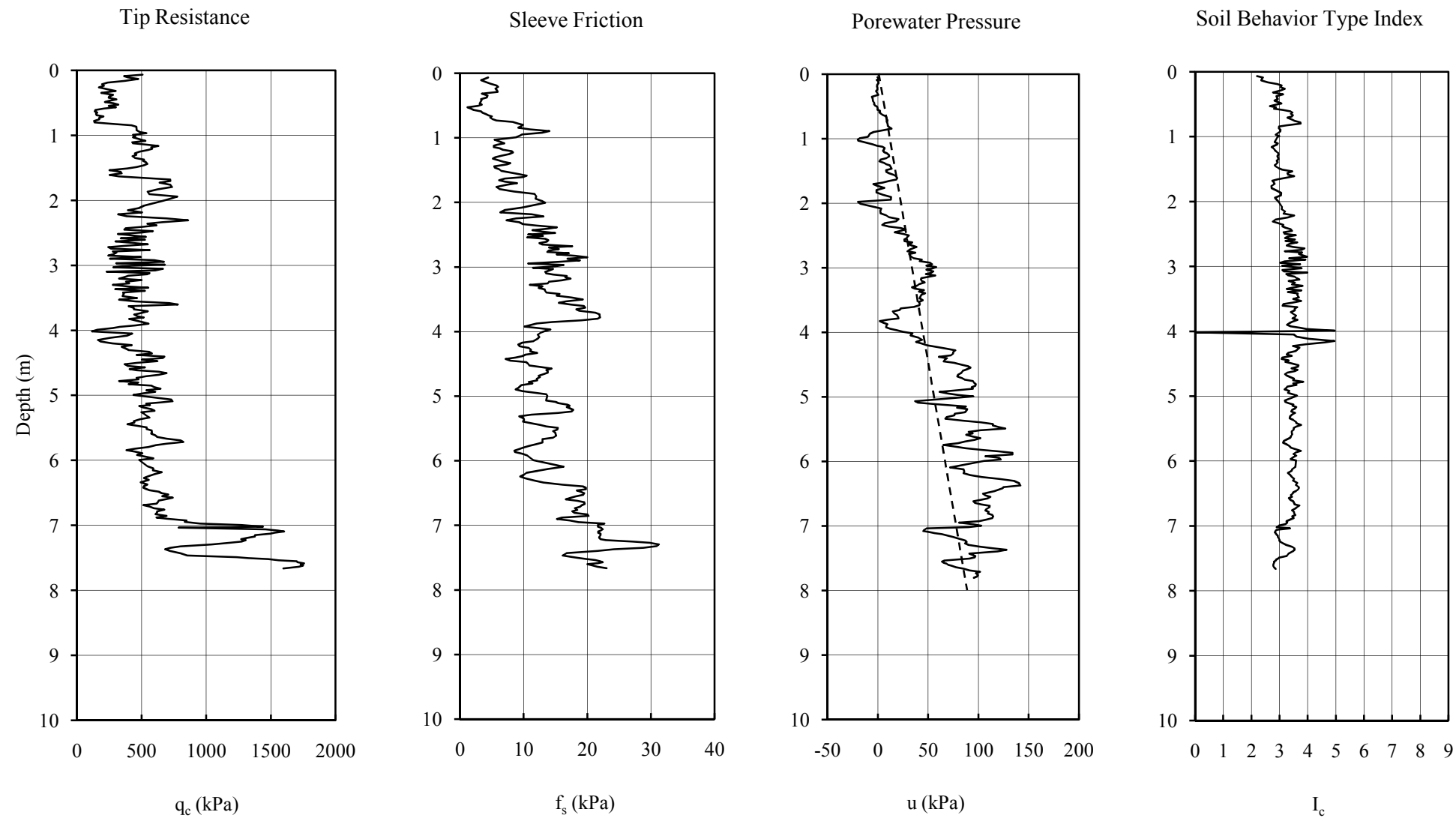
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Laronde Mine - Pressiac, Quebec

|         |     |
|---------|-----|
| CPT NO. | S10 |
|---------|-----|



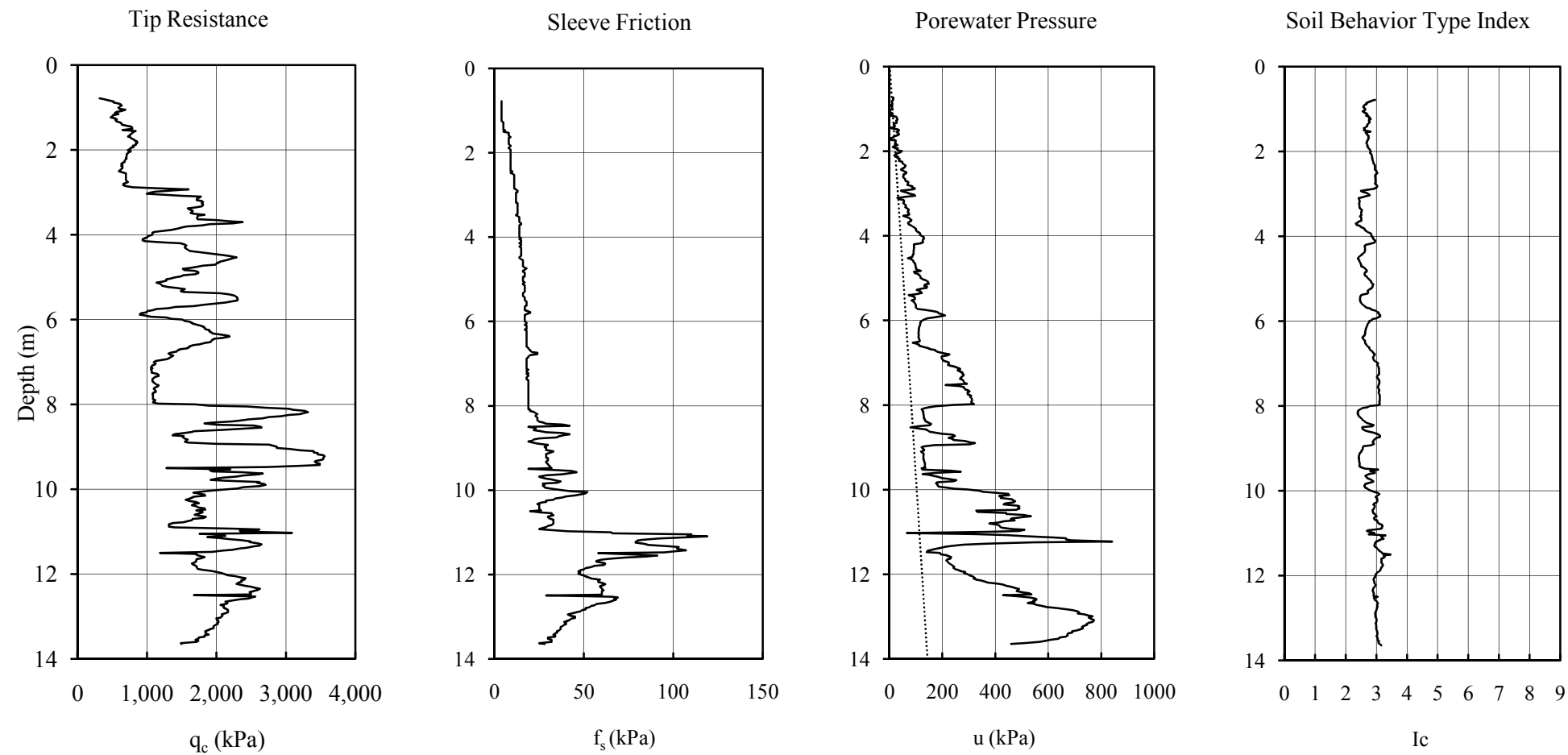
Tailings Impoundment at Dike No. 1  
Laronde Mine - Pressiac, Quebec

|         |     |
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| CPT NO. | S11 |
|---------|-----|



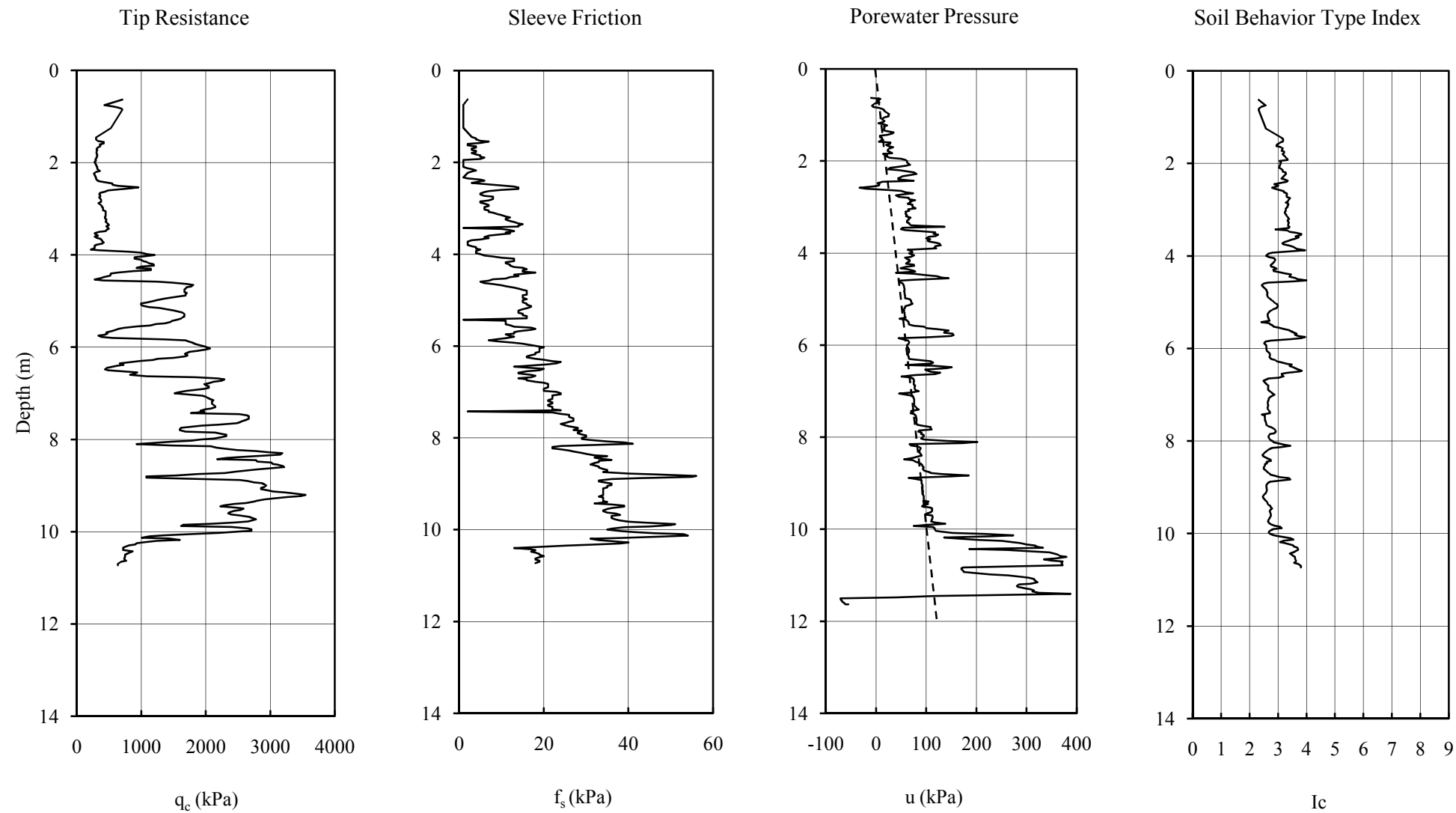
Tailings Impoundment at Dike No. 1  
Laronde Mine - Pressiac, Quebec

|         |       |
|---------|-------|
| CPT NO. | 02-02 |
|---------|-------|



Tailings Impoundment at Dike No. 1  
Laronde Mine - Pressiac, Quebec

|         |       |
|---------|-------|
| CPT NO. | 02-03 |
|---------|-------|



Tailings Impoundment at Dike No. 1  
Laronde Mine - Pressiac, Quebec

|         |       |
|---------|-------|
| CPT NO. | 02-04 |
|---------|-------|

