6.5.2.3.2 Full Sub-Excavation and Preloading

Taking into consideration the depth to the bottom of the clay deposit (i.e., up to about 13.5 m below the existing ground surface), full sub-excavation of the cohesive deposit is not considered practical for High Fill H2 due to: the potential requirement for specialized drag-line equipment; the substantial time and costs required to complete the sub-excavation and backfilling activities; the need for extra rock fill; the increase in long-term settlement of the rock fill; and the requirement for preloading for 12 months to reduce the long-term (post-construction) settlement. The full sub-excavation alternative, if adopted, eliminates the risk associated with long-term consolidation settlement associated with the silty clay to clay deposit and the long-term settlement of the rock fill after a 12 month preload period is estimated to be 30 mm. It should be noted, however, that the cost of sub-excavation and backfilling may be of the same order of magnitude and likely greater as some of the other options, including wick drains and staged construction as no off-site rock fill would have to be supplied to site at an added cost, however, the time to conduct the sub-excavation operations and subsequent preloading would likely be longer.

6.5.2.3.3 Partial Preloading and Lightweight Fill

If there is insufficient space to accommodate toe berms, an alternative to reduce the post-construction settlement is to partially preload the embankment and incorporate lightweight (EPS) fill into the embankment mass. The Highway 17 WBL embankment can be constructed to the maximum stable embankment height of 3.1 m and the St. Pothier Road embankment can be constructed to the maximum stable height of 2.5 m without the use of toe berms. Assuming the St. Pothier Road embankment will be built at the same time as the Highway 17 WBL and EBL embankments and as such would act as a “toe berm” for the Highway 17 EBL embankment, a 4.0 m surcharge could be constructed on the Highway 17 EBL embankment. After the partial preloading of the WBL and St. Pothier Road and the surcharging of the EBL, the Highway 17 WBL and St. Pothier Road embankments would be constructed to the final height by incorporating a 1.5 m and 1.0 m thick zone of EPS into the embankments, respectively. The EBL embankment would not require the use of EPS due to the large surcharge which could be partially removed to achieve the final embankment height.

In this case, the up to 3.6 m thick organic deposit should be removed and replaced with rock fill. In areas where EPS is required (WBL and St. Pothier Road embankments), the embankments should be constructed out of granular fill to facilitate placement of the EPS. The EBL embankment should be constructed of rock fill. The appropriate side slopes should be utilized as per Section 6.2.1.

After partial preloading for about 1.8 years (without using wick drains), the total post-construction settlement at the end of the partial preloading period for the Highway 17 WBL embankment is estimated to be 100 mm (comprised of 30 mm remaining primary settlement plus 65 mm creep settlement plus 5 mm settlement of the above ground rock fill). At the end of the partial preloading period for the St. Pothier Road embankment the total post-construction settlement is estimated to be 200 mm (comprised of 120 mm remaining primary settlement plus 75 mm creep settlement plus 5 mm long-term rock fill settlement).

After surcharging the Highway 17 EBL embankment for about 1.8 years, the total post-construction settlement for the Highway 17 EBL is estimated to be 100 mm (comprised of 20 mm remaining primary and 75 mm creep settlement and 5 mm long-term rock fill settlement).

The main disadvantage of this option is the high cost of EPS fill, which is typically an order of magnitude higher than other fill materials.

6.5.2.3.4 Surcharging, Wick Drains with Toe Berms

As an alternative to staged construction or the use of EPS, surcharging the Highway 17 WBL, EBL and St. Pothier Road embankments, while incorporating wick drains into the clay stratum and constructing toe berms to support the embankments, would achieve stable embankments and minimize the post-construction settlements and subsequent maintenance of the new roadway surface.

Surcharging the embankment increases the load on the underlying soils thereby reducing the delay time required to meet the settlement criterion. Wick drains provide a pathway for the dissipation of excess pore pressure in the cohesive deposit thereby further reducing the time required to meet the settlement criteria. The main disadvantages of this alternative is that large toe berms would be required (and thus property may need to be acquired), the double handling of the surcharge material and the cost of designing and installing the wick drains, including an instrumentation and monitoring program.

A 2.0 m surcharge above the final profile grade for the WBL and EBL embankment and a 1.0 m surcharge for the St. Pothier Road embankment would reduce the time required for preloading and decrease the long-term post-construction settlement including creep. In this case, the up to 3.6 m thick organic deposit would be removed and replaced with granular fill to facilitate installation of the wick drains and the embankments can be constructed out of rock fill.

The maximum stable embankment height without toe berms is 2.9 m for the Highway 17 WBL, for the Highway 17 EBL is 4.4 m and for the St. Pothier Road embankment it is 2.5 m. The embankment plus surcharge height for each embankment is 6.4 m, 6.4 m and 3.9 m, respectively, therefore toe berms would be required to improve stability of the surcharged embankment to achieve a FoS equal to or greater than 1.3. The toe berm required on the north side of the Highway 17 WBL embankment would be14 m wide and 1.5 m high and the toe berm required on the south side of the St. Pothier Road embankment would be 22 m wide and 1.5 m above ground surface. Also a "toe berm" about 1.5 m above ground surface that connects the Highway 17 EBL and the St. Pothier Road embankments would be required.

Preliminary analysis of consolidation of the cohesive deposits under the three embankments enhanced by wick drains spaced at 1.5 m in a triangular pattern to full depth through to the bottom of the cohesive deposit indicates that 90 per cent of primary consolidation would be completed in about 10 months.

After surcharging for 10 months, the total post-construction settlement of the EBL embankment is estimated to be 100 mm (95 mm creep settlement plus 5 mm long-term rock fill settlement).

After surcharging the St. Pothier Road embankment for 10 months, the total post-construction settlement is estimated to be 200 mm (50 mm primary, 130 mm creep settlement plus 20 mm short and long-term rock fill settlement).

To facilitate the assessment for the end of the surcharge period, instrumentation and monitoring during and after construction would be required. A detailed wick drain analysis has not been completed for this area and the preliminary analysis used to estimate the wait periods presented in this report is based on undrained analyses. As such, the above number of stages and wait times are approximate. Further, the actual wait period is dependent on the results of the monitoring program and could be shorter or longer than estimated.

6.5.2.3.5 Surcharging with Toe Berms

Surcharging the Highway 17 WBL, EBL and St. Pothier Road embankments and incorporating toe berms into the embankments will achieve stable embankments and minimize the post-construction settlements and subsequent maintenance of the new roadway surface. However, without the use of toe berms, the surcharging would take longer.

The maximum stable embankment height without toe berms is 3.3 m for the Highway 17 WBL, for the Highway 17 EBL is 2.4 m and for the St. Pothier Road embankment it is 2.9 m. The embankment plus surcharge height for each embankment is 6.4 m, 6.4 m and 3.9 m, respectively, therefore toe berms would be required to improve the stability of the surcharged embankment to achieve a FoS equal to or greater than 1.3. The toe berm required on the north side of the Highway 17 WBL embankment would be 12 m wide and 1.5 m high and the toe berm required on the south side of the St. Pothier Road embankment would be 20 m wide and 1.5 m above ground surface. Also a "toe berm" about 1.5 m above ground surface that connects the Highway 17 EBL and the St. Pothier Road embankments would be required.

In this case, the up to 3.6 m thick organic deposit will be removed and replaced with granular fill to facilitate installation of the wick drains and the embankments can be constructed out of rock fill.

After surcharging the WBL and EBL embankments for 2.5 years, the total post-construction settlement of the EBL embankment is estimated to be 100 mm (10 mm primary, 80 mm creep settlement plus 10mm long-term rock fill settlement).

After surcharging the St. Pothier Road embankment for 1.5 years, the total post-construction settlement is estimated to be 200 mm (110 mm primary, 80 mm creep settlement plus 10 mm long-term rock fill settlement).

To facilitate the assessment for the end of the surcharge period, instrumentation and monitoring during and after construction would be required.

The main disadvantages of this option are the wait time required for surcharging without the use of wick drains and the requirement for large toe berms which may require the purchase of additional property. If the length of the construction schedule is not a consideration this would be the most cost effective option.

6.5.2.3.6 Other Mitigation Options

The option of partial sub-excavation is considered not feasible since in this case, wick drains would not be able to be installed through the rock fill backfill and thus full preloading to reduce post-construction settlement of the remaining clay deposit would still be required. As a minimum, a 12 month preload period would be required for rock fill compression.

The option of ground improvement, consisting of either dry/wet soil mixing or rammed aggregate piers (geopiers) is also considered not feasible since the amount of cement or aggregate required would result in costs far exceeding other options. Further, additional design and bench scale testing would be required to determine the ultimate feasibility of these options and it may be that there would be insufficient strength gain of the clay deposit to make the soil mixing option feasible.

6.5.2.4 Mitigation of Stability Issues and/or Time Dependent Settlements: Highway 17 EBL/WBL Embankments Built Independently from the St. Pothier Road Embankment

Construction of the three embankments concurrently is critical to maintaining stability of the embankments and is also a major factor in choosing the preferred mitigation alternative. Essentially, the St. Pothier Road embankment will act as a "toe berm" for the south side of the Highway 17 EBL embankment. If the St. Pothier Road embankment is not constructed concurrently with the Highway 17 embankments, then the global stability of the proposed 4.4 m high EBL embankment would be compromised. A toe berm would be required on the south side of the Highway 17 EBL embankment with approximately the same dimensions as the proposed St. Pothier Road embankment (i.e., extending over 25 m wide) to support the EBL embankment. Therefore, the number of technically feasible options is reduced when only the Highway 17 EBL and WBL embankments are considered.

As discussed in Section 6.5.2.3, we recommend surcharging in combination with wick drains and toe berms along the embankments integrated into a staged construction schedule as the preferred mitigation alternative, provided all three embankments are constructed concurrently. We do not recommend constructing the St. Pothier Road embankment at a later time as both stability and long-term settlement of the new EBL/WBL embankments would affect roadway performance and likely construction itself. Further, the costs associated with mitigation of all the embankments would be excessive.

If, however, it is not possible to construct the St. Pothier Road embankment at the same time as the Highway 17 EBL and WBL embankments, then the alternative of partial preloading with lightweight fill (EPS) is considered the only technically feasible option to mitigate both the settlement and stability concerns related to the construction of the EBL embankment. Further, if the St. Pothier Road embankment is constructed at a later date, settlement of the cohesive deposit under the new loading would induce settlement under the EBL embankment.

6.5.2.4.1 Partial Preloading and Lightweight Fill

If the construction schedule does not allow for all three embankments to be built concurrently the only technically feasible alternative to reduce the post-construction settlement while maintaining stability is to partially preload the Highway 17 WBL and EBL embankments and to incorporate lightweight (EPS) fill into the embankment mass. The Highway 17 WBL and EBL embankments can be constructed to the maximum stable embankment height of 2.2 m without the use of toe berms. Partial preloading at this embankment height for 1.8 years would be required to allow for sufficient consolidation settlement of the cohesive deposit and settlement of the rock fill prior to the construction of the pavement structure. After the partial preloading of the WBL and EBL, the embankments could be constructed to the final height by incorporating a 3.0 m thick zone of EPS into the embankments.

After partial preloading for about 1.8 years (without using wick drains) the total post-construction settlement in the Highway 17 WBL is estimated to be 100 mm (comprised of 30 mm remaining primary and 65 mm creep settlement and 5 mm long-term rock fill settlement) and the post-construction settlement in the Highway 17 EBL is estimated to be 100 mm (comprised of 20 mm remaining primary and 75 mm creep settlement and 5 mm long-term rock fill settlement).

The St. Pothier Road embankment can subsequently be constructed to the maximum stable embankment height of 2.5 m without the use of toe berms. Partial preloading at this embankment height can then be carried out for 1.8 years to allow for sufficient consolidation settlement of the cohesive deposit and settlement of the rock fill to occur prior to the construction of the pavement structure. A 1.0 m thick zone of EPS would then be required to raise the embankment to the design grade. After completion of the preload period, the total post-construction settlement is estimated to be 200 mm (comprised of 120 mm remaining primary and 75 mm creep settlement and 5 mm long-term rock fill settlement).

The main disadvantage of this option is the substantial cost of EPS fill, which is typically an order of magnitude higher than other fill materials. The construction of toe berms could reduce the amount of EPS material currently specified. Also, wait times could be reduced by incorporating more EPS material into the embankment or utilizing wick drains.

6.5.3 Highway 17 WBL – STA 13+900 to 14+200
Highway 17 EBL – STA 13+900 to 14+200
High Fill H3

Due to the close proximity and overlap of the realigned Highway 17 WBL and EBL embankments and the existing Highway 17 WBL and EBL embankments, these embankments areas have been combined into one high fill/swamp area H3.

Generally, the proposed Highway 17 WBL and EBL embankments overlap the existing Highway 17 WBL and EBL embankments throughout the high fill area with essentially a widening of the existing embankments of up to about 7 m to the north of both the WBL and EBL embankments between STA 13+950 and 14+150. Between about STA 13+900 and 13+950 and between about STA 14+150 and 14+200, there will either be a cut or minimal to no grade raise. Between about STA 13+950 and 14+150, an embankment widening up to about 7 m and a grade raise up to 3.1 m above the existing embankment will be required to achieve the horizontal and vertical highway profile.

The subsurface soils along the WBL and EBL alignments in High Fill Area H3 consist of surficial layers of peat/topsoil or asphalt and embankment fill, underlain by an upper deposit of sand to sandy silt. These upper deposits are underlain by the main cohesive deposit of clayey silt transitioning into varved silty clay to clay transitioning to clayey silt to silt underlain by a silt deposit, which is further underlain by a deposit of sand to sand and silt. The cohesive deposit is up to 16.8 m thick at some locations and extends to depths up to 19.5 m below ground surface. Resistance to dynamic cone penetration and borehole advancement was encountered at depths of up to 28.0 m ground surface. Details of the subsurface conditions for this swamp crossing area are presented in Sections 4.8 and 4.9 and shown on Drawings C1 to C4 in Appendix C.

The simplified stratigraphy and the associated unit weight, strength, deformation and time-rate consolidation parameters employed for the different soil types encountered in this area are summarized in Table 3. Additional details of foundation engineering parameters employed for the cohesive deposits (i.e., clayey silt/silty clay/clay) encountered in H3 are provided on Figure C22 in Appendix C. The piezometric condition used in the analyses is the water table just below the top of the native organic material (Elevation 241.6 m).

The critical section used in the analysis is located at approximately STA 14+100, where the existing embankments are to be widened thus requiring grade raises at the existing north crest of slope of 1.9 m and 3.1 m above the existing ground surface at the toes of the existing WBL and EBL embankments, respectively . At

STA 14+100, the grade raises will be approximately 0.8 m and 1.1 m above the existing highway grade at the new centrelines of the WBL and EBL, respectively. Boreholes drilled in the WBL and EBL embankments encountered up to 4.7 m and 5.5 m of existing fill, respectively. At this location, the cohesive deposit is up to 14.0 m thick.

6.5.3.1 Stability

At the critical section as described above, the FoS for slope stability would be greater than 1.3 for granular fill or rock fill embankments constructed on the existing fill and subsoils, provided that all organics have been removed below the widened embankment footprint, as shown on Figures C23 and C24 in Appendix C.

6.5.3.2 Settlement

To estimate the magnitude of the expected settlements due to new construction, analysis was carried out at the critical section representative of the subsurface conditions within the high fill area, at approximately STA 14+100. The critical section was chosen in the area of the largest embankment widening, which corresponds to the largest stress loading on the subsoils. At the north side of the EBL which is most critical for settlement, the widening of about 6 m creates a grade raise of 3.1 m above the existing ground surface at the crest of the slope and a grade raise of about 1.1 m above the 5.6 m of existing fill at the proposed EBL centreline.

Based on the results of the settlement analysis for the EBL embankment widening, the short-term settlement of the foundation soils under approximately the new outside edge of pavement (assumed to be the edge of the travelled lane in this analysis) is estimated to be about 115 mm. This estimated settlement in the Highway 17 WBL is comprised of about 25 mm of immediate settlement due to compression of the cohesionless deposits and about 90 mm of primary consolidation of the 14.0 m thick cohesive deposit.

Based on an average coefficient of consolidation (c_v) of about 2.0×10^{-3} cm^2/s estimated for the cohesive deposit, the imposed loading conditions for the approximately 3.1 m grade raise and assuming two-way drainage of the 14 m thick cohesive deposit, it is estimated that about 90 per cent of the primary consolidation settlement will be completed in about 6 years.

The magnitude of secondary consolidation (creep) settlement for the cohesive deposit is expected to be about 100 mm per log-cycle of time for this area corresponding to about 60 mm over a 20-year period following completion of construction (i.e., from 6 years to 20 years).

If rock fill is utilized for the embankment widening, the total settlement of the rock fill embankment itself (based on 3.1 m grade raise at the critical section) is estimated to be about 25 mm, with about 15 mm expected to occur within six months of construction of the embankment, 5 mm occurring during the next six months and about 5 mm expected to occur over the remaining design life of the embankment. If granular fill is utilized, settlement of properly placed and compacted granular fill is estimated to occur quickly during construction with no post-construction settlement.

Since the total post-construction settlement is estimated to be about 175 mm (comprised of 90 mm primary consolidation, 60 mm of creep and 25 mm rock fill settlement – if utilized), and exceeds the settlement criterion of 50 mm for an embankment widening, settlement mitigation measures are required for the Highway 17 WBL and EBL embankments in the High Fill Area H3. Further, the estimated differential settlement of 40 mm between the new centreline and north edge of pavement also exceeds the criterion of 200:1. It should be noted that higher magnitudes of total and differential settlement are expected to occur beyond the outside edge of pavement along the slope.

6.5.3.3 Mitigation of Stability Issues and/or Time Dependent Settlements

In order to construct the embankments in the widened areas and minimize post-construction settlements, the alternatives presented below can be considered. The alternatives described have been evaluated and ranked on the basis of the advantages, disadvantages, relative costs and risk/consequences and are summarised in Table C1 in Appendix C. A summary of the results of settlement analysis for each alternative is provided in Table 4.

Outside of the critical areas, there will be a minimal grade raise and little to no embankment widening and therefore no settlement or stability mitigation will be necessary. The sections listed below do not require settlement or stability mitigation:

- Highway 17 WBL and EBL – STA 13+900 to 13+950;
- Highway 17 EBL – STA 14+150 to 14+200; and
- Highway 17 WBL, – STA 14+175 to 14+200.

The areas not listed above will require settlement mitigation. Given the thick cohesive deposit (the bottom of which is up to about 19.5 m below ground surface), the associated magnitude of primary and secondary consolidation settlement (150 mm) and 40 mm of expected differential settlement of the foundation soils under a 3.1 m grade raise in the widened area, the most practical method of construction is to preload the embankment widening, allowing settlement to occur while the traffic is using the widened highway section, followed by maintenance of the roadway in the future. This method does not meet the MTO settlement criteria for post-construction settlement but is more practical from a cost and a construction standpoint compared to other technically feasible options.

6.5.3.3.1 Consolidation and Maintenance

We recommend a construction approach that involves constructing (widening and raising) the embankments to their final geometry, utilizing the embankments as the travelled highway and then conducting ongoing maintenance, as may be required to re-grade the highway to accommodate the estimated 80 mm of settlement (approximately 90 per cent of the primary consolidation settlement) expected to occur over about 6 years. While this construction option does not meet the MTO settlement criteria in the short term, it is still considered the most practical option given that the magnitude of total settlement at the new outside north edge of the EBL pavement is about 150 mm (90 mm primary and 60 mm creep). The widened embankment will remain stable while in use as a travelled lane but the expected post constructed settlements will require maintenance. This alternative relies on the fact that while the expected settlements exceed the MTO settlement criteria for a widened embankment (Figure 3, MTO 2010), the embankment can still function as a travelled lane while consolidation takes place.

While this construction approach does not strictly require the installation of instrumentation to monitor for settlement, it would be prudent and it is recommended that settlement be monitored, however, it is not required to monitor pore pressures for embankment stability. The embankment monitoring can consist of a series of settlement plates installed within the embankment at the crest of the widened portions of the embankments provided guide rail installation is not impacted and the monitoring points remain accessible. Settlement plates in the shoulder or on the slope (or nail pins in pavement) will be required to be installed along the full length of the high fill section on the south side of the widened embankment at offsets to be determined once the final cross sections are known. For a 300 m long section, settlement plates at approximately 50 m spacing would be appropriate. Monthly readings of the settlement plates are recommended for the first year of monitoring and quarterly readings afterwards until the decrease in the rate of settlement indicates that the remaining settlement is within the MTO criteria, likely up to 6 years.

The total post-construction settlement (i.e., after construction of the widened embankments is complete and traffic is using the lanes) for the Highway 17 EBL embankment expected during the consolidation period is estimated to be 150 mm (comprised of 90 mm of primary settlement plus 60 mm creep settlement plus fill settlement) which exceeds the settlement criteria. The differential settlement of 40 mm between the new centreline and new outside edge of pavement lane also exceeds the criterion of 200:1. During the approximately 6 year consolidation period, approximately 80 mm of settlement will have occurred on the new outside edge of pavement and approximately 50 mm at the new highway centreline. The estimated total and differential settlement after approximately 6 years is about 50 mm and 5 mm at the new outside edge of pavement, respectively, which meet the MTO criteria. The results of the analysis are shown on Figure C25.

The main advantages of this option are that there is neither a delay in the construction schedule nor any need to divert traffic for multiple years during staged construction. The disadvantages of this option are that it does not meet the MTO settlement criteria and future highway maintenance is likely to be required.

6.5.3.3.2 Lightweight Fill

In order to meet the settlement criteria in the short term, lightweight (EPS) fill could be incorporated into the widened embankment mass. The Highway 17 WBL and EBL embankments can be widened to the north using a 1 m thick layer of EPS under the pavement structure of the new embankment (full width, not to interfere with guide rail installation) and an additional 1 m of EPS (for a total of 2 m) would be required within the remainder of the north half of the new embankment. This will require sub-excavation of the existing fill to accommodate the EPS. The EPS should be stepped in 0.3 m to 0.5 m increments across the embankment and in the taper zones longitudinally along the highway. Essentially, with the incorporation of this volume of EPS into the embankment mass, the induced settlement will be minimal and will not result in creep settlement. Total and differential post-construction settlement is estimated to be less than 10 mm.

The main advantages of this option are that it meets the post-construction settlement criteria in the short term and does not create delays in the construction schedule. The disadvantage of this option is the substantial cost of EPS fill, which is typically an order of magnitude higher than other fill materials, as well as the need to excavate a portion of the existing embankments in order to install the EPS. Generally, this option is not considered practical due to the added cost of material compared to the consolidation and maintenance option.

6.6 Subgrade Preparation and Embankment Construction

The following sections discuss general aspects of subgrade preparation and embankment construction for the high fill/swamp crossing areas, including: removal of organic materials; excavation and replacement of soft, cohesive deposits; groundwater control; placement of embankment fills, slope flattening and platform widening.

A summary of the recommended/preferred foundation mitigation option for each high fill/swamp crossing area is presented in Table 5. The summary contains: recommendations on embankment fill types and side slope profiles; estimated maximum depth of organic deposits encountered; the magnitude of estimated settlement (during and post-construction) for the embankment materials and the foundation soils; recommended width of platform widening as may be required to accommodate future raising of the embankment; and the recommended Ontario Provincial Standard Drawings (OPSD) excavation guideline.

6.6.1 Removal of Organic Deposits

Based on the subsurface information from the boreholes advanced during the field investigation, the thickness of organic deposits (i.e., peat and topsoil) in the proposed Highway 17 alignment generally ranges from about 0.1 m to 4.0 m, as presented in Table 3. After clearing and grubbing the high fill/swamp crossing areas and prior to the placement of any fill for the new construction, all organic deposits should be stripped from the plan limits of the proposed works, including toe berms, if applicable. The organic materials should be removed using construction procedures in accordance with OPSS 209 (Embankments Over Swamps and Compressible Soils) where the removal and backfilling operations are carried out simultaneously. An NSSP for excavation of organics should be included in the contract documents and an example is included in Appendix D.

In areas where the new embankments are being constructed away from existing embankments, the excavation limits should be consistent with OPSD 203.010 (Embankments Over Swamp, New Construction, modified to remove the restrictions on the height of the embankment and the depth of excavation (i.e., Note A). In areas where the existing embankments are to be widened, the organics should be removed below the toe of the widened embankment in accordance with OPSD 203.020 (Embankments over Swamp, Existing Slope Excavated to 1H:1V). If space is not sufficient for the proposed slopes (as be determined by the grading), then temporary roadway protection may be required as per OPSS 539 (Temporary Protection Systems) using Performance Level 2.

All excavations must be carried out in accordance with Ontario Regulation 213 of the Ontario Occupational Health and Safety Act for Construction Projects (as amended). In addition, provisions for traffic control measures should be included in the Contract Documents to maintain the safe operation of Highway 17, St. Pothier Road and any associated side roads or detours that are in close proximity to the excavation operations.

6.6.2 Groundwater and Surface Water Control

Excavation within the plan limits of the proposed works will be required to remove organic deposits prior to embankment fill placement, which will extend below the water table. Groundwater flow into the excavations will occur due to the presence of relatively permeable deposits and relatively high groundwater levels observed in the low-lying high fill/swamp crossing areas. Unwatering is not required for the excavation and backfilling in the high fill/swamp crossing areas, however, surface water should be directed away from the excavations at all times.

6.6.3 Backfilling

In general, it is recommended that rock fill be used for replacement of the sub-excavated materials. However, in areas where wick drains are required to mitigate stability and/or post-construction settlements, it is recommended that OPSS.PROV 1010 (Aggregates) Granular 'B' Type II be used for the replacement of the sub-excavated materials. Where sub-excavation of organic deposits is being carried out as a foundation mitigation option, it will not likely be possible to place rock fill or granular fill in accordance with OPSS.PROV 206 (Grading), as discussed in Section 6.6.5. For placement below the water table, rock fill and granular fill will likely have to be end dumped as the excavation advances.

6.6.4 Embankment Fill Placement

Placement of rock fill and granular fill above the water table for construction of new embankments should be should be placed and compacted in accordance with OPSS 501 (Compacting) and with the requirements as outlined in OPSS.PROV 206 (Grading). The rock fill should not be dumped in final position, but should be deposited on and pushed forward over the end of the layer being constructed. Voids and bridging should be minimized by blading, dozing and 'chinking' the rock to form a dense, compacted mass. Side slopes for rock fill embankments should be no steeper than 1.25H:1V.

Where a surcharge fill or EPS levelling pad is required, granular fill should be placed in regular lifts with loose thickness not exceeding 300 mm and compacted to at least 95 per cent of the standard Proctor maximum dry density. Side slopes for granular fill should be no steeper than 2H:1V.

Where a large thickness of EPS is required in the embankment and a partial preload is recommended, consideration should be given to constructing the preload embankment of OPSS.PROV 1010 (Aggregates) Granular 'B' Type II at side slopes of 2H:1V.

Where the existing embankments are to be widened, the new fill should be "keyed-in" or benched into the existing embankment fills, in accordance with OPSD 208.010 (Benching of Earth Slopes).

The EPS fill should be installed in accordance with the manufacturer's requirements. It is recommended that a levelling pad comprised of a minimum 300 mm thick layer of OPSS.PROV 1010 (Aggregates) Granular 'A' be placed prior to the installation of the EPS. The EPS should be encapsulated by a 10 mil thick polyethylene sheet, and a minimum 125 mm thick reinforced concrete pad (designed by others) should be constructed on top of the EPS, followed by the placement of a protective cover/pavement structure over the EPS (for a minimum thickness of 1 m including the concrete pad, compacted granular materials and asphalt). The EPS on the side slopes of the embankments should be covered with a 2 m thick layer of conventional soil. The EPS should be placed to avoid conflict with guide rail installation, if any. Specifications to supply and install the EPS should be incorporated into an NSSP in the Contract (an example is included in Appendix D.

6.7 Slope Flattening

We understand that consideration is being given to flattening the proposed embankment rock fill slopes using surplus excavated materials, which is typically considered for all embankments under 4.5 m high as per OPSD 203.010 (Embankments Over Swamp) and OPSD 203.020 (Embankments over Swamp, Existing Slope Excavated to 1H:1V). However, depending on the type of material used, and the timing of placement of the surplus material, slope flattening may adversely affect the long-term performance of the roadway by inducing further post-construction settlement. Considerations with respect to settlement and stability are discussed below. It is assumed that the rock fill embankment side slopes will be constructed at an inclination of 1.25H:1V and that the flattened side slopes will be constructed at 3H:1V or flatter. It is also understood that the material used for the slope flattening will likely consist of the excavated organic material or other excess earth material, excavated elsewhere or locally.

6.7.1.1 Stability

In general, global stability is enhanced when side slopes are flattened, hence the FoS of the flattened embankment slopes would be greater than the FoS of the existing embankment slopes.

6.7.1.2 Settlement

Post-construction settlement of the embankments will occur as a result of placement of the excess material in the slope flattening areas of the embankments. Therefore, the timing of placement of the additional/excess material load should be considered in determining whether slope flattening should be implemented. Three scenarios are presented below for different stages of placement of the additional slope flattening material as well as the corresponding settlement implications.

1) Concurrently with construction of the embankment (in stages where required). This construction method would produce the least amount of post-construction settlement of the roadway embankment.

2) After construction of the preload embankment and prior to placement of the final surcharge and/or prior to the full preload/surcharge period. Any settlement induced prior to construction of the final roadway could be accommodated by grading operations.

3) After the preload/surcharge period is complete. This construction method imposes additional loads from the slope flattening material, which will cause immediate and long-term settlement beneath both the embankment side slopes and the roadway and is the least preferred construction method. The magnitude of the settlement could be significant, depending on the embankment geometry and subsoil conditions in the area.

6.8 Embankment Platform Widening

In accordance with the requirements of MTO Northern Region Engineering Directive NRE 98-200, Northern Region Embankment Design Guidelines, the construction of the embankments should include an allowance for platform widening (in 0.5 m increments) to accommodate settlements during construction, as well as post-construction settlements, so that the minimum standard shoulder widths are maintained if future grade raises on the embankments are required. According to NRE 98-200, the need for future raises in road grade could occur due to settlement/compression of the embankment fill, settlement of the foundation soils and to accommodate future pavement overlays up to 200 mm thick. We understand that this directive applies to all rock fill embankments, as well as for granular fill embankments, where widening restrictions are present (such as the presence of a sensitive body of water or due to space/property issues). It is further understood that the minimum required platform widening on major highways (i.e., including Highway 17) over swamp crossings is 2 m per side, unless the preferred mitigation option eliminates uncertainty regarding embankment settlement/performance (i.e., full sub-excavation to bedrock and backfilling with granular material). For non-major highways and roadways (i.e., St. Pothier Road) over swamp crossings, the minimum required platform widening is 1 m per side.

The minimum required embankment platform widening (per embankment side) is calculated based on the estimated consolidation settlement of the foundation soils (including creep) and the settlement/compression of the embankment fill plus an additional 200 mm for the future pavement overlay, multiplied by the horizontal component of the side slope of the pavement structure (4H:1V), but cannot be less than the minimum platform widening requirements as described above.

For the proposed embankments in these swamp crossing/high fill areas, the minimum platform widening values are summarized in Table 5. The initial platform widening is required to account for settlement during and post construction. The final platform widening is required to account for post-construction settlement and future overlay.

7.0 CLOSURE

This report was prepared by Mr. Evan Childerhose, P.Eng., and the technical aspects were reviewed by Ms. Sarah E. M. Poot, P.Eng., a senior geotechnical engineer and Associate of Golder. Mr. Jorge M.A. Costa, P.Eng., Golder's Designated MTO Contact for this project and a Principal of Golder, conducted an independent quality control review of the report.

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OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS PROV. 206	Construction Specification for Grading
OPSS PROV. 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

Ontario Water Resources Act:

Ontario Regulation 903/90 Wells (as amended)

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
ln x,	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
FoS	factor of safety

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
σ_1, σ_2, σ_3	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

* Density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index $= (w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index $= (w - w_p) / I_p$
I_C	consistency index $= (w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index $= (e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
c_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio $= \sigma'_p / \sigma'_{vo}$

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = tan δ
c'	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes: 1 $\tau = c' + \sigma' \tan \phi'$

2 shear strength = (compressive strength)/2

LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:
The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; N_d:
The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure
PM: Sampler advanced by manual pressure
WH: Sampler advanced by static weight of hammer
WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)
A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

Density Index / Relative Density	**N Blows/300 mm or Blows/ft**
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils
Consistency

	c_u, s_u kPa	c_u, s_u psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

Note: 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

V. MINOR SOIL CONSTITUENTS

Per cent by Weight	**Modifier**	**Example**
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand

Table 1: Summary of High Fill Areas

Foundation Investigation Area	Foundation Investigation High Fill Area Designation	Maximum Proposed Embankment Height[1]	Boreholes/DCPTs	Appendix
Highway 17 WBL STA 12+220 to 12+570 Township of Louise	H1	5.7 m	16 Boreholes (H1-1 to H1-9, H1-11 to H1-15, C1-1 and C1-2) and 6 DCPTs (H1-DC1 to H1-DC6)	A
Highway 17 EBL STA 12+220 to 12+570 Township of Louise	H1	5.7 m	17 Boreholes (H1-16 to H1-30, C1-3, C1-4) 6 DCPTs (H1-DC7 to H1-DC12)	A
Highway 17 WBL STA 13+140 to 13+390 Township of Louise	H2	5.0 m	21 Boreholes (H2-1 to H2-21) 10 DCPTs (H2-DC1 to H2-DC10)	B
Highway 17 EBL STA 13+140 to 13+390 Township of Louise	H2	5.0 m	22 Boreholes (H2-22 to H2-43) 11 DCPTs (H2-DC11 to H2-DC21)	B
St. Pothier Road STA 9+400 to 9+600 Township of Louise	H2	4.4 m	17 Boreholes (H2-44 to H2-60) 8 DCPTs (H2-DC22 to H2-DC29)	B
Highway 17 WBL STA 13+900 to 14+200 Township of Denison	H3	3.8 m	13 Boreholes (H3-1 to H3-13) 6 DCPTs (H3-DC1 to H3-DC6)	C
Highway 17 EBL STA 13+900 to 14+200 Township of Denison	H3	3.8 m	13 Boreholes (H3-14 to H3-26) 6 DCPTs (H3-DC7 to H3-DC12)	C

Note: 1. Based on centreline of highway and existing ground surface profiles, dated February 2013. Prepared by: EC Checked by: SEMP

Table 2: Summary of Consolidation Test Parameters

Foundation Investigation Area	Borehole/ Sample No.	Elevation (m)	σ_{vo}' (kPa)	σ_p' (kPa)	$\sigma_p' - \sigma_{vo}'$ (kPa)	OCR	e_o	C_c	C_r	c_v* (cm^2/s)	Appendix
Highway 17 EBL High Fill H1	H1-19/Sa 6	236.4	31	256	225	8.3	1.86	1.04	0.02	2.1×10^{-3}	A
Highway 17 EBL High Fill H1	H1-25/Sa 8	234.6	56	135	79	2.4	1.52	0.66	0.02	3.8×10^{-3}	
Highway 17 EBL High Fill H2	H2-26/Sa 7	233.3	39	128	89	3.2	1.67	0.48	0.01	2.0×10^{-3}	B
Highway 17 EBL High Fill H2	H2-36/Sa 8A	232.7	47	132	85	2.8	2.13	0.48	0.08	3.8×10^{-4}	
Highway 17 WBL High Fill H3	H3-12/Sa 7	231.4	97	129	32	1.3	1.13	0.41	0.02	1.3×10^{-3}	C
Highway 17 EBL High Fill H3	H3-24/Sa 9	231.3	149	149	0	1.0	1.14	0.36	0.05	1.2×10^{-3}	

Note: For the normally consolidated stress range. Prepared by: EC Checked by: SEMP

where:
- σ_{vo}' is the in situ vertical effective overburden stress in kPa
- σ_p' is the preconsolidation stress in kPa
- OCR is the over consolidation ratio
- e_o is the initial void ratio
- C_c is the compression index
- C_r is the recompression index
- c_v is the coefficient of consolidation in cm^2/s

Table 3: Summary of Foundation Engineering Parameters

Foundation Investigation Area	Stratigraphic Unit	Top Elevation (m)	Thickness (m)	γ' (kN/m^3)	ϕ' (°)	c' (kPa)	S_u (kPa)	σ_p' (kPa)	e_o	C_c	C_r	m_v (kPa^{-1})	E' (MPa)	c_v (N/C) (cm^2/s)
High Fill Area 1 Highway 17 WBL STA 12+220 to 12+570 Highway 17 EBL STA 12+220 to 12+570	Existing Embankment Fill - Granular	246.5 to 241.6	0.2 to 6.1	21	33	-	-	-	-	-	-	-	12	-
	Peat/Topsoil	244.6 to 241.0	0.1 to 1.4	12	27	1	-	-	-	-	-	-	-	-
	Sand and Silt to Sandy Silt	242.1 to 237.2	0.2 to 2.3	19	28	-	-	-	-	-	-	-	12	-
	Clayey Silt to Silt	240.6 to 240.0	0.9 to 2.4	16.6	25	-	18 - 40	82 – 182	1.0 – 1.8	0.5 – 0.9	0.05 – 0.09	1.3×10^{-4}	-	2.0×10^{-3}
	Silty Clay to Clay	244.4 to 238.2	2.1 to 8.2											
	Clayey Silt	241.2 to 231.9	0.8 to 2.4											
	Silt to Sandy Silt	241.0 to 231.0	0.8 to 7.6	18	28	-	-	-	-	-	-	-	8	-
	Sand and Silt to Sand	240.3 to 227.9	0.4 to 8.8	18	28	-	-	-	-	-	-	-	10	-
	Sand and Gravel to Gravelly Sand	239.0 to 225.6	1.0 to 5.4	19	35	-	-	-	-	-	-	-	15	-
High Fill Area 2 Highway 17 WBL STA 13+140 to 13+390 Highway 17 EBL STA 13+140 to 13+390 St. Pothier Road 9+400 to 9+600	Peat / Organics	242.1 to 239.5	0.1 to 4.0	12	27	1	-	-	-	-	-	-	-	-
	Silty Sand	239.3	0.6	19	28	-	-	-	-	-	-	-	12	-
	Clayey Silt to Silt	242.0 to 235.9	0.5 to 5.7	16.2	25	-	16 – 22	73 – 100	1.0 – 1.8	0.5	0.05	1.3×10^{-4}	-	2.0×10^{-3}
	Silty Clay to Clay	241.7 to 233.6	1.7 to 9.8											
	Clayey Silt to Silt	237.2 to 229.5	1.3 to 4.9											
	Silt to Sandy Silt	240.6 to 226.0	0.5 to 10.4	18	28	-	-	-	-	-	-	-	8	-
	Sand and Silt to Sand	239.8 to 217.3	0.6 to 7.5	18	28	-	-	-	-	-	-	-	10	-
	Sand and Gravel to Gravelly Sand	238.0 to 217.7	0.1 to 4.2	19	35	-	-	-	-	-	-	-	15	-
High Fill Area 3 Highway 17 WBL STA 13+900 to 14+200 Highway 17 EBL STA 13+900 to 14+200	Existing Embankment Fill - Granular	247.8 to 240.9	0.9 to 7.2	21	33	-	-	-	-	-	-	-	12	-
	Existing Embankment Fill – Cohesive			20	30	-	-	-	-	-	-	-	-	-
	Peat / Topsoil	243.5 to 239.2	0.1 to 2.0	12	27	1	-	-	-	-	-	-	-	-
	Sand to Sandy Silt	244.0 to 239.1	0.6 to 3.1	18	28	-	-	-	-	-	-	-	10	-
	Clayey Silt	240.3 to 238.8	0.8 to 3.4	18.2	27	-	23 – 33	105 – 150	1.0 – 1.8	0.2 – 0.4	0.02 – 0.04	1.3×10^{-4}	-	2.0×10^{-3}
	Silty Clay to Clay	241.0 to 236.6	3.0 to 15.2											
	Clayey Silt to Silt	237.9 to 224.4	0.9 to 2.2											
	Silt to Sandy Silt	236.3 to 222.8	1.4 to 7.2	18	28	-	-	-	-	-	-	-	10	-
	Sand (Interlayer)	231.4 to 228.0	1.5 to 1.7	18	28	-	-	-	-	-	-	-	10	-
	Sand to Sand and Silt	236.3 to 219.2	1.1 to >4.3	18	28	-	-	-	-	-	-	-	15	-

Prepared by: EC
Reviewed by: SEMP

Table 4: Summary of Settlement Analyses

Foundation Investigation Area	Settlement (mm) / Delay Time	No Mitigation	Estimated Post-Construction Settlement Over 20-Year Period at the Critical Section (mm)									Preferred Foundation Mitigation Option
			Staged Construction with Toe Berms, Surcharge and Wick Drains	Surcharge and Toe Berms (Large)	Surcharge, Toe Berms (Large) and Wick Drains	Consolidation and Maintenance	Partial Preloading and Lightweight Fill		Partial Preloading, Lightweight Fill and Wick Drains	Partial Embankment Sub-Excavation and Lightweight Fill	Full Sub-Excavation and Preloading	
High Fill Area 1 Highway 17 WBL STA 12+220 to 12+570	$\delta_{primary}$ $\delta_{secondary}$ $\delta_{rock\ fill\ -\ short}$ $\delta_{rock\ fill\ -\ long}$ $\boldsymbol{\delta_{total}}$ t_{delay} Criterion = 50 mm (Widening)	70 50 0 0 **120** 3 years	n/a	n/a	n/a	70 50 0 0 **120** 3 years	50 0 0 0 **50** 2 months		n/f	n/f	n/f	Consolidation and Maintenance
High Fill Area 1 Highway 17 EBL STA 12+220 to 12+570	$\delta_{primary}$ $\delta_{secondary}$ $\delta_{rock\ fill\ -\ short}$ $\delta_{rock\ fill\ -\ long}$ $\boldsymbol{\delta_{total}}$ t_{delay} Criterion = 100 mm	585 75 50 10 **720** No delay	0 90 0 10 **100** 1.7 yrs	0 90 0 10 **100** 2.1 yrs	0 90 5 10 **100** 10 months	n/f	15 75 0 10 **100** 3.2 yrs (2.5 m EPS)		0 90 5 5 **100** 10 months (2.5 m EPS)	n/f	n/f	Staged Construction with Toe Berms, Surcharge and Wick Drains
High Fill Area 2 (Constructed Concurrent with St. Pothier Road Embankment) Highway 17 WBL STA 13+140 to 13+390 Highway 17 EBL STA 13+140 to 13+390	$\delta_{primary}$ $\delta_{secondary}$ $\delta_{rock\ fill\ -\ short}$ $\delta_{rock\ fill\ -\ long}$ $\boldsymbol{\delta_{total}}$ t_{delay} Criterion = 100 mm	615 70 60 10 **755** 3.2 years	0 95 0 5 100 1.7 years	10 80 0 10 **100** 2.5 years	0 95 0 5 **100** 9 months	n/a	20 75 0 5 100 1.8 years (EBL)	30 65 0 5 100 1.8 years (WBL)	n/f	n/f	n/f	Staged Construction with Toe Berms, Surcharge and Wick Drains
High Fill Area 2 (Constructed Prior to St. Pothier Road Embankment) Highway 17 WBL STA 13+140 to 13+390 Highway 17 EBL STA 13+140 to 13+390	$\delta_{primary}$ $\delta_{secondary}$ $\delta_{rock\ fill\ -\ short}$ $\delta_{rock\ fill\ -\ long}$ $\boldsymbol{\delta_{total}}$ t_{delay} Criterion = 100 mm	615 70 60 10 **755** 3.2 years	n/a	10 80 0 10 **100** 2.5 years	0 95 0 5 **100** 10 months	n/a	20 75 0 5 **100** 1.8 yr. 3 m EPS (EBL)	30 65 0 5 **100** 1.8 yr. 3 m EPS (WBL)	n/f	n/f	n/f	Not Recommended

Foundation Investigation Area	Settlement (mm) / Delay Time	No Mitigation	Estimated Post-Construction Settlement Over 20-Year Period at the Critical Section (mm)								Preferred Foundation Mitigation Option
			Staged Construction with Toe Berms, Surcharge and Wick Drains	Surcharge and Toe Berms (Large)	Surcharge, Toe Berms (Large) and Wick Drains	Consolidation and Maintenance	Partial Preloading and Lightweight Fill	Partial Preloading, Lightweight Fill and Wick Drains	Partial Embankment Sub-Excavation and Lightweight Fill	Full Sub-Excavation and Preloading	
High Fill Area 2 St. Pothier Road 9+400 to 9+600	$\delta_{primary}$	425	65	110	50		120				Staged Construction with Toe Berms, Surcharge and Wick Drains
	$\delta_{secondary}$	70	130	80	130		75				
	$\delta_{rock\ fill\ -\ short}$	60	0	0	10		0				
	$\delta_{rock\ fill\ -\ long}$	10	5	10	510		5				
	$\boldsymbol{\delta_{total}}$	**565**	**200**	**200**	**200**	n/a	**200**	n/f	n/f	n/f	
	t_{delay}		1.7 years	1.5 years	10 months		1.8 years				
	Criterion = 200 mm										
High Fill Area 3 Highway 17 WBL STA 13+900 to 14+200 Highway 17 EBL STA 13+900 to 14+200	$\delta_{primary}$	90				90			10		Consolidation and Maintenance
	$\delta_{secondary}$	60				60			0		
	$\delta_{rock\ fill\ –\ short}$	20				20			0		
	$\delta_{rock\ fill\ –\ long}$	5				5			0		
	$\boldsymbol{\delta_{total}}$	**175**	n/f	n/f	n/f	**175**	n/f	n/f	**10**	n/f	
	t_{delay}	6 years				6 years			0 years (1 m EPS)		
	Criterion = 50 mm (Widening)										

n/f = not feasible

Prepared by: EC
Reviewed by: SEMP

Table 5: Summary of Preferred Foundation Mitigation Options

Foundation Investigation Area	Foundation Design Issue (Maximum Height of Fill)	Topography and Surface Conditions	Recommended Embankment Side Slope and Platform Widening	Maximum Thickness of Organics Encountered Along Alignment[1]	Preferred Stability/ Settlement Mitigation Option[2,3]	Estimated Settlement (δ) During Construction at the Critical Section	Estimated Post-Construction Settlement (δ) Over 20-Year Period at the Critical Section	Swamp Excavation/ Organic Removal Specification
High Fill Area 1 Highway 17 WBL STA 12+220 to 12+570 Highway 17 EBL STA 12+220 to 12+570	High Fill (5.6 m) High Fill (5.7 m)	Low-lying swamp area with moderate forest to the east and an existing highway embankment running along the same alignment as the proposed WBL.	1.25H:1V (Rock Fill) 2 m initial platform 1.5 m final platform	Topsoil and near surface cohesive soils up to about 10.2 m below ground surface.	Consolidation and Maintenance	$\delta_{Immediate} = 50$ mm $\delta_{Primary} = 70$ mm $\delta_{Rock\ Fill} = 25$ mm	$\delta_{Primary} = 70$ mm $\delta_{Secondary} = 50$ mm $\delta_{Rock\ Fill} = \sim 0$ mm (maintenance required)	OPSD 203.020
					Staged Construction with Toe Berms, Surcharge and Wick Drains (total surcharge 1.7 years)	$\delta_{Immediate} = 110$ mm $\delta_{Primary} = 735$ mm $\delta_{Rock\ Fill} = 60$ mm	$\delta_{Primary} = 0$ mm $\delta_{Secondary} = 90$ mm $\delta_{Rock\ Fill} = 10$ mm	OPSD 203.010
High Fill Area 2 (Constructed Concurrent with St. Pothier Road Embankment) Highway 17 WBL STA 13+140 to 13+390 Highway 17 EBL STA 13+140 to 13+390	Swamp Crossing (about 5.0 m)	Low-lying swamp covered by tall grasses.	1.25H:1V (Rock Fill) 2 m initial platform 1.5 m final platform	Peat and near surface cohesive soils up to about 13.5 m below ground surface.	Staged Construction with Toe Berms, Surcharge and Wick Drains (total surcharge 1.7 years)	$\delta_{Immediate} = 75$ mm $\delta_{Primary} = 820$ mm $\delta_{Rock\ Fill} = 65$ mm	$\delta_{Primary} = 0$ mm $\delta_{Secondary} = 95$ mm $\delta_{Rock\ Fill} = 5$ mm	OPSD 203.010
High Fill Area 2 St. Pothier Road 9+400 to 9+600	Swamp Crossing (about 4.4 m)	Low-lying swamp covered by tall grasses.	1.25H:1V (Rock Fill) 1 m initial platform 1 m final platform	Peat and near surface cohesive soils up to about 13.5 m below ground surface.	Staged Construction with Toe Berms, Surcharge and Wick Drains (total surcharge 1.7 years)	$\delta_{Immediate} = 80$ mm $\delta_{Primary} = 485$ mm $\delta_{Rock\ Fill} = 65$ mm	$\delta_{Primary} = 65$ mm $\delta_{Secondary} = 130$ mm $\delta_{Rock\ Fill} = 5$ mm	OPSD 203.010

Table 5: Summary of Preferred Foundation Mitigation Options

Foundation Investigation Area	Foundation Design Issue (Maximum Height of Fill)	Topography and Surface Conditions	Recommended Embankment Side Slope and Platform Widening	Maximum Thickness of Organics Encountered Along Alignment[1]	Preferred Stability/ Settlement Mitigation Option[2,3]	Estimated Settlement (δ) During Construction at the Critical Section	Estimated Post-Construction Settlement (δ) Over 20-Year Period at the Critical Section	Swamp Excavation/ Organic Removal Specification
High Fill Area 3 Highway 17 WBL STA 13+900 to 14+200 Highway 17 EBL STA 13+900 to 14+200	High Fill (3.8 m) High Fill (3.8 m)	A low-lying swampy area with the existing four-lane highway transitioning into a two-lane undivided highway from east to west.	1.25H:1V (Rock Fill)	Peat and near surface cohesive soils up to about 19.5 m below ground surface.	Consolidation and Maintenance	$\delta_{Immediate}$ = 25 mm $\delta_{Primary}$ = 90 mm $\delta_{Rock\ Fill}$ = 25 mm	$\delta_{Primary}$ = 90 mm $\delta_{Secondary}$ = 60 mm $\delta_{Rock\ Fill}$ = 25 mm (maintenance required)	OPSD 203.020

Prepared By: EC Reviewed By: SEMP

MINISTRY OF TRANSPORTATION, ONTARIO

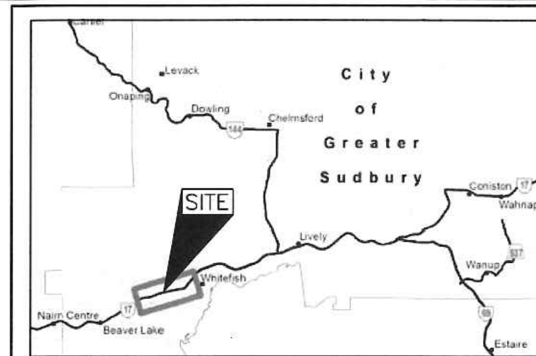
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 156-98-00

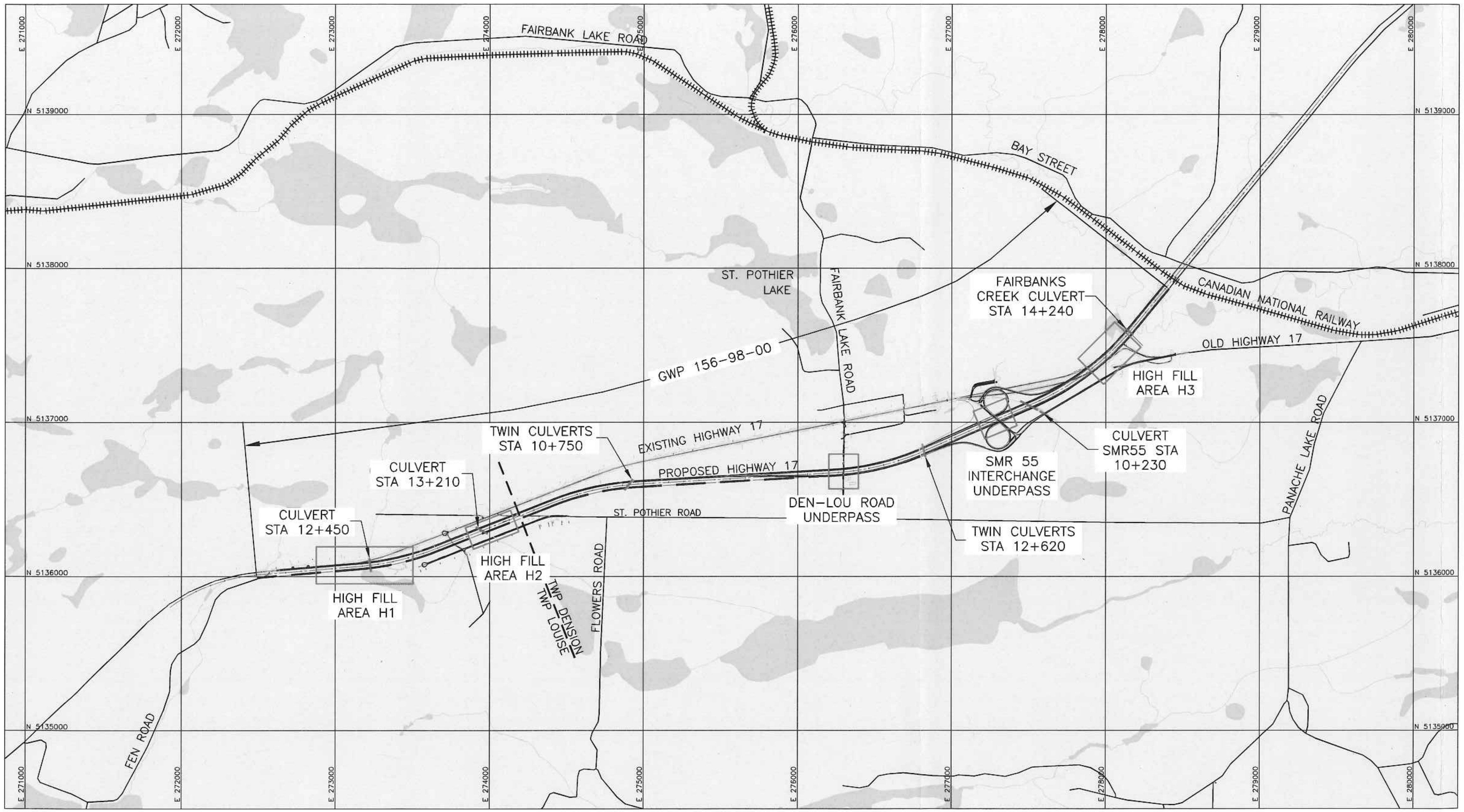
SHEET

HIGHWAY 17
SITE LOCATION PLAN

Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA



KEY PLAN
10 0 10 20 km



PLAN

SCALE
300 0 300 600 m

REFERENCE

Base plans provided by Golder GIS and highway alignment provided in digital format by DM Wills, drawing file EBL & WBL PROFILES.dwg received Feb 28, 2013.

NO.	DATE	BY	REVISION

HWY. 17	PROJECT NO. 11-1191-0007		DIST.
SUBM'D. MT	CHKD.	DATE: APR 2015	SITE:
DRAWN: TB	CHKD. SEMP	APPD. JMAC	DWG. 1

APPENDIX A

HIGHWAY 17 WBL – STA 12+220 TO STA 12+570 AND HIGHWAY 17 EBL – STA 12+220 TO 12+570 (HIGH FILL H1)