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SHOREPLAN

October 22, 2018

Laurie Wills, P. Eng.
Director, Public Works Division
Town of Cobourg
740 Division Street, Building 7
Cobourg, ON K9A 0H6

lwills@cobourg.ca

Dear Laurie Wills,

Re: Cobourg East Pier Investigation
Our File: 18-2775

Shoreplan Engineering Limited (Shoreplan) engineering was retained by the town of Cobourg to investigate the condition of the East Pier in Cobourg located between the Cobourg marina and the Cobourg Beach along the north shores of Lake Ontario. The pier is approximately 250m long. It is approximately 20m at the north end and 30m at the south end. The south part has steel sheet piles on the east and west sides while the north part has steel sheet piles on the west side and a stone revetment on the east side. The pier and the breakwater that extends from its south end of the pier protect the adjacent marina to the west from wave action. A plan of the pier area is provided on Figure 1.

This investigation was in response to recent and long term settlement issues with the asphalt deck on the pier. Shoreplan's investigation comprised of two stages. An initial dive inspection of the outer walls of the pier was conducted to investigate potential paths for removal of the core material from the pier and guide selection of locations of interior investigations. This was then followed by the excavation of investigative pits through the deck. The test pits were completed in lieu of a full geotechnical investigation as they were deemed more appropriate based on the findings of the background and underwater review.

We contacted Small Craft Harbour branch of the Department of Fisheries and Oceans to request any design drawings or information that may be in their files. We were advised that the files now rest with the Public Works Canada and are archived within their system. A request for the information will be made by them. No information has been received to date.

Dive Inspection

The inspection of the outside walls of the pier structure was conducted on August 2nd 2018, by a dive team from Dundee Marine Inc. (Dundee) that was supervised by a Shoreplan engineer. The inspection began at the north end of the revetment

on the east side of the pier. This end was marked as station 0-105m. Station chainage is illustrated on Figure 2. Water level on the day of the dive was approximately 75.0 m IGLD85, as recorded at the water level gauge in Cobourg.

East Wall

Stones along the revetment were found to be placed in a random fashion with small gaps between them as seen in Photo 1. The lake bottom composition was observed as mostly sand material. There was no evidence of movement in the revetment stones, no missing stones or evidence of material spilling out from behind the revetment.

A steel sheet pile wall starts at the south end of the revetment (Photo 2). This point was marked as chainage 0+000m. The next corner to the east was noted at 0+015m. Water depth at the corner at station 0+015 was approximately 1.0m on the day of inspection. Stones extending from the revetment against this wall do not continue around the corner.

From 0+000 continuing south the steel sheet pile wall is composed of z-piles. The steel sheet pile wall includes a shallow concrete cap from chainage 0+000 to 0+150 which is approximately 30 cm high. Between chainage 0+150 and 0+163 the concrete cap has sections missing in it (Photo 3). At chainage 0+163 there is a 90 degree corner and the sheet piles that continue south no longer have a cap (Photo 4). The deck is also 0.5m lower after 0+163m.

Wale bolts were located approximately 1m above the water level on the day of the dive inspection which puts them at an elevation of approximately 76m IGLD85. A few bolts were found to be missing along the length of the wall (Photo 5).

At approximately chainage 0+60m, water was seen running in and out of a small hole approximately 5cm in diameter that had been cut in the wall at water level. Rock backfill material could be seen behind the wall and there was no evidence of loss of fill material. Other similar sized holes (Photo 6) were found at chainages 0+061m, 0+098 (2 holes), 0+100m, 0+118m (above water level), 0+150 and 0+180m (above water level).

Sheetpile thickness readings were taken using an ultrasonic thickness gauge. Readings were difficult to obtain as the steel was pitted up to 1mm in depth creating an uneven surface. Both water level and below water level readings were taken at four locations along the east side of the pier. Measurements were taken around the cut hole at 0+060m to check for section loss. None was apparent as it compared to measurements of intact sheet pile directly adjacent. On average the below water level thickness measurement were in the 14mm to 18mm range. At water level the thickness measurements were less and ranged between 9.5mm to 13.5mm. It is common to find the least thickness between average and low water, which is consistent with our findings.

It was observed that all sheet piles along the entire length of the east facing wall penetrated the sandy bottom material of the lakebed and there was no evidence of undermining or any notable lean to the wall.

The sheet pile wall turns west at 0+191m at a 45 degree angle and the z-piles change to u-piles. On the day of inspection the water depth at this location was approximately 3.0m. The u-piles end at station 0+240 (Photo 7) and the breakwater continues south as a concrete cap with timber cribs beneath (Photo 8). The steel sheet piles do not continue south across the end of the pier. There is a visible void behind the sheet piles that can be seen looking in from the end towards the south.

West Wall

At the south end of the west wall there is no concrete cap, similar to the east side. A concrete cap on top of the steel sheet pile wall starts at station 0+315 and is much thicker on the west wall measuring over 1.0m thick (Photo 9). The water level was measured at 38cm below the bottom of the cap. Wall brackets were observed by the divers along this face near the lakebed. It is likely that these brackets correspond to locations of toe pins.

Similar to the east wall, small holes were found cut in the sheetpiles of the west wall. A small 4cm diameter hole was found underwater at the south end, at chainage 0+245. Stone fill material was observed behind this hole and there was no loss of material apparent. The piles change from u-pile to z-pile at chainage 0+276m with the z-piles continuing north until 0+415 where it changes back to u-pile. At the first change of piles, chainage 0+276m, another small 4cm diameter hole with ¾" stone behind it was observed below water level. Again there was no loss of material at this location.

Closer to the north end of the west wall the zebra mussel coverage increased making it difficult to observe defects in the wall however a few of the small (4 to 6cm diameter) cut holes were observed above water at chainage 0+451m and 0+475m (2 holes). Smaller holes with a maximum 3cm diameter were observed at chainages 0+567m, 0+571m and 0+578m, near the level of the tie rod bolts approximately 30cm above water line. Coarse fill material was visible through all the openings. There was also evidence of patches above and below water (Photo 10). These patches were only welded on the corners and not continuously around all edges. Tie rod bolts were seen every in-pan, a few with small holes in the wall at the edges of the square washer plates (Photo 11).

Water level and below water level ultrasonic thickness readings were taken at five locations along the west side. Thicknesses range from 13.3 to 18.6mm near the lake bed and 12.2 to 13.7 near water level. The one exception is the U-pile which underwater and at water level had a thickness reading of 13.6mm.

Metal debris, possibly a barrel, was found in front of the wall near chainage 0+526m. It was mostly covered in sand, forming a ledge.

Investigative Excavation

Three areas of interest were identified for investigation. It was noted that the majority of the settlement issues had been reported on the north end. This was evident through multiple patches in the pavement. On the south end past the revetment section fewer patches were noted. In order to identify any differences

in the substructure of the pier from the north to the south, the excavation included 2 locations on the north end of the pier in the area of the revetment, and one on the south end between the sheet pile walls on the east and west sides. On the north end areas of previous patch work was avoided.

At all three locations trenches approximately 1.5m wide were dug across the width of the pier in the east to west direction. On the south end the trench was dug approximately 1.5m deep while investigation of irregularities in the south end required deeper trenching, up to 2.5m deep. Further digging was completed in a north south direction as detailed below. The excavations were completed with the assistance of a local contractor Earthworks Excavating on September 13th and 14th.

South Trench (43° 57.2960N, 78° 9.8570W)
This trench is located approximately between chainage 0+040m and 0+440m on the south section and widest part of the pier. The location is indicated on Figure 3.

Two layers of asphalt were found, one approximately 0.5m above the other, with sand in between (Photo 12). The top layer is a double lift of asphalt measuring approximately 100mm in thickness while the lower layer is a single lift and thus approximately half the thickness at 50mm. The top layer of asphalt has a wire mesh in the top lift. The sand between the layers appears to have not been compacted as it was loose and easily removed.

A tie rod was found running east west 0.65m below the surface and just below the second lift of asphalt (Photo 13). The tie rod dips down slightly as it progresses from west to east. A turn-buckle in the tie rod was found at approximately mid span. The ties rod did not run parallel with the trench and the ends were not located along the wall, however the elevation did match the tie bolts seen from the waterside of the wall.

Just east of the centreline of the pier a concrete block was found approximately 4m wide buried 0.6m below the surface. The north edge of the block was visible, however, the south edge extended beyond the south side of the trench. The length of the block could not be determined. The trench was dug approximately 1.5m down from deck level and the bottom edge of the concrete block was not found. The tie rod runs on-top of centre block with a steel pin holding it in place (Photo 14).

Fill material encountered in this trench below the lower layer of asphalt consisted mostly of sand with some larger boulders/stones in the centre third of the pier. The fill material in the outer thirds of the trench near the east and west walls was granular material similar to Granular A or B consistency (Photo 15).

Middle Trench (43° 57.3130N, 78° 9.8490W)
This trench is located approximately between chainages 0-002m and 0+449m on the north end of the pier. The location is indicated on Figure 3.

The 2 layers of asphalt with wire mesh and sand fill were found similar to the conditions in the south trench. An approximately 4m wide concrete cap is located below the asphalt on the east side of the pier. Excavation started on the west side of the cap. The concrete cap recesses approximately 0.5m east at a depth of approximately 0.6 m. We were able to dig down approximately 1.8m in front the face of the concrete cap and found a timber beam running towards the west.

A concrete block was found east of the centre line of the pier. It is approximately 1.2m wide (east west) and 1.1m high. It was found buried 0.5m below the surface with the top in line with the second lift of asphalt. There was another 1.2m wide block found close to the west side. No obvious reason(s) for the presence of these blocks was determined.

Further digging was completed across the top the block located at centreline in the north south direction. Digging across top approximately 3m south did not expose the south edge of the block so the length is undetermined. The south edge of the 3m long excavation was almost in line with south end of this north narrow part of the pier, where the sheet pile wall and the wider section of the pier start.

Steel pipes were found around mid-point of the pier running in a north south direction (Photo 16). The pipes were just below the second layer of asphalt. Another pipe was found near the east side concrete block. No fluid was observed in the pipes.

Fill material in this trench below the lower layer of asphalt is mostly un-compacted sand, often with large stones randomly intermixed. Larger stones and rubble material was found at lower elevations.

North trench (43° 57.3470N, 78° 9.8490W)
This trench is located approximately between chainage 0-063m and 0+510m, on the north end of the pier. The location is indicated on Figure 3.

The east side of this trench had a concrete cap similar to the south and centre trenches. We were able to dig 2.2m down from top of deck (Photo 17). The east concrete cap was 1.6m thick and approximately 3m wide (east-west) extending from the top of the revetment westward. The top of the concrete block is approximately 0.6 m below the pier surface just below the lower asphalt layer.

Tie rods were found approximately 80cm down from top of concrete cap on the east side. Digging along length of pier in a north south direction immediately east of the east concrete cap, it was found that there was approximately 3.4m

between the tie rods at this location. A total of three tie rods were uncovered in this north south excavation.

A mid-point concrete block was found 1.2m below the surface. The block is approximately 0.7m wide. The top of concrete has a rough surface. Digging down in front of the block exposed timbers running east west under the concrete. The waterline was reached approximately 2.1m down from top of deck.

A concrete block 1.1m by 1.1m by 1.3m deep was also found 3.8m from the west edge cap beam. The top of the block was above the lower asphalt lift with only the top lift above it and no fill under the top lift. No obvious reason(s) for the presence of this block was determined.

Fill material at this location both below and above the lower asphalt layer, is mostly un-compacted sand. At deeper elevations larger stones and rubble material was found. Sand was not found between the large stones that were placed adjacent to the east concrete cap at deep elevations (Photo 18).

Conclusions around Condition

The Cobourg pier is known to be over 180 years old with records of its presence stretching back to 1832. Since this time it has been modified and expanded as became obvious digging through the pier and from review of readily available historical photographs.

Specific deficiencies are noted below and believed to combine to be responsible for the sink holes in the deck. In summary, typical age related deficiencies in the pier structure allow the compacted sand fill to move into the crevices that either exist or are gradually created in the lower part of the pier structure. No one component of the pier was found to a single cause of the observed settlement and sinkholes.

Outside Steel Sheet Pile Wall and Revetment Condition

Inspection of the outside steel sheet pile wall did not indicate any failures in the wall including no signs of separation of the sheet piles nor undermining of the sheets. Although small cut holes were found, they contained coarse fill material behind them and would not account for any major material loss through the wall.

The revetment on the east end of the northern section is in good condition with no signs of movement or settlement of armour stones. It is not known if the sheet pile wall found south of the revetment extends north behind the revetment. The lack of steel sheet pile may be an issue if there are only timber cribs directly behind the revetment without filter cloth material or improperly placed or deteriorated filter cloth. The deterioration of the cribs could lead to a slow leak of material through the revetment.

Presence of Timber Cribs

Removal of the asphalt cap and digging of trenches across the pier revealed the presence of timber cribs at lower elevations below concrete elements. The cribs

are lower than 2m below the top of deck. These cribs are severely disintegrated. This deterioration is to be expected as they were likely a part of the original construction. Disintegration of timber results in loss of volume and could create voids as it progresses.

Sub-par Fill Material

Fill material in the central and northern section adjacent to the revetment consisted of uncompacted sand material and large boulders. In the most southern trench it was found that the centre third has a similar fill material while the east and west sides have proper fill material. The double layer of asphalt approximately 0.5m apart also had a layer of compacted sand material between them.

Sand is not considered an ideal fill material. It was clear that the sand was not compacted. As digging progressed the fill was easily removed and often fell into the hole as it was being dug. Fine sand can be also readily transported by water movement into crevices between rock fill, crevices created by deteriorating timber structures or loss the rough the minor holes found in the steel sheet pile structure.

Pipes were found running down the centre of the pier. These pipes were heavily deteriorated. Fill material around these pipes was not compacted and of random consistency. It could be seen on the deck that the centre line of the pier had many location where repairs to sinkholes had been completed.

Options for Repair

The pier is beyond its design life and the factors contributing to the settlement issues are related to the age or the structure and modifications of the pier completed over the decades. It is our opinion that if left as is there will be additional deterioration and settlement as times goes on. No one localized repair can resolve the potential settlement of the surface of the pier that can occur anywhere in the pier.

The options below intend to mitigate the settlement issues. However they will not stop the deterioration of the old component of the pier that are the underlying cause of the settlement. A full replacement of the pier designed to today's design standards would be the only way of ensuring an as-new function. This option has not been considered further.

In considering options for repair and remediation of the pier, intended use is a driving force. It is understood that past use has included pedestrian and vehicle access for the local public and visitors to the area. The pier has also been used for lifting boats in and out of the marina and in the past the local fair has set up rides on the pier.

Four options presented below give alternatives for retaining all or some of these functions.

Option 1 - Closed to Traffic and Naturalization
This option considers naturalization of the pier for use as a park space. This option closes the pier to any vehicular traffic. In choosing this option the only permitted use would be pedestrian traffic. You would lose any ability to use the pier for removal and launching of boats in the marina or for operating carnival rides for the local fair.

Naturalization would include removal of the asphalt topping and supporting material down 0.5m and replacement with fill material topped with grass and an asphalt pedestrian path. Natural settlement would still occur as this option does not repair any of the deficiencies discussed in this report. Regular maintenance would be required to address this settlement. However, the settlement would not lead to any serious or safety related consequences. Repairs could likely be carried out by Town's owned forces and part of typical park maintenance.

Option 2 - Replace Top Fill Material
This option retains the current look of the pier while addressing the settlement issues associated will poor fill material and poor compaction and attempts to minimize backfill penetration into the lower parts of the pier. It replaces the top 1m of existing fill with proper granular fill material, compacting it to accepted standards. This then allows for repaving of the surface. A geotextile would be used under and around the placed backfill fill and geogrid reinforcing mesh would be incorporated under the paved surface areas for added reinforcement.

This option will mitigate the settlement issues but will probably not eliminate them entirely. Maintenance will be required for occasional settlement however this option will reduce the likelihood of it occurring. As complete stability of the surface cannot be guaranteed it is recommended that access be restricted to pedestrians and small vehicles travelling at low speeds.

Any lifting operations or carnival rides would be prohibited. The one exception would be if localized installation of concrete pads, described under Option 3 below, were adopted. These pads could be specifically designed for their intended use to ensure stability over the long term.

Option 3- Piled Deck
This option leaves the current pier in place but creates a stable concrete deck using a steel piled foundation within its footprint. The concrete deck could span any portion of the pier or the entire pier. In this option we describe a span of 10m in width and the entire length of the existing pier. It could be placed to line with the west side of the existing pier to allow movement of boats in and out of the marina. As it would be supported by a piled foundation it would not be affected by any settlement of the existing structure. As such there would be no restriction for use of this deck.

The remaining foot print of the pier could be naturalized for pedestrian access, as described under Option 1 above. Assuming the 10m wide concrete deck is aligned to the west part of the pier, this would create an approximately 10 to 20m wide area to the east for park space. This area would be subjected to settlement as the removal of asphalt and placement of grass would not repair the

deficiencies. Regular maintenance would be required to address future settlement. Option 2 could be also implemented in this area.

Option 4 – Light Vehicle and Naturalization
This option considers a combination of Option 1 and Option 2. It includes a 10m wide paved area on the west side of the pier as described in Option 2 and the naturalization of the remaining area to the east as described in Option 1.

This option allows for light vehicle use on the west, paved area and pedestrian only traffic on the east park space. The park space would include a paved pedestrian pathway.

Construction Costs Estimates

Construction costs estimates were developed for each option and are summarized below in Table 1. A full breakdown of these costs can be found attached to this report in Table 2. These estimates exclude design fees and taxes.

Table 1 - Construction Cost Summary

Option 1 – Naturalization	Total $ 440,220.00	Cost/m^2 $ 70.00
Option 2 – Replace Asphalt and Fill 1m	Total $ 1,091,420.00	Cost/m^2 $ 173.00
Option 3 – Piled Deck	Total $ 3,795,660.00	Cost/m^2 $ 602.00
Option 4 – Light Vehicle & Naturalization	Total $ 719,180.00	Cost/m^2 $ 114.00

Closing Comments

The letter describes four options for dealing with the settlement experience in the surface of the pier. The ultimate solution can be any combination of the options described in the report that will support the desired uses described in your waterfront plan.

Should you have any questions please do not hesitate to contact the undersigned.

Yours truly,

Shoreplan Engineering Limited

B. Lane, P. Eng.

C.c. Terry Hoekstra - thoekstra@cobourg.ca

Figures, Pricing and Photos to follow

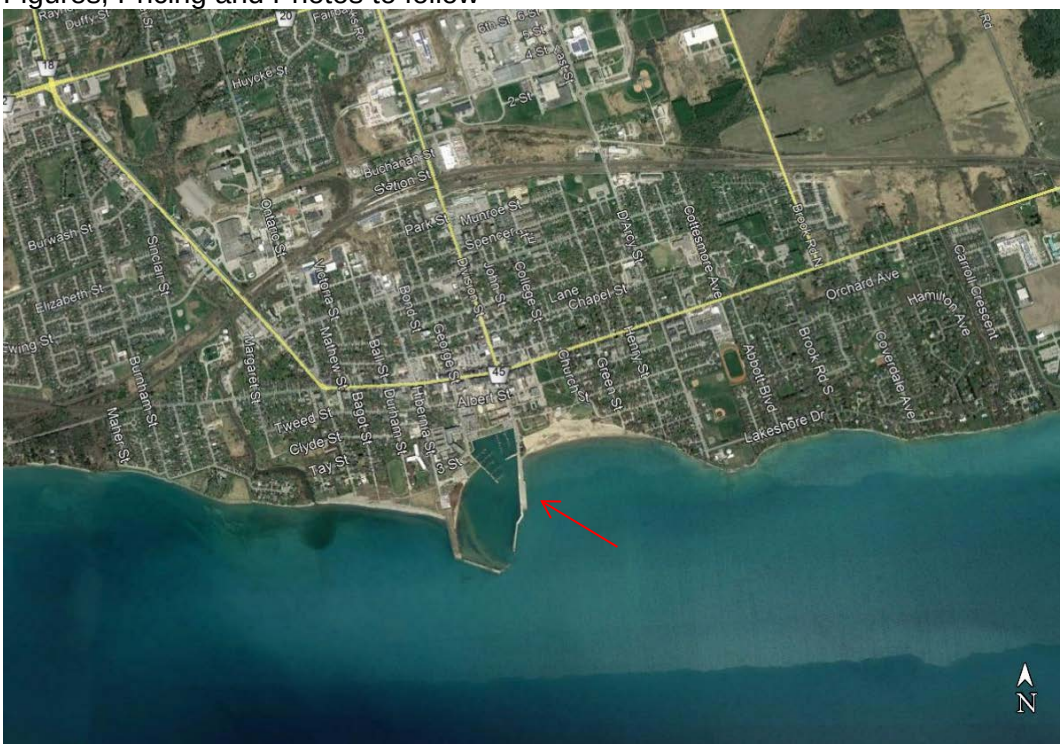

Figure 1 – Site Plan

Figure 2 – Chainage

Figure 3 - Test Pit Locations

Table 2 Cost Estimate (excludes engineering and taxes)

Option 1	**Naturalization**		**Cost/m^2**		**$**	**70.00**
Asphalt Removal	**Amount**	**Unit**		**Unit Price**		
Disposal	7100	tonne	$	12.00	$	85,200.00
Equipment	15	Day	$	3,500.00	$	52,500.00
Sod and Path						
Fill Material & Top Soil	7560	tonne	$	15.00	$	113,400.00
Sod	5550	m^2	$	12.00	$	66,600.00
Asphalt Path	750	m^2	$	40.00	$	30,000.00
Equipment	15	Day	$	3,500.00	$	52,500.00
			10% Contingency		$	40,020.00
				Total	**$**	**440,220.00**
Option 2	**Replace Asphalt and Fill 1m**		**Cost/m^2**		**$**	**173.00**
Asphalt and Fill Removal	**Amount**	**Unit**		**Unit Price**		
Disposal	14200	tonne	$	12.00	$	170,400.00
Equipment	15	Day	$	3,500.00	$	52,500.00
Rehabilitation						
Fill Material	15120	tonne	$	15.00	$	226,800.00
Asphalt repaving	6300	m^2	$	75.00	$	472,500.00
Equipment	20	Day	$	3,500.00	$	70,000.00
			10% Contingency		$	99,220.00
				Total	**$**	**1,091,220.00**
Option 3	**Piled Deck**		**Cost/m^2**		**$**	**602.00**
Piled Deck with Concrete Cap	2500	m^3	$	1,300.00	$	3,250,000.00
Using a deck 10m wide for entire length (250m)						
Naturalized Remaining Area						
Asphalt and Fill Removal	**Amount**	**Unit**		**Unit Price**		
Disposal	4300	tonne	$	12.00	$	51,600.00
Equipment	10	Day	$	3,500.00	$	35,000.00
Rehabilitation						
Fill Material & Top Soil	4560	tonne	$	15.00	$	68,400.00
Sod	3800	m^2	$	12.00	$	45,600.00
			10% Contingency		$	345,060.00
				Total	**$**	**3,795,660.00**

Option 4	Light Vehicle and Naturalization		Cost/m		$	114.00
Asphalt Removal	**Amount**	**Unit**		**Unit Price**		
Disposal	9900	tonne	$	12.00	$	118,800.00
Equipment	15	Day	$	3,500.00	$	52,500.00
Rehabilitation						
Fill Material	6000	tonne	$	15.00	$	90,000.00
Asphalt repaving	2500	m^2	$	75.00	$	187,500.00
Equipment	10	Day	$	3,500.00	$	35,000.00
Sod and Path						
Fill Material & Top Soil	4560	tonne	$	15.00	$	68,400.00
Sod	3050	m^2	$	12.00	$	36,600.00
Asphalt Path	750	m^2	$	40.00	$	30,000.00
Equipment	10	Day	$	3,500.00	$	35,000.00
			10% Contingency		$	65,380.00
			Total		**$**	**719,180.00**

Photo 1 - Revetment East Side

Photo 2 - East Side Steel Sheetpile Wall

Photo 3 - Deteriorated Concrete Cap Chainage 0+150

Photo 4 - South End Sheetpiles Without Concrete Cap

Photo 5 - Tie Rod Bolts Missing East Wall

Photo 6 - Cut Hole in East Wall

Photo 7 - South End of Pier East Sheetpiles

Photo 8 - Concrete Cap Breakwater

Photo 9 - West Side Wall

Photo 10 - Small Patches West Wall

Photo 11 - Tie with Small Hole Beside West Wall

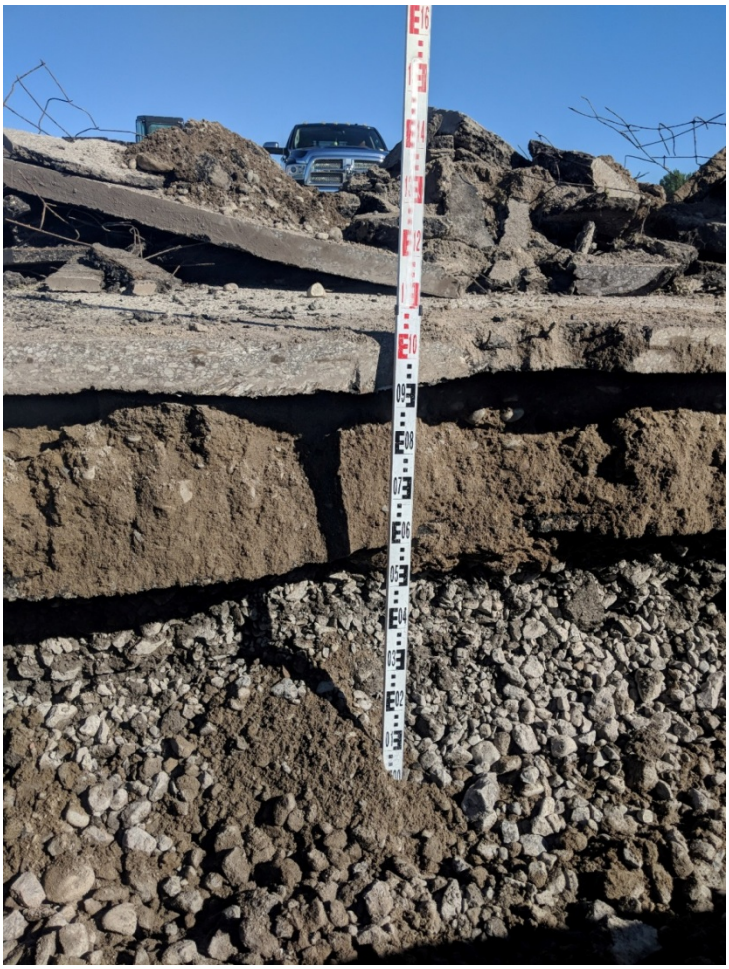

Photo 12 - Double Layer of Asphalt

Photo 13 - South Trench Tie

Photo 14 - Pin Holding Tie On Top of Concrete Block

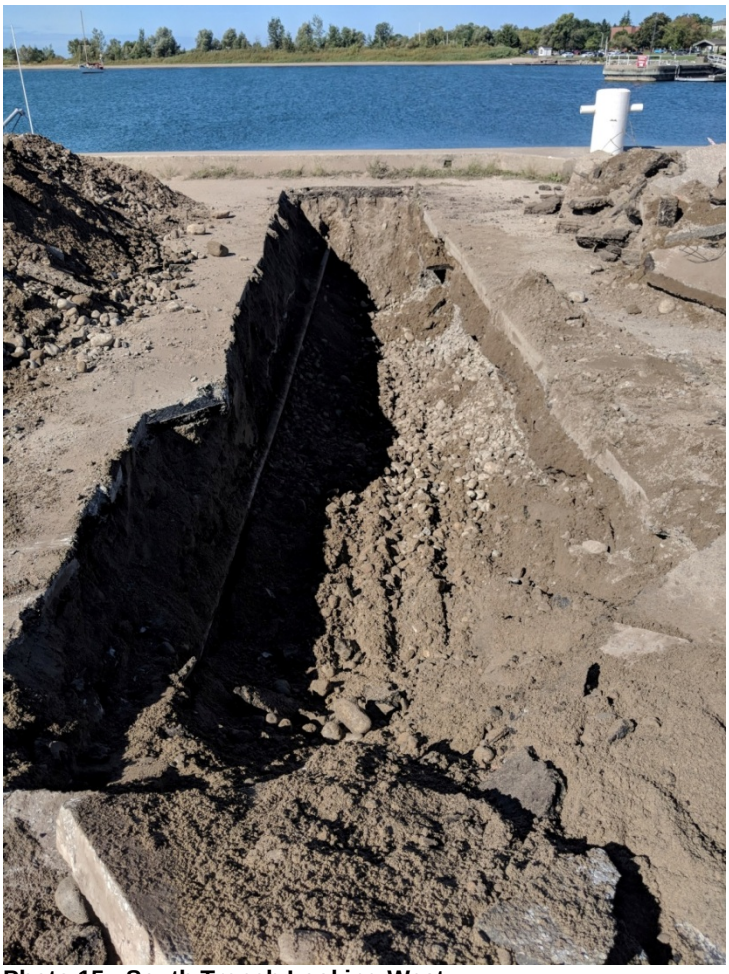

Photo 15 - South Trench Looking West

Photo 16 - Centreline Pipes

Photo 17 - North Trench Looking East

Photo 18 - North Trench Large Stone Fill Without Sand