PIPELINE CONCEPTUAL DESIGN AND CONSTRUCTION METHODOLOGY REPORT

Prepared For

NORTHERN PULP

NOVA SCOTIA CORPORATION

A PAPER EXCELLENCE COMPANY

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MOE Contract No. 36002

September, 2019

EXECUTIVE SUMMARY

Makai Ocean Engineering, Inc. has completed a preliminary study of the new marine outfall construction for Northern Pulp Nova Scotia Corporation (Northern Pulp) for the pulp mill in Abercrombie N.S. This report provides an opinion of the likely construction methods and design features of the pipeline, based on the available data and standard practices for marine pipelines.

The marine portions of the pipeline include a segment in Pictou Harbor adjacent to a short causeway heading North from the mill, prior to a terrestrial segment of the outfall which extends to Caribou Harbor. The final leg of the proposed Northern Pulp Outfall pipeline is a 3.6km of 36" diameter high density polyethylene (HDPE) marine pipeline, extending out from the Caribou Harbor ferry terminal area. The proposed pipeline will be ballasted with concrete weights, buried along the length of the marine route to the west of the ferry channel, and terminate offshore at a discharge diffuser in approximately 20m of water depth.

Considerations for design have included available staging sites for the 3.6km offshore pipeline, ballasting and weighting for long term on-bottom stability, and burial for protection from vessel traffic and ice scour.

Caribou Harbor and the nearby section of the Northumberland Straight is susceptible to ice scour, predominantly due to ice floes. To protect the proposed pipeline from damage due to impact or bearing pressure, the pipeline is envisioned to be buried to a depth of up to 3m. Burying the pipeline below the deformation region of the soil is the most effective measure to protecting pipelines from overstraining due to ice induced forces. In the 2019 survey of the proposed pipeline route by CSR GeoSurveys LTD, ice scour indicators were found between 1-9m of water depth. The depth of these scour marks was commensurate with the historically observed iceberg activity in the area, with a maximum observed scour depth after the 2018-2019 winter of 0.4m. Given the sandy-silt and light gravel soil type of the sea bottom along the pipeline route, the planned 2m of soil cover over the pipeline is anticipated to be enough to distribute the expected bearing pressure of an ice flow and provide sufficient protection. No history of ice scour was found at the planned location of the diffuser port, located outside of Caribou Harbor in 20m water depth, during the survey by CSR. Given the water depth, the shelter provided by Caribou Island, and the lack of any scour indicators an ice strike at this location appears unlikely.

Given the water depth and surveyed soil type, the recommended method of excavating the pipeline trench is mechanical means, specifically clamshell excavator, cutter-suction dredge, and long-reach backhoe excavator types. The exact method used for dredging will be determined by the selected marine contractor based on schedules, costs, and available equipment resources. The marine portions of the HDPE pipe will be constructed of extruded HDPE pipe segments. Longer segments of the HDPE pipes will be staged with concrete ballast, most likely in Pictou Harbor where the pipe can then be floated and towed into position. When ready, the pipeline will be gradually flooded along its length where it will settle into the excavated trench. Once placed, the trench will be filled to provide soil coverage to existing grade.

The 2019 geotechnical survey indicates surficial sediment layers of sand, silt, and gravely sand. Layers of glacial till, and possibly some section of bedrock, may exist several meters below these surficial sand layers. The route's shallow water depth and trench height is expected to allow for these layers, if they exist, to be broken up by mechanical means (e.g. ripper, hammer, clamshell digger). The need for blasting is considered very unlikely. Spoils from the excavation will be re-purposed as fill to cover over the trenched pipeline once placed. Excess spoils would be disposed of according to local regulations and permitting.

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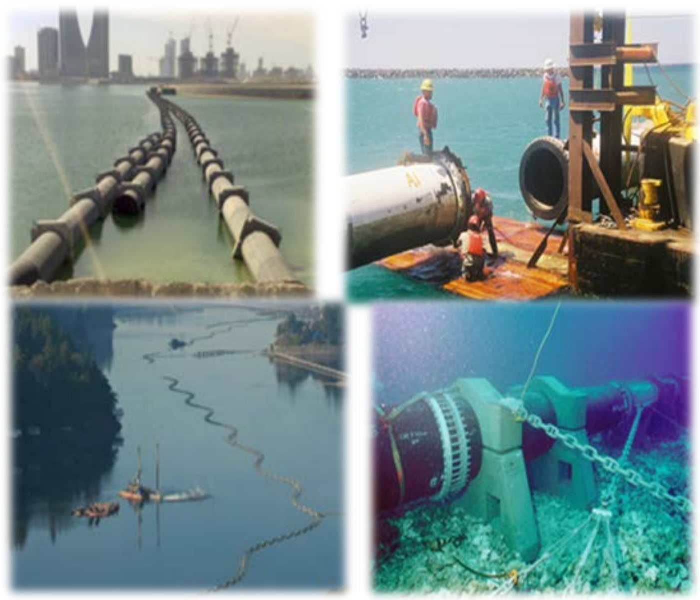
INTRODUCTION

Purpose of Document

This report describes a preliminary assessment of the construction methodology and routing for the marine portion of the Caribou Harbor outfall system, completed by Makai Ocean Engineering, Inc. (Makai) for Northern Pulp.



The approach presented in this report represents an opinion on possible ways to install the high-density polyethylene (HDPE) pipeline and is based on Makai's past project experience and standard marine pipeline installation practices. Makai has designed and been involved in the installation of numerous marine pipeline systems. Throughout the history of our HDPE projects we have provided services ranging from initial feasibility through to construction management and have built up a unique understanding of the complete HDPE process and important lessons learned from 40 years of HDPE pipeline experience; including but not limited to the design and installation of the world's largest deepest HDPE pipelines in Kona, Hawaii; the award-winning Lake Oswego Interceptor Sewer in Oregon; and others (*pictured at right*).

This report focuses on providing an overview of the technical installation and construction methodologies. Discussion or analysis of environmental permitting constraints or environmental impacts was beyond the scope of this report, including specification of turbidity limits or development of soil sampling or soil disposal requirements that may be identified elsewhere in the permitting process.

While Makai has extensive experience with HDPE pipeline installations and has taken considerable efforts to consider the site specifics and likely approaches for this project, the actual means and methods and construction processes will remain the responsibility of the Marine Contractor, and may vary from this approach.

Marine Outfall Description

The following provides an overview description of the route location, pipeline materials and the methods of construction.

The marine portion of the route consists of two section: (1) short segment of pipeline extending across Pictou Harbor adjacent to the causeway and (2) a longer segment of pipeline extending out Caribou Harbor. The offshore segment in Caribou Harbor starts in the area of the Caribou Ferry Terminal. The diffuser end is located in 20 meters water depth approximately 3.4km northeast from the Ferry Terminal docks; at position 526737.00E 5067239.45N (WGS84, UTM Zone 20).

This outfall system will be constructed from a 36" outer diameter (OD) high-density polyethylene (HDPE) pipe. The pipeline will be lightly ballasted with concrete weights, buried along the length of the marine route to the west of the ferry channel, and terminate offshore at a discharge diffuser. In total, approximately 3.6 km of 36" HDPE pipeline will be laid into a trench and buried. The concrete ballast weights used to sink the pipeline have an estimated dry weight of 1.8 metric tons.

The pipeline can be delivered by standard freight in lengths up to 16.7m (55'), towed in longer continuous segments of approximately 500m length, or, possibly, extruded on-site. Regardless of delivery method of the initial HDPE pipeline segments, the pipelines will be stored on-site at the Northern Pulp mill and fused into longer, continuous sections. An alternate manufacturing method for the pipeline is to manufacture it directly on site, using a mobile extrusion plant (e.g. TUBI) to fabricate the pipeline in single, uninterrupted lengths. Makai has not been involved in a project using this on-site technology, but with industry standard quality controls there is not a technical reason this alternative should not be considered. Extrusion plants are known to extrude directly into coastal inlets and fjords (e.g. AGRU North America and PIPELIFE Norway) in order to extrude longer pipeline segments. The pipe weights, made from re-enforced concrete, will be pre-cast off-site and delivered and stored at the same on-site location. The pipelines will be pulled into Pictou Harbor. During this process pipe weights can be added onto the pipelines, with lengths over 1 kilometer possible. Pipe weights can be added as pipelines are pulled into the harbor, or added to the pipelines alongside a dedicated barge as the pipelines are floating. The fused and ballasted pipelines can be towed to Caribou Harbor and moored until deployment. In this case, the pipeline would be towed at several knots, taking 4-8 hours to complete. The pipelines may also be towed un-weighted, with pipe weights similarly attached via a barge at a Caribou Harbor mooring site.

In order to eliminate flanges along the majority of the offshore pipeline route, all segments would require a butt-welded fusion connection. These fusion joints could be completed at the Pictou Harbor staging site, although it is more likely to occur in Caribou Harbor via jack-up barges with pipeline clamping equipment and HDPE fusion machines. Non-destructive testing of joints can be completed for additional on-site quality control.

Prior to installation along the outfall route, the seafloor will be dredged to a depth of up to 3 meters below natural grade. The pipelines will be pulled into position, and controllably submerged into their final position before backfilling and burying.

REPORT CONTENTS

The remainder of this report presents a more detailed opinion of possible construction means and methods including:

- The onshore staging method and staging sites for the HDPE pipeline and concrete weight materials storage, HDPE pipeline fusion, and initial deployment into Pictou Harbor.
- Pipeline towing from Pictou Harbor to Caribou Harbor.
- Temporary storage of ballasted HDPE pipelines at moorings located in Caribou Harbor.
- Dredging of the pipeline route prior to pipeline installation.
- Fusion of HDPE pipeline segments at the Caribou Harbor mooring, followed by controlled submergence of the pipeline into the pre-dredged alignment.
- Connection of pipeline end coupling connections to the diffuser and terrestrial pipeline.
- Backfill and commissioning of the HDPE outfall system.

Figure 1, Figure 2, Figure 3, and Figure 4 on the following pages shows an overview of the route and location, a concept design of the concrete ballast pipe weights, and an example of a 3 meter pipeline trench.

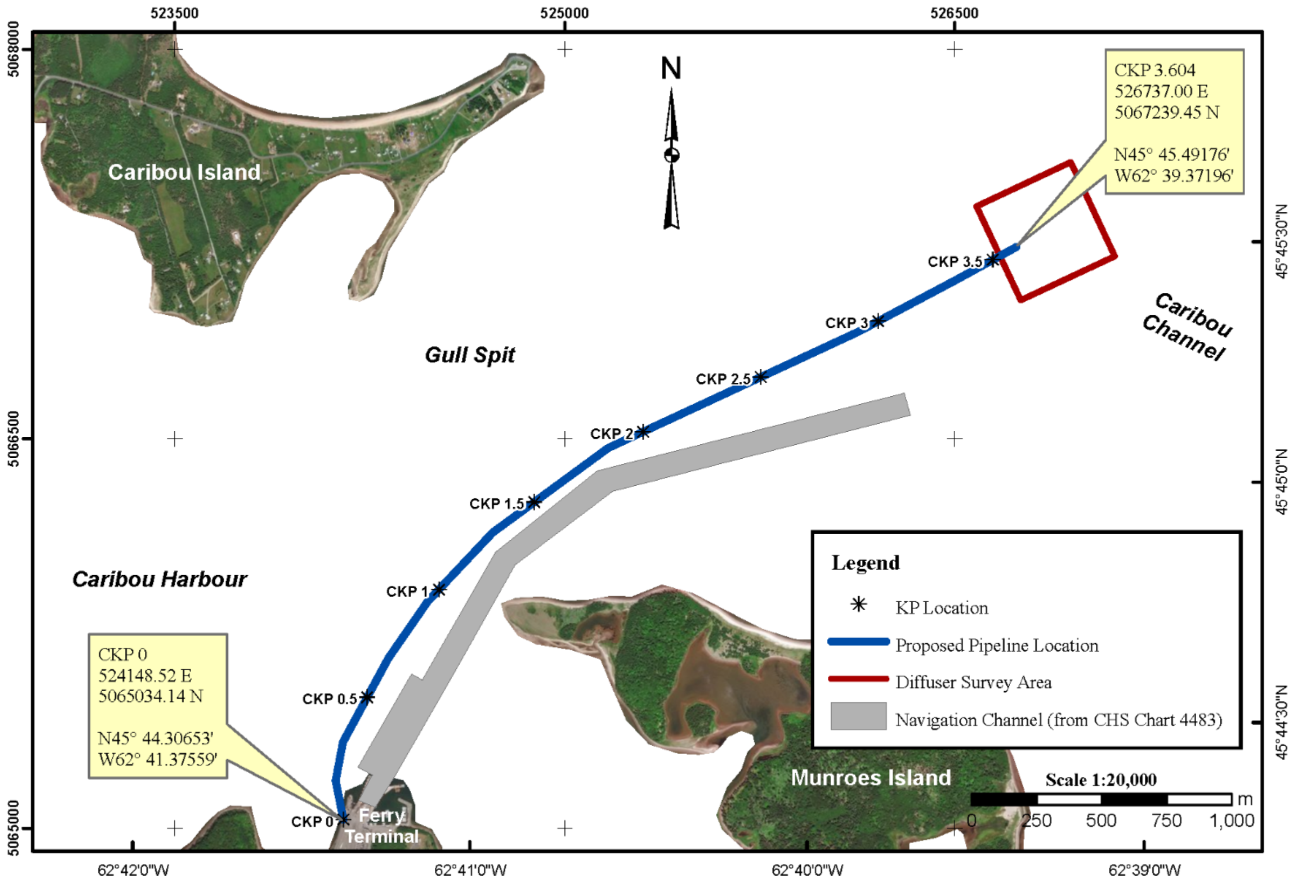


Figure 1. ***Chart of Caribou Harbor showing proposed route and location of diffuser end.***

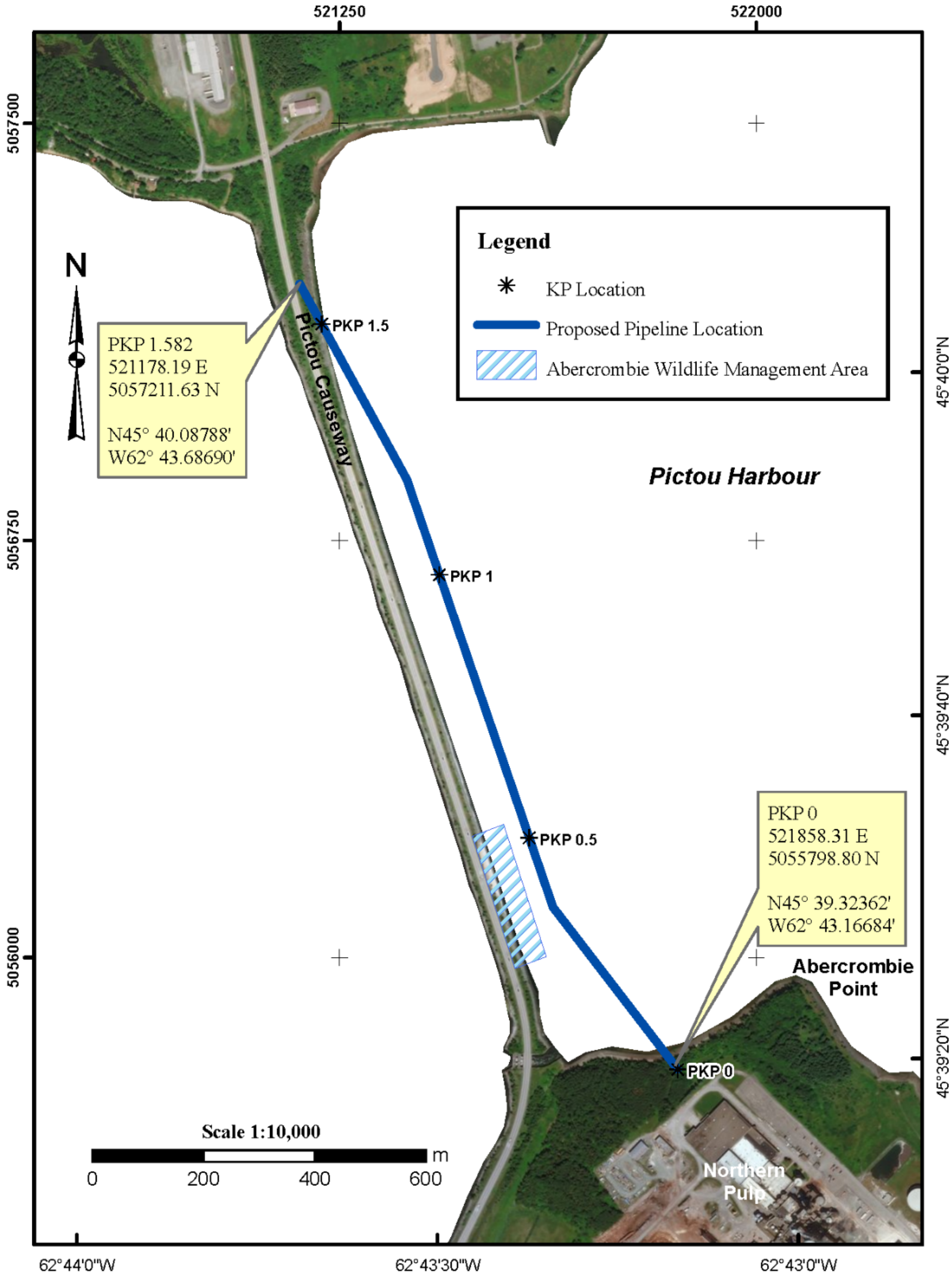


Figure 2. Chart of Pictou Causeway showing proposed route.

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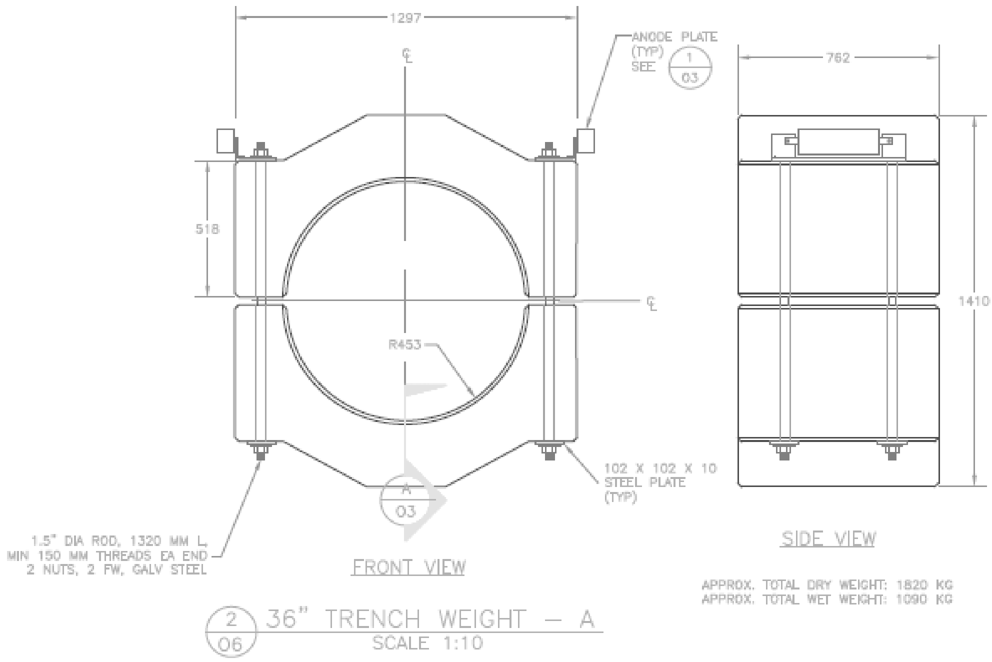


Figure 3. Example of 36" HDPE pipe weights for Caribou Harbor Outfall

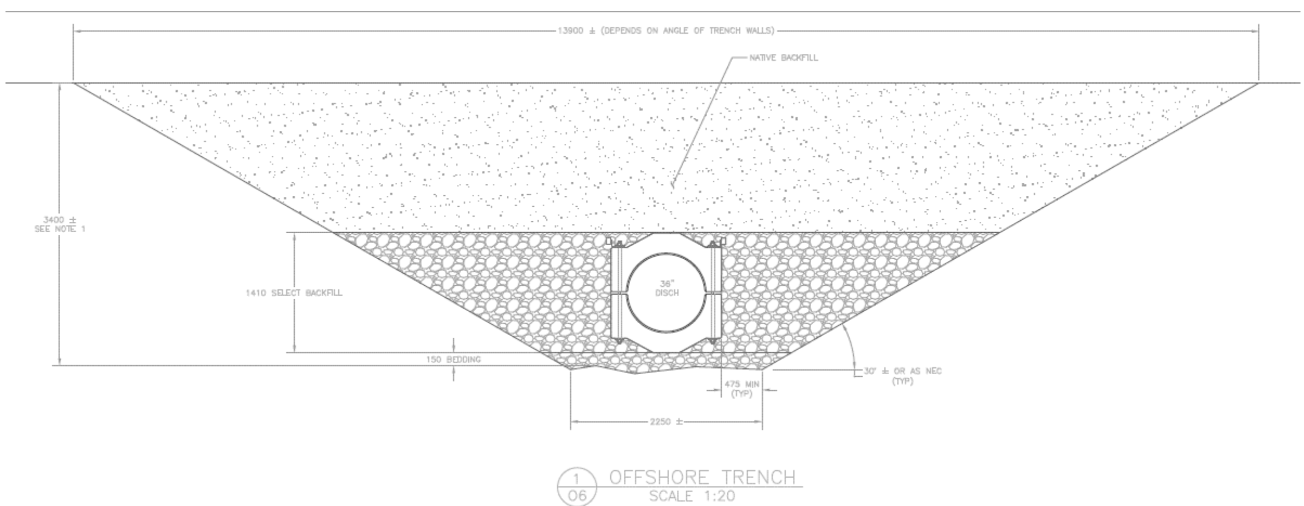


Figure 4. Example of dredged trench for 36" HDPE pipeline for Caribou Harbor Outfall, based on 2:1 side wall slope.

MATERIAL STAGING AND ASSEMBLY SITES

This chapter describes the staging sites required to support construction. A more detailed step-by-step process for the pipeline deployment follows in later sections.

NORTHERN PULP MILL: PRIMARY STORAGE AND ASSEMBLY SITE

The HDPE pipelines can be delivered by standard freight delivery, via train and truck. Standard lengths of delivered pipe, or "sticks" will be stacked in cradles. Upon delivery the pipes will be moved, via forklift or crane, onto the primary Northern Pulp Mill staging site shown below in Figure 5. Individual sticks will then be fused together, using HDPE butt fusion machines, to form longer continuous lengths. Alternatively, long segments of approximately 500m could be towed in, or manufactured on-site using technology such as TUBI on-site pipeline extrusion. Whether shipped, towed, or extruded on-site, once fused into longer sections, the pipe lengths will then be stored on-site until the contractor is ready for towing them to Caribou Harbor. To deploy the pipes for towing, these lengths may be pulled into the water along a temporary rail system, pipe weights may be attached. At this stage, the pipe lengths would be lengths up to, or exceeding, one kilometer.

Pipe weights, similar to those shown in Figure 3, will be constructed at a pre-cast yard, and will be delivered and stored at this primary staging location.

A secondary staging site, shown in Figure 6, will be available to contractors if needed.

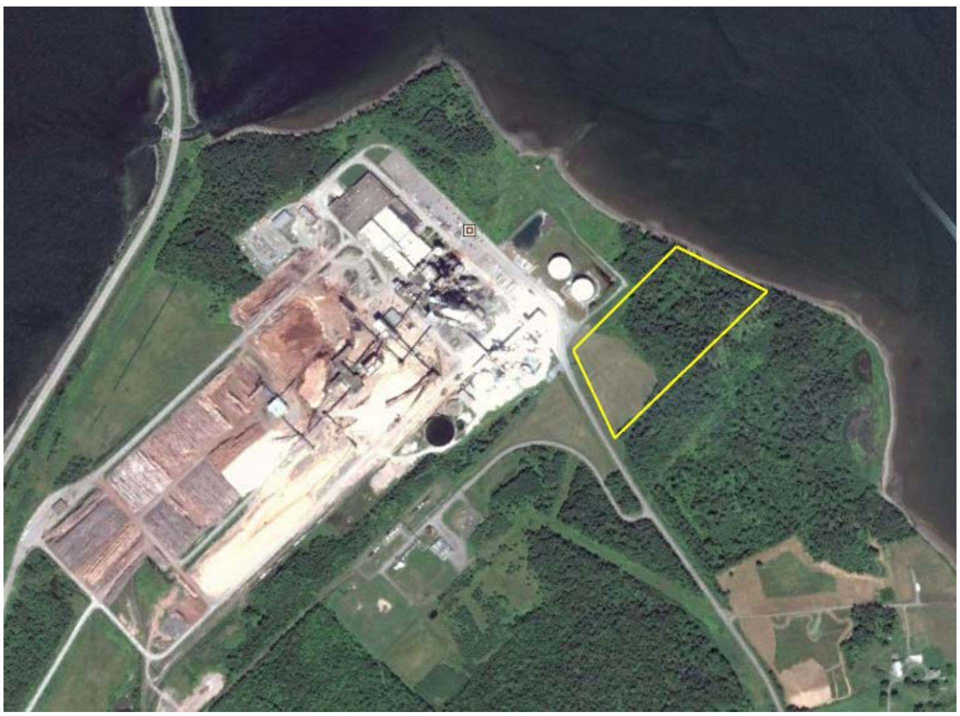


Figure 5. Aerial image of the primary staging site on Northern Pulp Mill property.

Figure 6. Aerial image of the secondary staging site on Northern Pulp Mill property.

Deployment and Pipeline Towing Impacts

To facilitate deployment of the fused pipelines into Pictou Harbor, where they will be pulled out and towed to Caribou Harbor, a temporary causeway may be built large enough for small work and construction vehicles. As the pipelines are pulled into Pictou Harbor the pipe weights may be attached to the pipelines for ballast, the details of which are described in other sections.

Alternatively, the pipelines may be pulled in un-weighted and towed into position. Any pipe weights not installed at the Northern Pulp Mill staging site will be transported to a barge and assembled to the pipelines while floating at a Caribou Harbor or Pictou Harbor mooring.

Figure 77 shows an example of a temporary causeway built in 2009 to support an HDPE pipeline deployment at the Northern Pulp Mill.

Figure 88 shows a view of the same project of the HDPE pipeline being pulled into Pictou Harbor.

Figure 99 shows the layouts and schematics of the pipeline storage, pipe weight storage, and the likely steps for the pipeline deployment into Pictou Harbor.

Previous HDPE pipe installations have taken place at the mill, including a 1500m crossing of the Harbor in 2009. The project used the pulp mill site where HDPE sticks were fused together, and deployed via rollers into Pictou Harbor.

Figure 7. Example of temporary causeway built for HDPE pipeline deployment at the Northern Pulp Mill staging site. Photo from 2009 courtesy of Northern Pulp.

Figure 8. Staged pipeline towed into Pictou Harbor from Northern Pulp Mill, 2009, images courtesy of Northern Pulp.

Figure 9. Schematic of primary staging site (yellow box) with pipe sticks (red lines in staging site), pipe weight storage (gray area in staging site), and the initial floating and towing stages for longer pipe lengths from Pictou to Caribou Harbor (green lines representing initial deployment, tow hookup, and towing).

CARIBOU HARBOR IN-WATER STAGING SITE

Once towed to Caribou Harbor, pipeline segments will be moored at a temporary site west of the Ferry Terminal and Ferry Channel, as shown in Figure 1010. Any pipe weights that still need to be assembled onto the pipeline will be transported and subsequently assembled onto the moored pipeline segments. Given that the pipeline is floated in, the staging and work area at Caribou Harbor is minimal.

Equipment will be needed to capture and pull the floating pipeline end into position. This is usually performed by a bulldozer or anchored winch. Details of this process are described in later sections.

On on-shore staging site, or shoreline access, in Caribou Harbor would be desirable for contractor crew and small equipment loading and off-loading.

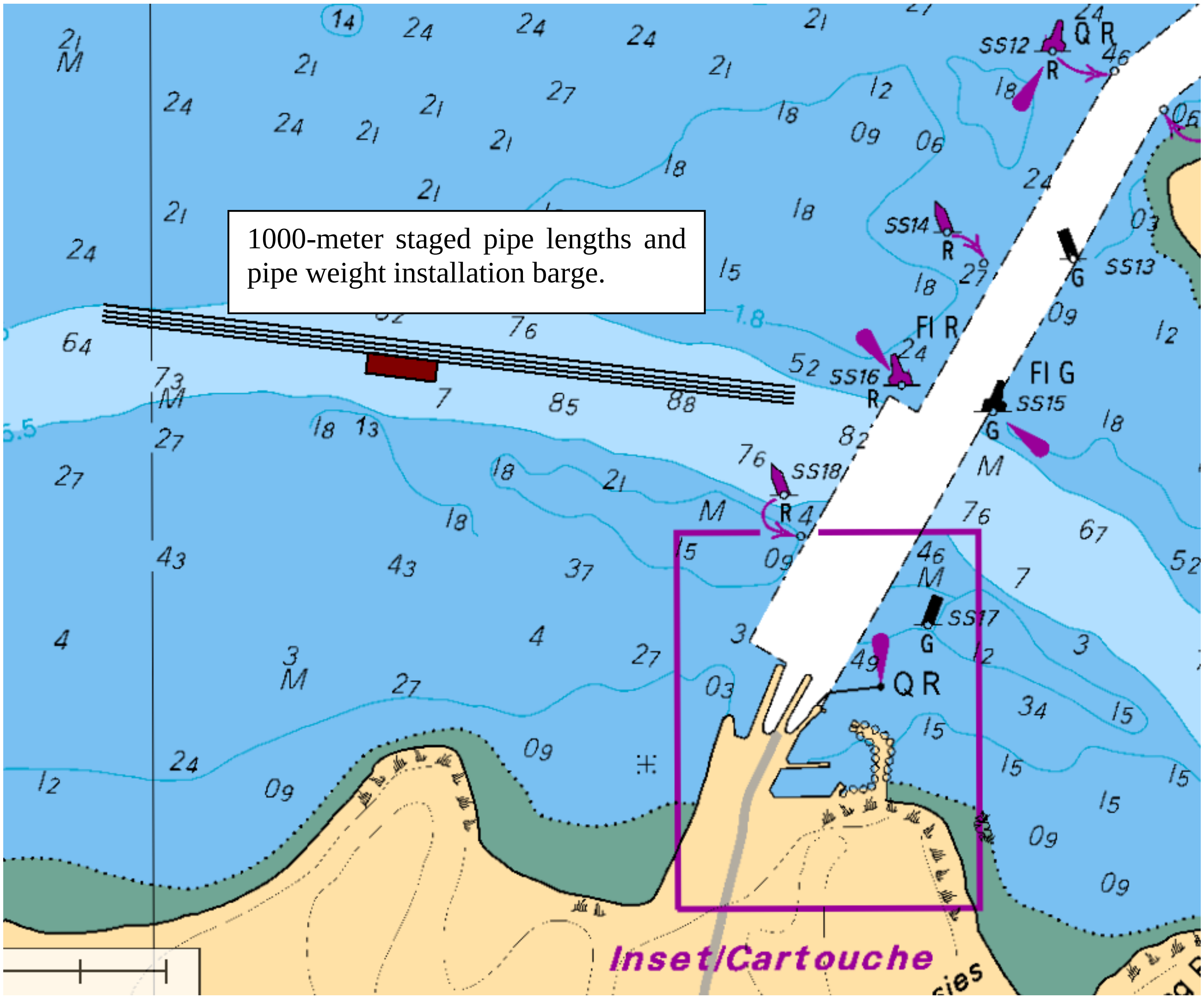


Figure 10. Example of in-water staging site for temporary storage and pipe weight installation on 500m to 1000m length pipeline segments; required immediately prior to submergence and installation.

DREDGING

At the same time that these pipeline assembly and staging activities are taking place, the trenching operations can be underway.

This chapter presents the primary dredging design considerations, the available trenching methods and alternatives, and ends with a discussion of the recommended dredging approach.

DREDGING DESIGN CONSIDERATIONS

There are multiple factors in Caribou Harbor that significantly impact the design and selection of methods for placing the effluent outfall pipe. Chief among these are 1) ice scour and 2) water depth.

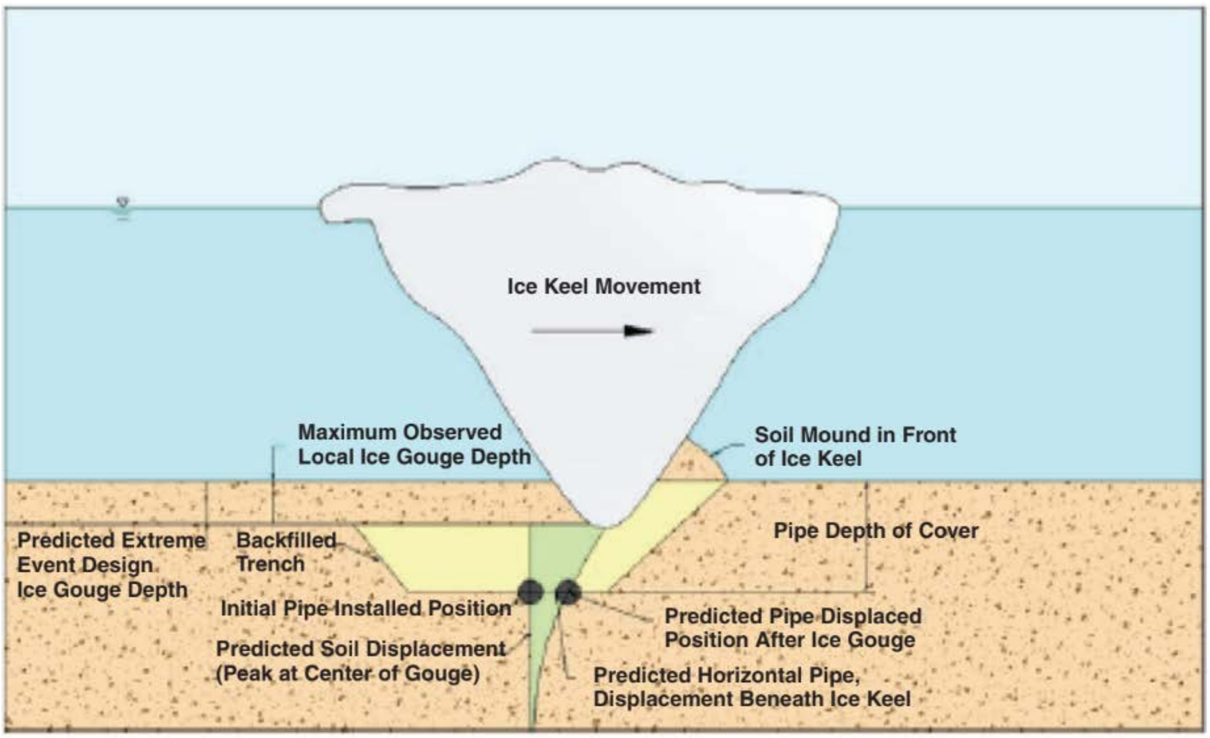


Figure 11. Graphical explanation of ice scour on the seafloor.

Ice scour, illustrated in Figure 111, is the possibility of damage to the pipeline by floating ice, both by direct tearing of the pipeline or by deformation of the pipeline by applied pressure to the soil around it. The real possibility of damage by ice scour requires that the pipeline be protected in order to prevent damage. The most effective method available that can withstand the large forces presented by ice is to bury the pipeline deep enough in a trench that the ice cannot interfere with or directly impact it.

The marine geotechnical surveys show ice scour along the proposed pipeline route. Other projects with ice scour at similar latitudes by the oil industry indicate that the pipeline will require up to 2 meters of soil protection to prevent damage by marine ice ("*Offshore pipeline protection against seabed gouging by ice: An overview*", P. Barrette). This translates to a trench up to 3m in order to accommodate the 1m diameter effluent outfall pipeline. Detailed engineering will be completed to determine final burial depths, with design standards and criteria in accordance with the DNV Submarine Pipeline Systems standard (DNV-OS-F101). Given an assumed angle of repose for the soil of 30 degrees, a trench 3m deep equates an opening at the surface of approximately 12m with a cross-sectional area of 20 square meters. This results in an excavated volume of 20,000+ cubic meters per kilometer.

In order to ensure protection for the pipeline, the trenching would be done pre-lay, with the pipeline floated in and placed behind it into the trench. Gravel bedding will provide an approximately 6" thick stable layer below the pipeline. Once placed, the pipeline may be covered by gravel haunching, and to the maximum extent possible the previously excavated spoils. Once the trench is covered in soil, it could either be graded down using a towed grader bar, or left to the elements if local currents and sediment transport is agreeable.

Pipeline Armor: To protect the pipeline from anticipated ice scour the pipeline will have to be buried. The exact depth of burial can be calculated based on existing ice scour marks observed during surveying, as well as historical data. For this document, we are assuming up to 2 meters of coverage with local soil. Armor stone protection may be considered for sections of the pipeline in the final design.

Water depth is also a factor which sometimes limits the type of trenching equipment and placement methods that can be used. Some equipment, such as a plow for trenching, are not suitable for shallow water applications. Common equipment, such as long reach backhoe excavators operated from barges, are limited to shallower water depths such as those in the inshore region of the Caribou pipe route.

Water depth and tide range also affect the type of barges and the anchoring methodologies used (spuds vs anchors vs self-powered). Water depth impacts the materials handling of sediment spoils, as the amount and weight of spoils on the barge will determine barge draft and working depth requirements, and will also dictate the feasibility of side-casting.

The dredging method will affect project schedule and cost. For this reason, final means and methods are often decided by the qualified marine contractors who take into consideration additional tradeoffs between the locally available equipment options and their associated costs. The remainder of this chapter describes the broad range of methods available and Makai's opinion of likely contractor methods based on the site conditions.

Trenching Options

Common pipeline trenching methods include conventional excavation, hydraulic suction, ploughing (both pre- and post-lay), water jetting, and mechanical trenching. The options are presented in more detail in the following section.

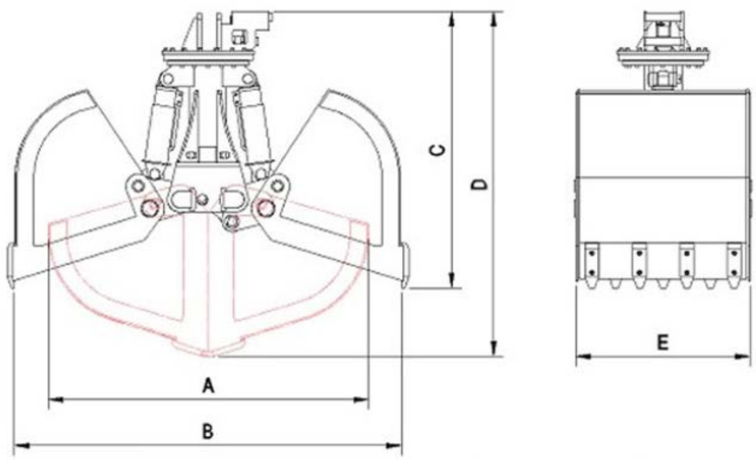
Conventional Excavation includes such equipment as hydraulic backhoes, clam-shell bucket dredges, or other similar methods that are used to excavate a pipeline trench in shallow waters. These methods are proven and are generally suitable for areas up to 15m water depth. These methods can be more time-consuming than more advanced alternatives, but more often utilize lower cost locally available equipment, labor and vessels. In adequate water depths, clam-shell excavators may be used to side-cast dredge spoils without surfacing any of the dredged materials. This may have benefit in areas where side-casting is allowed, and if so, reduces topside materials handling.

Figure 122 and Figure 133, below, shows typical clam-shell bucket and backhoe excavators, and mechanical dredger.

Figure 12. (Left) Example of typical clam-shell excavator, taken from Manson Construction website, http://www.mansonconstruction.com/andrew/ and (right) example of long arm backhoe on barge.

Figure 13. Conventional excavation dredging

As shown to the right in Figure 144, the typical clam-shell buckets with >4m^3 per load capacity have bucket heights (dimension D) of 112” (2.8m). Buckets with ~1m^3 capacity per load have heights of ~1.5m from bottom of bucket to the top lifting point.



Model	A	B	C	D	E	Weight	Capacity	Excavator Wt.
YC-600	58 1/2”	69 5/8”	54 5/8”	70 1/8”	31 7/8”	1,980 lb	0.8 yd^3	26,400~35,200 lbs
YC-800	65 7/8”	78 3/4”	58 3/4”	78 ”	35 3/8”	2,430 lb	1.0 yd^3	40,000~52,900 lbs
YC-1000	74 7/8”	85 1/4”	62 ”	80 3/4”	38 5/8”	3,300 lb	1.3 yd^3	57,300~66,000 lbs
YC-1200	75 5/8”	90 1/8”	65 1/8”	86 5/8”	40 1/8”	3,970 lb	1.6 yd^3	66,000~70,000 lbs
YC-1500	80 3/4”	96 1/2”	69 ”	91 5/8”	44 1/8”	4,400 lb	2.0 yd^3	70,000~88,000 lbs
YC-2000	88 1/4”	105 3/8”	71 1/8”	98 5/8”	48 ”	5,400 lb	2.6 yd^3	88,000~99,200 lbs
YC-2500	92 ”	110 1/4”	72 3/4”	101 3/8”	50 3/4”	6,000 lb	3.3 yd^3	99,200~110,000 lbs
YC-3000	95 7/8”	114 1/8”	73 3/8”	103 1/2”	54 5/8”	6,500 lb	3.9 yd^3	115,000~130,000 lbs
YC-4000	102 ”	124 3/4”	83 3/4”	112 3/4”	60 1/2”	7,200 lb	5.2 yd^3	130,000~150,000 lbs
YC-6000	128 7/8”	149 7/8”	97 1/4”	132 7/8”	66 1/2”	8,400 lb	7.8 yd^3	180,000 lbs~

Figure 14. Examples of typical clam-shell bucket dimensions and load capacities.

Figure 15. A clamshell excavator placing spoils in a dredge box

The progress of a clam-shell excavator is heavily dependent on a number of factors, including size of the clam-shell bucket, water depth, and more. However, for preliminary planning, it is reasonable to estimate approximately one lift and side-cast be accomplished every 2 minutes with up to a 4 m^3 bucket. This equates to approximately 120m^3/hour excavation rates. This results in a trenching rate of roughly 21 days per kilometer of pipeline, assuming 8 productive hours per day and up to 3m deep trench described previously. Additional steps throughout the construction process, such as trenching through localized bedrock layers or the use of smaller clam-shell buckets, would result in longer dredge schedules.

An excavation rate of 120 cubic meters/hour equates to a trenching rate of roughly **21 days/kilometer of pipeline**, given a trench depth of 3m and an angle of repose of 30 degrees.

Hydraulic suction dredging works by sucking up a mixture of sediment and water (known as slurry) from the bottom surface and then transferring the mixture through a pipeline to another location. This dredge acts like a giant floating vacuum, removing sediment. The two most common forms of hydraulic dredging used for pipeline trenching are cutter suction dredgers (CSD) and trailing suction hopper dredges (TSHD).

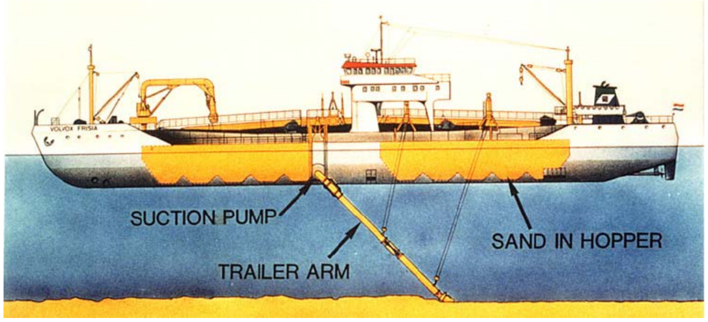


Figure 16. Representation of a Trailing Suction Hopper Dredge

Figure 17. Cutting Suction Dredge

CSD uses a rotating cutting head connected to hydraulic suction to break up the soil on the seabed and then suck it up onto a spoils barge or discharge at adjacent locations, as shown in Figure 16. The CSD excavates the trench with a rotating cutter head on the end of a ladder extended to the seabed. As the cutter head breaks the soil, it pumps the soil/water slurry through the pipe and through a discharge pipe. The end of the discharge pipe is typically located within a couple hundred meters from the dredge and is moved often to prevent excessive dredged spoil from accumulating in one area, which is an important consideration for shallow waters where any side-casted materials would need to be dispersed in order to maintain reasonable water depths. This enables more efficient spreading of dredge spoils compared to the less mobile clam-shell dredgers. Spoils can also be disposed of by discharging into barges, which can then travel to a disposal area. Barge disposal results in lower amounts of sediment in the water column, but requires additional disposal considerations. Silt curtains have been used successfully to limit sediment dispersion.

When using the Cutting Suction Dredge method, the dredge advances by sweeping the cutter head back and forth while advancing longitudinally using spud piles. Due to the sweeping motion of the vessel the trench tends to be wide, which is advantageous for the Caribou pipe application.

Side cast dredging operations with suction dredgers, shown in Figure 18, are a form of suction dredging frequently used in shoals and other shallow dredging areas. This method of side-casting is used due to the low freeboard of the dredging vessels and their relatively high speeds of dredging. A side casting suction dredge is three to five times faster than the anticipated mechanical method with spoils capture. Suitability of side casting with CSD or TSHD, and allowable turbidity levels, will require input from the permitting authorities. Also, as a result of the side casting, the spoils will not be able to be easily recovered for possible re-use in burying the exposed pipeline and trench. CSD or

TSHD methods can be used with the spoils directed to hopper barges or materials handling containers, made available for later use as trench backfill.

Figure 18 . Side cast Dredge Merritt, Corps of Engineers

The progress of a cutting suction dredge is heavily dependent on a number of factors, including size and speed of the cutting head, suction pump power, hose length, spud/barge mechanics, and more. However, for planning, it is reasonable to estimate a volume acquisition (Ve – volume excavated in cubic meters/hour) of 500 m^3/hour. This excavation rate equates to a trenching rate of roughly 5 days per kilometer of pipeline.

An excavation rate of 500 cubic meters/hour equates to a trenching rate of roughly **5 days/kilometer of pipeline**, given a trench depth of 3m and an angle of repose of 30 degrees.

Marine Ploughing is very similar to ploughing on the surface, as the plough is advanced over the seabed by pulling with a large tug or a derrick barge. Ploughing can be done in a single pass, or multiple passes, and can be done pre- or post- placement of the pipeline. Pipeline-trenching ploughs tend to be quite large, approximately 90 to 270 tons dry weight and 9 to 27 m in length.

Figure 19. Subsea plow

Based on the deeper water depths required for subsea plows, as shown in Figure 19, these methods are generally not applicable for the Caribou outfall.

Figure 20. Water jet trenching / burial ROV

Water Jetting, Figure 20, involves either pulling a jet sled along the top of a pipeline after it has been installed or flying a jetting ROV along the specified route before or after laying the pipe. Jet sleds and ROV-jetting systems are more generically described as jetters. High-pressure water jets liquefy the soil, and air lift or educator pumps remove it from under the pipeline. To achieve a trench depth of up to 3m in most soil conditions, jetting often uses multipass techniques. Jetting would only work in certain soil types and would be ineffective against large boulders and bedrock. Because of the very large fluidized sediment load created, environmental concerns may also be an issue. These methods are generally not applicable for the Caribou outfall.

Mechanical Trenching (Figure 21) is used in open water conditions and supported by a large marine vessel. There are two main types of mechanical trenchers: barge-mounted chain cutters; and tracked, crawler-style trenchers. Both of these rely on hydraulic power to operate their cutters and tracks (where appropriate). The barge-mounted mechanical trenchers can be used in water depths of less than 100m. They often feature high-volume jetting capability for the removal of overburden and a large chain cutter for stiff soils or rock. Mechanical trenching will likely be required along the route if local bedrock is found within the trench sections.

Figure 21. Mechanical Subsea Pipeline Trenching Machine, showing the rotating cutting head used to break through stiff soils or rock.

DISCUSSION AND RECOMMENDATIONS

Due to the combination of water depth and size of the excavation Makai anticipates contractors will use the clam-shell excavators, backhoe excavators, or a suction based dredge (CSD) as the primary excavation method, or combinations thereof. The 2019 geotechnical survey by CSR GeoSurveying LTD indicated areas of strong shale or bedrock along the proposed pipeline route. If areas of subsurface bedrock are found, additional measures will be required in these localized zones to break apart the bedrock using mechanical trenching equipment. Further, survey reports completed by CSR include preliminary geological opinions that these hard substrate layers will be “rippable” using the proposed mechanical methods.

The seismic and seafloor survey conducted by CSR GeoSurveys, Ltd, displayed in Figure 22 through Figure 25 below, indicates predominantly sand and sand/gravel along the planned pipeline placement route in Caribou Harbor. An area of finer grained sediments exists nearshore. There is a slight range of gravel and cobble along the right side of the excavation path between points 0.6km and 1.5km. This soil range is well within the capabilities of both the clamshell dredging and suction dredging excavation methods. In Pictou Habor (Figure 24 and Figure 25) the pipeline route is relatively flat and shallow and predominantly silt with local areas of cobble and boulders interpreted as glacial till.

The water depth along the planned Caribou harbor pipeline route ranges from under 0.2m to 20m, as shown in Figure 23. A significant portion of the route from 0km to 2.0km, is less than 2.5m water depth. In several areas, it is less than 1m of water depth. The maximum tidal range for Caribou Harbor is 2m, with low tide observed at less than 0.5m and high tide at approximately 1.8m.

The CSR survey report provides more comprehensive analysis of the geotechnical and geological seafloor conditions, for the interested reader.

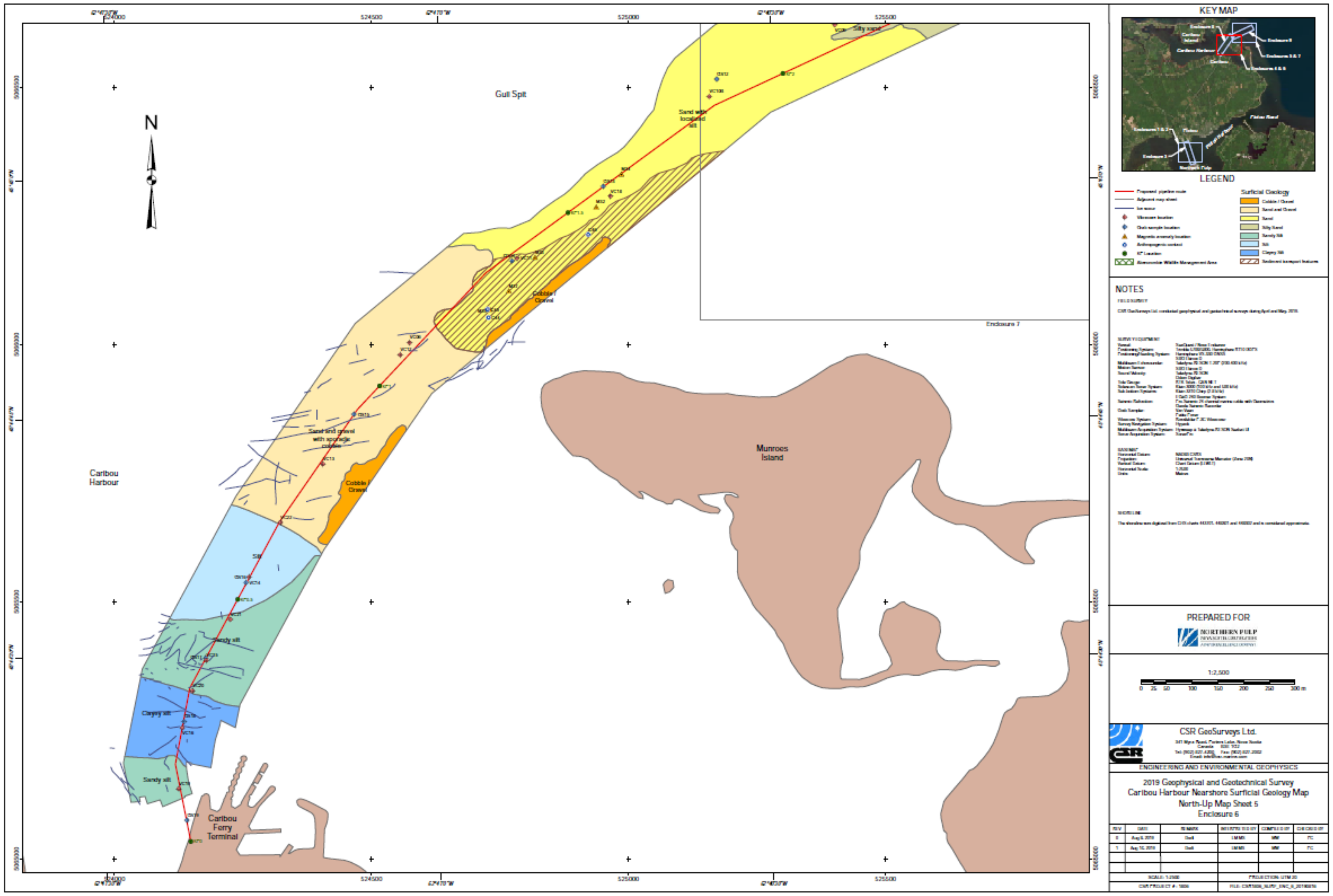


Figure 22. *Caribou Harbor proposed route with soil conditions.*

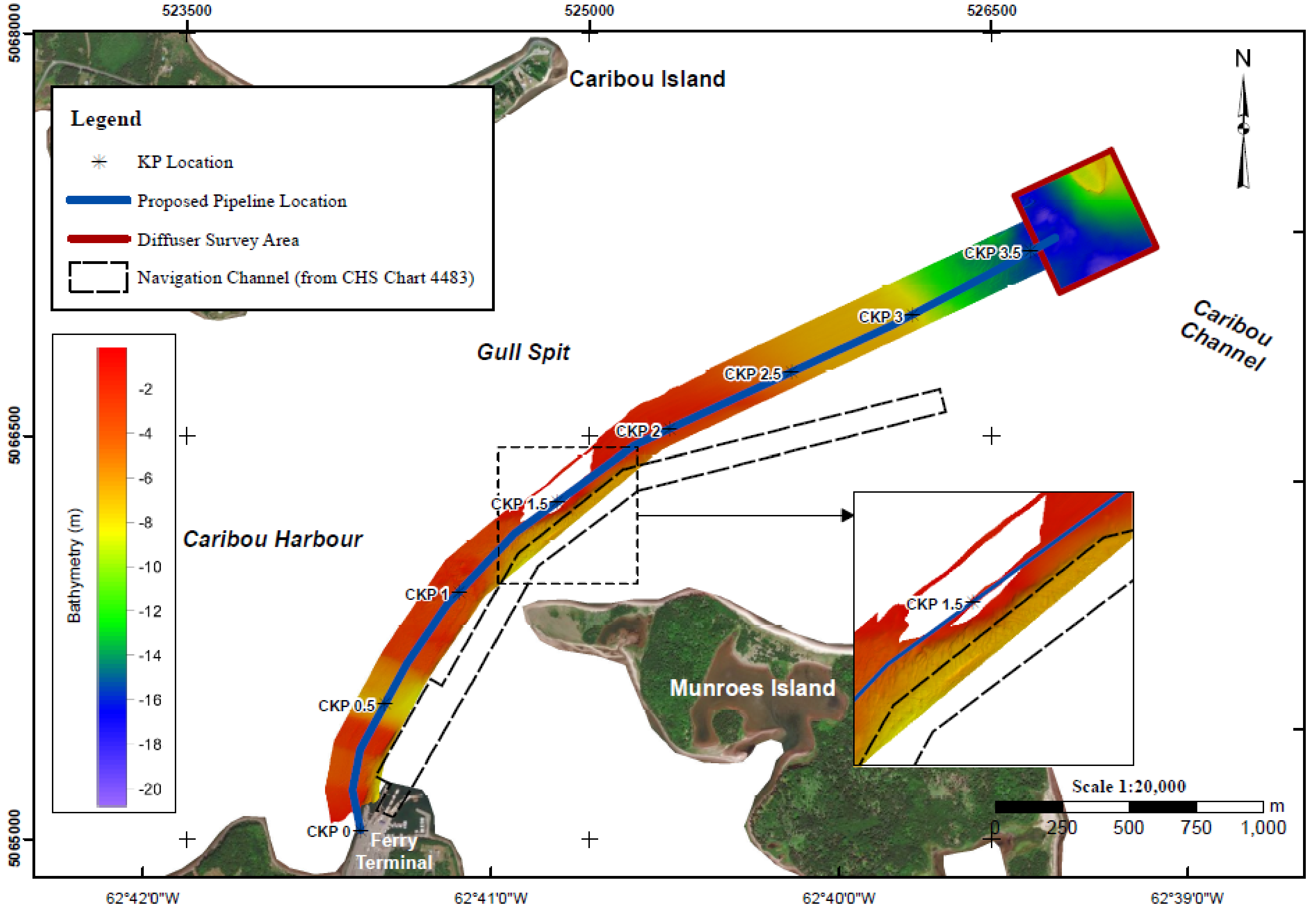


Figure 23. Caribou Harbor proposed route with depth in meters.

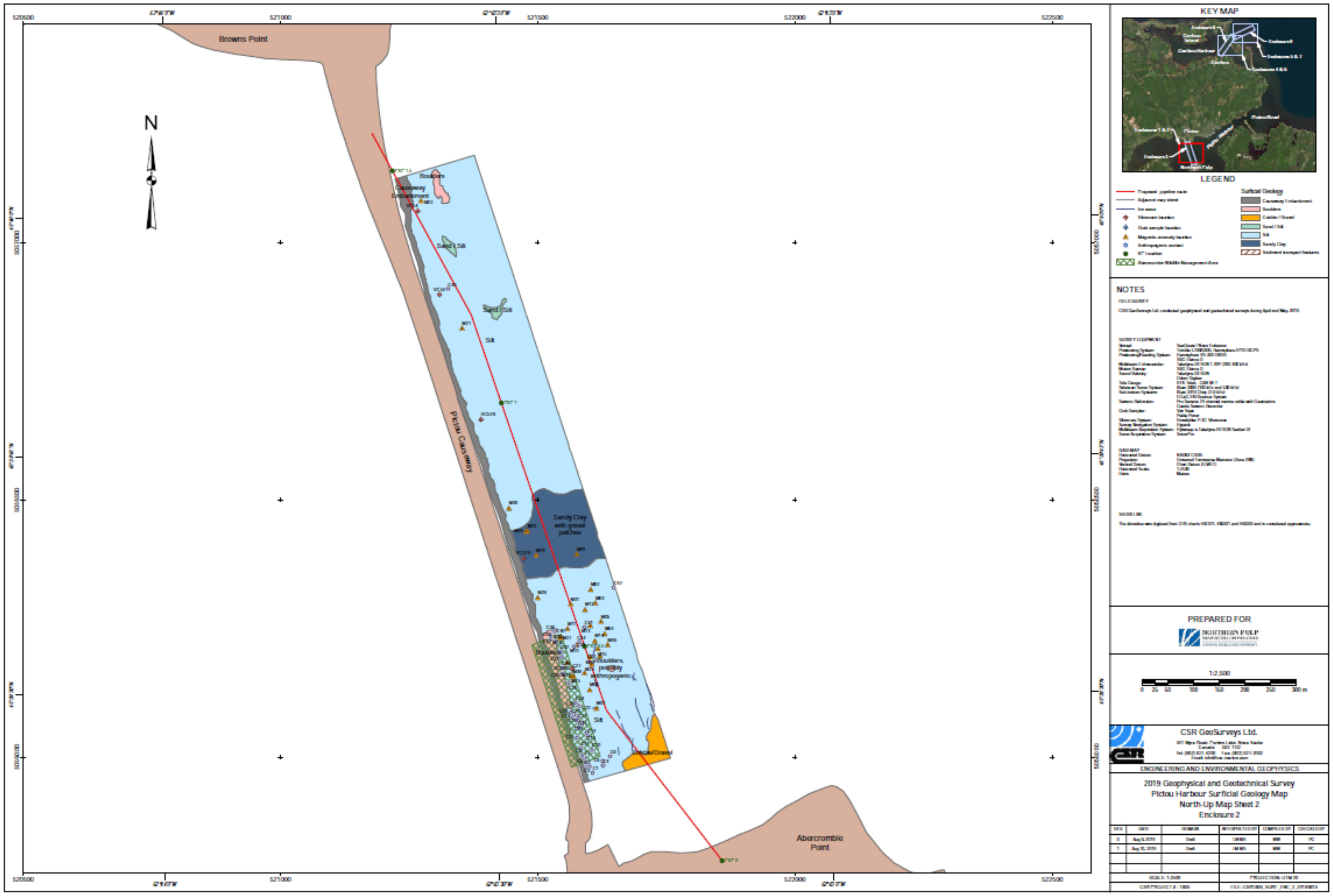


Figure 24. Pictou Causeway proposed route with soil conditions.

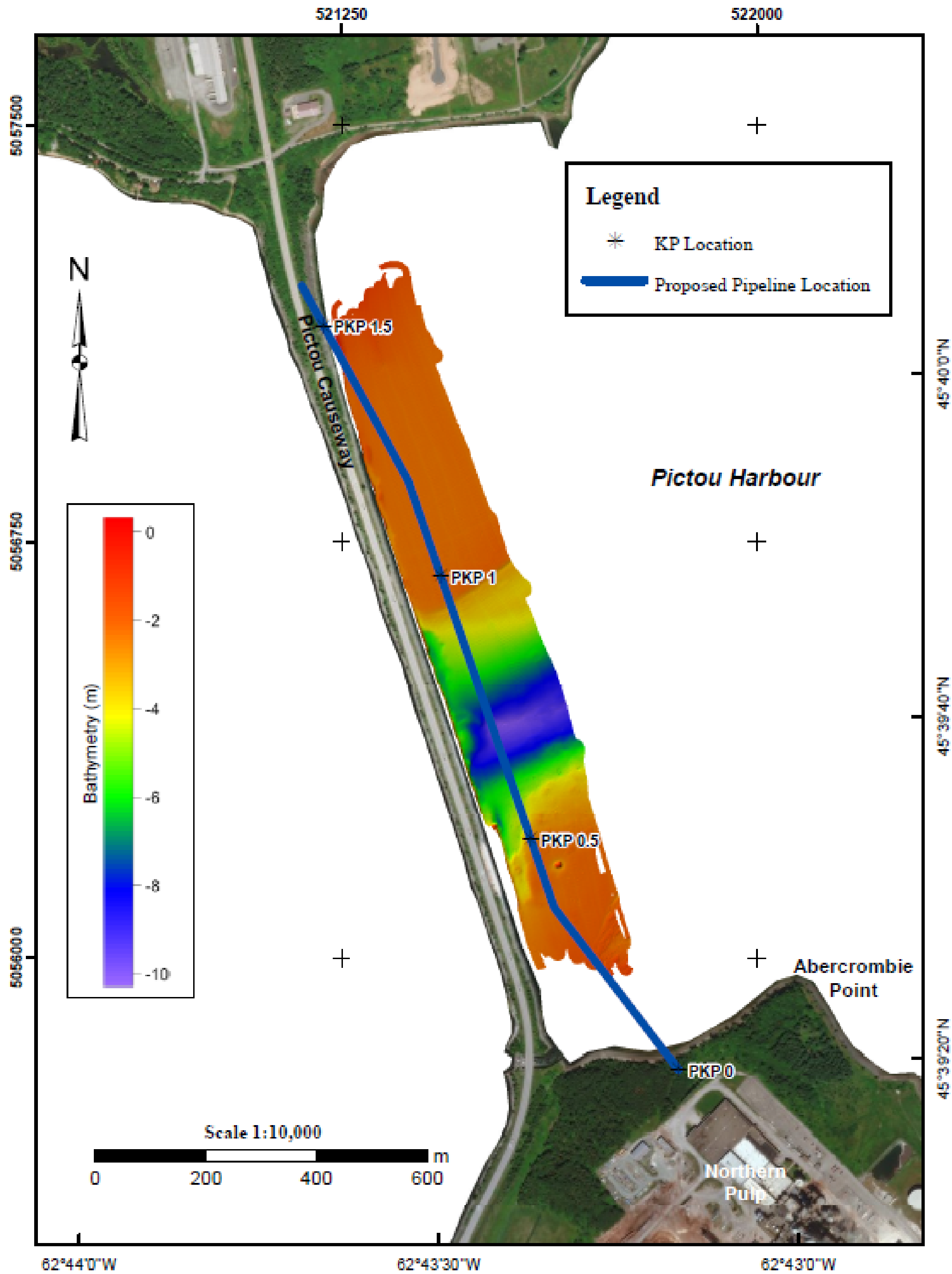


Figure 25. Pictou Causeway proposed route with depth in meters.

Spoil management for this excavation is directly dependent on local environmental regulations and specific environmental factors such as turbidity, allowable soil transport radius, sediment chemistry, marine habitat, and any additional governing community factors.

Clam-shell or backhoe dredging is most attractive in the first shallow (<3m deep) section of the route. This method generally results in less turbid, more readily contained, waters if side-casting is allowed. Use of varying sizes of clam-shell buckets, at the expense of production rates, may be considered. CSD remains a viable dredging option with some advantages from the increased productivity.

Regardless of methods used, there are two real possibilities as pertains to dredging in Caribou Harbor: (1) the dredged soil must be stored temporarily prior to removal or use as trench backfill or (2) the dredged soil can be side casted back into the ocean near the point of excavation where it can remain or be later used as trench backfill.

Historically in Nova Scotia, land-based disposal of dredged material followed best management practices, currently captured in *Guidelines for Disposal of Contaminated Solids in Landfills* (NSE, 2012). Based on conversations with Northern Pulp, the last documented dredging of the Caribou Harbor ferry terminal channel was in 2017 wherein the dredging operation was comprised of mechanical means with the spoils disposed of at sea.

A spoils barge or a barge with a hopper will be needed to capture dredge spoils which cannot be side-cast and will be re-used as trench fill, or spoils sent for land-based disposal, or for some combination thereof. To facilitate exporting the spoils from a spoils barge to a disposal site, or for later use in situ, a spoils container such as a shipping container or a dredge box should be used.

The operations are likely to be conducted in the following sequence:

Dredging Operations. The dredging equipment will be identified based on the permitting process and is dependent on soil conditions, soil testing, water depth, and other factors. All spoils should be re-used to the maximum extent possible to re-fill the trench and avoid disposal. The pipe and bedding material will also displace volume that will either need to be side-casted or disposed.

A spoils barge, or other containment method, would be paired with the dredger to capture the excavated sediment. Depending on the size of the barge – dictated by available equipment and barge freeboard requirements – multiple barges may be cycled back and forth to maintain production.

The dredger will move forward in a single pass, excavating the full trench as it moves forward along the path. At an excavation rate of 60-120 cubic meters per hour (depending on the equipment), the anticipated production schedule would be at least 21 days per kilometer.

Side-Casting. Side casting can be accomplished with clam-shell, backhoe, or CSD dredging methods. Clam-shell dredgers will lower and release side-cast material load by load near the seafloor, adjacent to the route. The maximum spatial range of disposal is dictated by the reach of the crane. CSD methods, if used, would continuously pump dredge spoils and deposit them adjacent to the route or, in shallower waters, deposit them more broadly to minimize buildup of the seafloor depths. Sediment control measures would include monitoring of nearby water column turbidity during operations, use of silt curtains, or video inspection within the harbor.

Trench Backfilling. Once the trench is cut and the pipeline placed, the trench will have to be backfilled. If it is permitted, the dredge spoils may serve as the main source of fill, reducing handling required for disposal of the majority of dredged material volumes. Backfill will most likely be placed using mechanical means such as a clam shell. Soil will be placed over the placed pipeline and any haunching in order to fill the trench to original grade, and this will be verified by multibeam survey in a post-lay inspection.

To smooth the placed fill, a grade bar can be towed behind a motor vessel that would drag along the sea floor and push the soil into position.

PIPELINE CONSTRUCTION AND PLACEMENT PROCESS

The overall sequence assembly and installation for an offshore pipeline is presented in this section. The information presented here is based on Makai's experience in construction oversight of several deep seawater intake pipelines. The process described here is not the only one possible; the selected marine contractor should be free to choose an assembly and installation process that best fits his equipment, manpower and technical expertise. It is the job of the construction management team to observe the construction process and ensure that the pipeline is not handled, stored or loaded in ways that are dangerous or damaging to the pipe and its attachments, and follows all final regulatory requirements.

STAGING

A staging site is needed for the fusing, testing, pipe weight installation, and assembly of the pipeline. The staging site locations have been identified and described above. The uses and requirements for the staging area are discussed in more detail below.

Pipe Weights: Pipe weights can be installed onto the pipeline at the required intervals as it is deployed into the water, or similarly by barge. Figure 26 and Figure 27 below shows the staging approach at the temporary causeway. The pipelines were pulled into the water by an excavator situated on a temporary jetty.

Pipe Lengths: HDPE pipe will be delivered in pipe lengths based on the selected delivery method. It is likely that the pipe is shipped in 40' to 55' lengths and fused into the full deployment length in the staging area. The pipe will be fused on site at the Northern Pulp staging area into longer sections, adjacent to a quiet water staging area so that the pipe can be fused and then pulled out into the water from storage – as was the case during the 2009 harbor crossing shown above. Alternatively, the long sections of HDPE pipeline could be manufactured and extruded on site as a single piece using a modular extrusion plant, or towed from an off-site extrusion facility. The selection of pipeline delivery impacts only project costs and schedules, with all options able to provide similar pipe material quality.

Pipeline Pressure Testing: Fused segments of pipe lengths at the staging site, prior to any pipe weight attachments or deployment, are pressure tested to confirm conformity to HDPE specifications and ratings.

Figure 26. Image of pipeline being pulled into Pictou Harbor, 2009, images courtesy of Northern Pulp.

Figure 27. Image of pipe weights being affixed to HDPE pipeline prior to deployment at Pictou Harbor, 2009, images courtesy of Northern Pulp.

Water Depth: An air-filled 1m (39") high density polyethylene (HDPE) pipe with ballast weights attached will only require about 1m of water depth to remain floating. However, the marine contractor will need to be able to work around that pipeline as well as install the pipe weights. It is possible to install pipe weights right at the shoreline as the pipe sections are buttwelded together and floated into the water, which will allow for continued operation in shallower areas, such as previous operations in 2009, shown above. There needs to be a good passage from the staging area out into the open harbor so that the pipes can be safely towed out and placed, which the transit from Pictou harbor to Caribou Harbor allows. With proper planning, pipelines with pipe weights can be safely towed several tens of kilometers.

<u>Pipe Towing:</u> The lengths of fused pipe will be pulled out from the on-shore staging site into the adjacent water way. During this process, additional lengths will be fused together to extend the section of floating pipelines being pulled into the water- to a total length of over 1 kilometer. As the pipelines are pulled into the water, the concrete ballast weights will be attached.

<u>Pipe Storage Space</u>: With the concrete weights attached, these pipes will be formidable obstacles in the water, so they need to be moored in a location away from boat traffic. At the Caribou Harbor in-water staging site, the contractor will put down moorings to hold the pipe in place while he works on them and installs any additional pipe weights.

Pipeline Assembly and Installation

The following is a conceptual description of the effluent outfall pipeline installation process. The process presented here is preliminary; the final pipeline assembly and deployment plans would be created by the selected pipeline contractor.

<u>Pipeline Configuration and Assembly:</u>

For this description it is assumed that the pipeline will be assembled from individual pipe lengths shipped in 55’ (16.7m) lengths over roads on flat bed hauler trucks. As an example, a pipe length (55’) will weigh around 9,000 lbs (4,100kg). Typically, the contractor would want to unload this pipe on shore and then fuse it together with the fusion machine located some 100’ or so back from the shoreline. A front-end would with forklift tines or a crane is used to move the pipe segments around on shore and load them into the fusion machine.

When the pipe segments are fused together a blind flange is connected to the end of the first segment. This segment is directed out into the water as successive pipe segments are fused on the other end forming a longer and longer pipeline. The air-filled pipe easily floats on the water and can be directed and controlled by small boats. It will take a couple weeks to complete the fusion of the entire discharge pipeline. It may be necessary to secure the offshore end of the pipe on a small barge or float, so that the partially assembled pipe can be pulled out to the mooring area when the fusion work is halted at day’s end. The pipe can then be retrieved the next morning, pulled back up onshore and fusion can continue. Figure 28 thru Figure 31 show a series of photos from a 63” pipe being fused into a long length and directed out into the water.

In addition to the offshore pipes, the marine contractor should also be made responsible to fuse the onshore pipes and connect them to the terrestrial pipeline. Once they are fused, they can also be moored in the protected water area of the harbor or stored on land until needed. When ready the on-land pipe can also be towed to the installation site and pulled up the shoreline into the prepared pipe trench. This will make pipe handling much more efficient.

Once the pipe fusion process is complete, the individual pipe sections will be hydrostatically tested. Seawater will be pumped into each pipe and maintained at a specified pressure for a fixed period of time to determine the integrity of the fusion joints. A separate subcontractor is hired to use non-destructive ultrasonic methods to verify the quality of each fusion joint. The pressure test can be conducted on land or in water, on each flange-capped section of staged pipeline. When the testing is complete the water is completely drained from the pipes.

Figure 28. Fusion machine set up to fuse 63" HDPE pipe.

Figure 29. Loading pipe (63") into fusion machine with front end loader.

Figure 30. Roller beds used to move fused pipe down to the water.

Figure 31. Fused pipe (63”) entering the water.

Makai assumes that the marine contractor will have constructed the concrete pipe ballast weights at a concrete precast yard and then transported them to the staging area. Pipe weights can be installed either at the shoreline or from a crane barge. The crane barge is usually more convenient as it can be moved along the pipe section while the pipe is moored in the harbor. An “elevator” apparatus can be installed on the side of the barge that will raise and lower the bottom half of a pipe weight. With the bottom half of a pipe weight placed on the elevator, it can be lowered into the water. Then the floating pipeline can be pulled into position above the pipe weight, and the elevator is raised to allow the pipe to rest in the pipe weight. The top half of the weight is then positioned by the crane, and laborers install the bolts to lock the pipe weight around the pipe. In Figure 32 this process is underway on a 55” pipeline assembled in Hawaii in 2001. Figure 33 shows a better view of the elevator platform looking down from the barge. Notice that the other pipe weights are stored on the flat deck barge adjacent to the crane barge. The air-filled pipeline is able to support all the concrete ballast weights and remain afloat.

Figure 32. Pipe weights being installed on floating pipeline using a crane barge with an elevator mounted on its side.

Figure 33. View of elevator platform mounted on a barge – here used for flange connections on 55" pipe in Hawaii 2001.

PRE-LAY TRENCHING OPERATIONS

The up to 3m deep burial trench of the entire marine pipeline length can be constructed before or during the pipeline buildup phase is going on. We recommend having the trench in place before pipeline placement ("pre-lay" trenching) in order to reduce the time the pipeline will be moored. Under this scenario, the trench would be cut ahead of time and the pipeline then towed to it and placed directly into the trench. As mentioned above, the preferred methods are the Clam-Shell Excavation or Cutting Head Suction Dredging approach.

The trench across the shore landing location at Caribou Harbor that traverses up onto the shore will allow the contractor to join to the terrestrial placed pipeline, which will have to be excavated. This will be conducted by traditional mechanical excavation, and depending on soil profile, blasting or jackhammering may be required to make construction easier. Figure 344 shows an example of a completed shoreline trench, with a 24" offshore pipeline pulled by a shoreline winch.

Anchors or dead men are needed to connect to bridles that are attached to a holdfast structure mounted on the shore end of the pipe. During pipe deployment, the pipe will have to be slightly tensioned to control alignment. In deeper waters, higher tensions will be required to limit bending during the controlled submergence. These tension loads are applied by a tug boat attached to the offshore end of the pipe. For the effluent outfall pipeline this pull load will be on the order 5-10 tons.

Figure 34. Completed pipe trench with pipe pulled in from offshore by shore winch.

End blind flanges equipped with special pipe fittings are installed on each end of the intake pipe to allow water to be pumped in at the shore end and air to be controllably expelled at the offshore end.

Pumps, manifolds, control valves and flow meters are set up onshore or to pump water into the pipeline during deployment. Electrical power from a diesel genset will be needed to run these pumps.

A second barge is set up with a large winch used to pull on the pipe and lower its end down to the seafloor when the deployment operation is complete. This barge also has compressors and air control equipment on it which will be used to control the discharge of compressed air from the pipeline at it offshore end.

Professional divers arrive in their workboat to assist during the pipeline deployment and in post-deployment anchoring activities.

Detailed deployment plans and calculations are completed by the marine contractor and his engineers and checked by the design engineer to verify that the entire installation operation is well thought-out and understood.

- Once all preparations are complete the prepared effluent outfall pipeline is carefully towed into position for lowering and placement. Figure 355 shows a 9000' long pipe under tow (pipe was painted white for improved visibility).

Figure 35. 55" towed deep-water pipeline immediately after assembly and departing for the deployment site.

- The pipeline is designed for installation by a controlled submergence process, one that has been used for many previous HDPE pipelines that have been deployed under similar conditions to those found in the Northumberland Strait, Nova Scotia. The pipeline deployments occur in one continuous operation lasting up to 12 hours (usually duration of night time) once pipeline flooding begins. For this installation, the pipeline may be installed in sections, with adjacent segments connected via fusion joints. This would require extra steps during construction to mobilize jack-up-barges for the at-sea fusion joints.
- Upon arrival at the installation site, the near shore end of the pipeline assembly is attached to the previously prepared anchors that can support the deployment pull loads.
- The pipeline is pulled tight to stretch it out along the surface over the planned pipeline route as shown in Figure 36.

Figure 36. *Alignment of a floating 55" deep water pipeline off Keahole, Hawaii.*

- The pump system is connected to the shore end of the pipe. The pumps are capable of delivering water at a rate to allow the pipe to be flooded in less than 8 hours.
- The pipeline is flooded by pumping water in at the near shore end while being tensioned by an offshore pulling tug. It is controllably submerged to the seafloor, always being under control and stable at all times. Air is released at the offshore end during the submerging process. See Figure 377 which shows the pipe shape in the water column and all the critical parameters during the submergence process; applicable for the deeper water and offshore portions of the pipeline path that reach 20m depth.

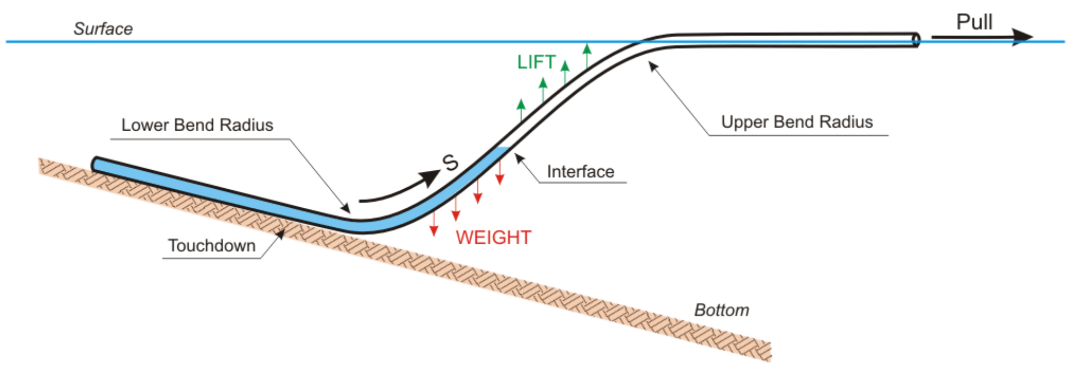


Figure 37. Pipeline shape in the water column during controlled submergence.

- The offshore tug, while maintaining the deployment pull, maneuvers the end of the pipeline to counter alongshore currents as the submergence continues to properly place it on the seabed. The submergence point must be maintained on the path. This is shown in an aerial view of a 40" pipe deployment in Hawaii in Figure 388.
- A diver or ROV inspects the pipeline at the touchdown area at critical points during the deployment.

Figure 38. Deep water pipe deployment – maneuvering to counter cross-currents.

DIFFUSER INSTALLATION AND FINAL INSPECTION

Once the pipeline is completely flooded, the end is lowered to the seafloor (20m depth).

The location and condition of the pipeline is inspected with an ROV or diver, if needed, prior to releasing the pipeline lowering cable. The pipeline can be brought to the surface and repositioned if needed as long as the lowering cable has not been removed. An example diffuser is shown in Figure 399, below.

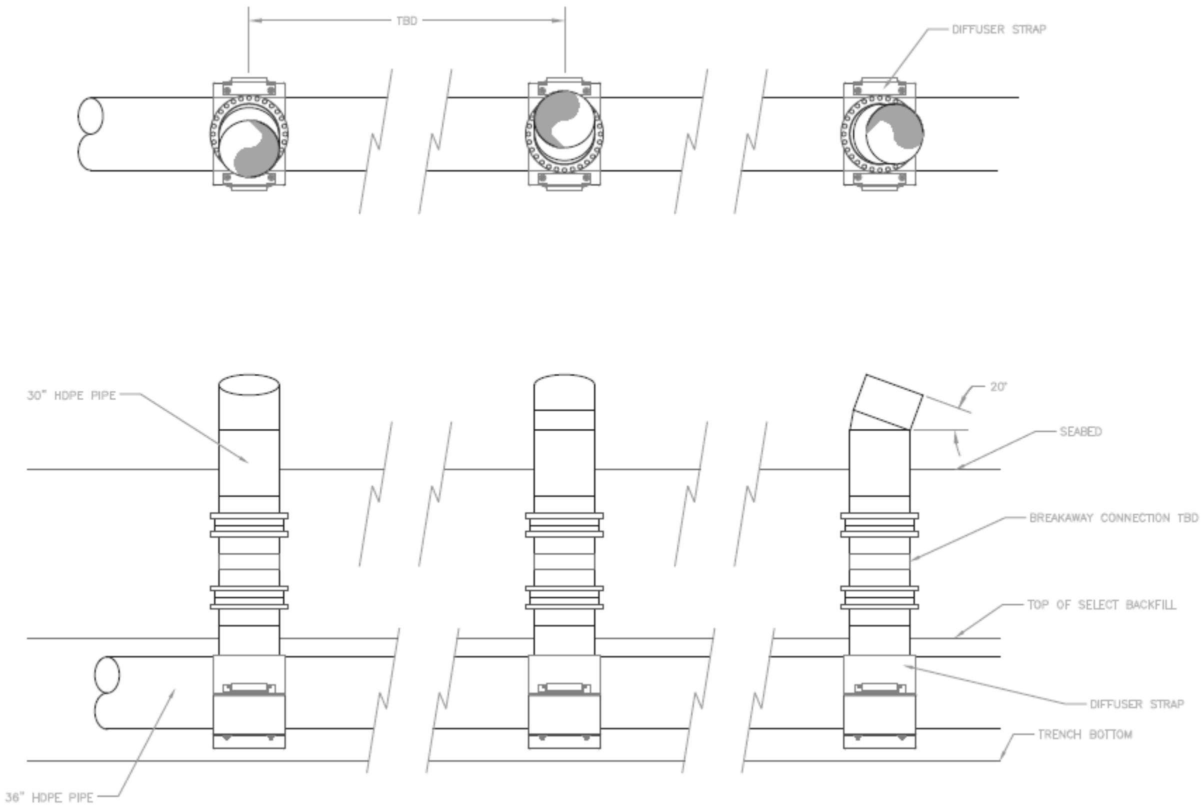


Figure 39. Example of a 3 port diffuser.

SCHEDULE

Impacts to ferry operations and channel navigation have been minimized in the proposed construction approach. Pipelines are staged on-site at Northern Pulp and each towed to Caribou Harbor, in towing operations taking less than 1 day. These tows are commonly done during night-time or planned "off hours when conflicts for use of the channel are lowest. Dredging and mooring of the pipelines in Caribou Harbor will take place to the west of the ferry channel, with movement of barges and support vessels working around the ferry operations. The final installation and deployment of the pipeline segments, each approximately 1km in length, can be expected to occur over only a few hours each, and would be planned to minimize schedule conflicts or impacts to channel navigation.

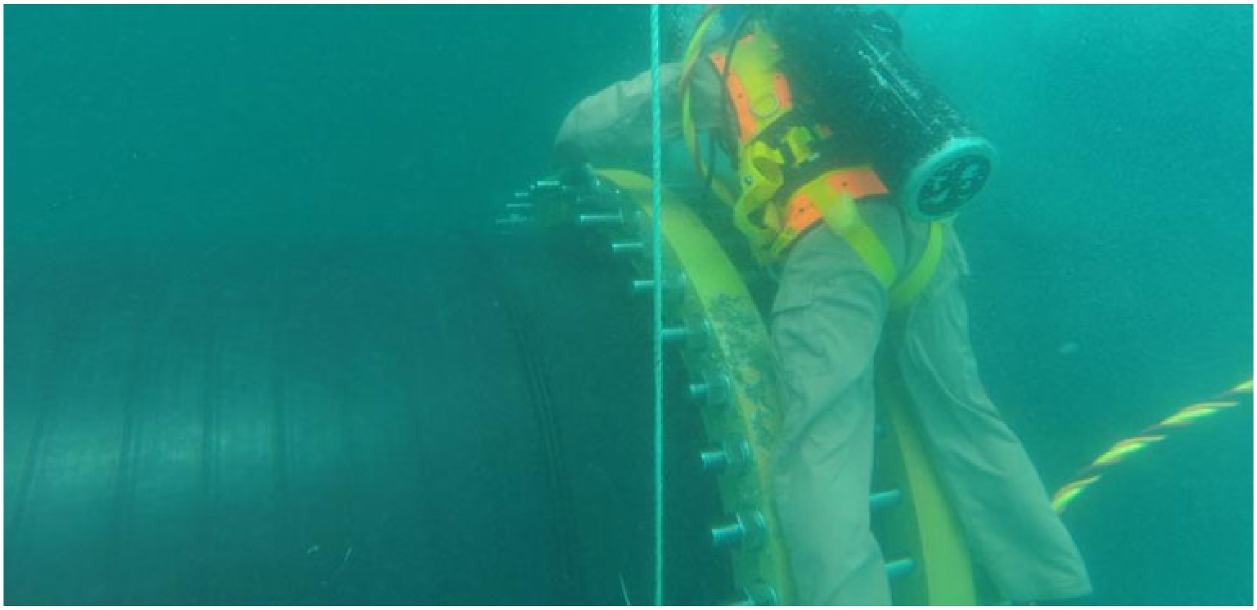


Figure 40. Diver working on HDPE pipeline connection.

FINAL SPOOL-PIECE CONNECTION

Once the pipeline is anchored into place in the trench, the trench will need to be filled back in with preference to use previously excavated side-cast materials. Depending on local environmental regulations, the previously excavated soil can be re-utilized, or fresh soil will have to be brought in on barges and placed. A grader bar can be dragged behind the placement barge to help place, smooth, and compact the soil over the trench.

At the same time that trenches are backfilled, the offshore pipeline is attached to onshore trenched pipe. This connection may have to be accomplished by constructing custom "spool pipe segments" to make the connection between the offshore pipe and onshore pipe for both the intake and discharge. Divers generally assemble a template between the two flanges and then construct a spool piece that exactly matches this template (Figure 40). The spool pieces can be constructed out of HDPE pipe by a skilled fusion technician.

APPENDIX: POTENTIAL FOR HORIZONTAL DIRECTIONAL DRILLING

HDD Considerations

Horizontal directional drilling (HDD) is not planned for the marine portion of the pipeline. However, if there exists some possibility that it may be used for shoreline crossings, then the feasibility of employing HDD at the shoreline crossing will require input form the chosen marine contractor. Regardless, the following section provides a general overview and discussion on the technology and application at this site.

Some benefits of HDD include the fact that the amount of pipeline trenching can be significantly reduced by using horizontal directional drilling (HDD). At the shoreline, HDD can have comparatively less environmental impact, as it tunnels underneath the shoreline and water areas.

Disadvantages include additional risk associated with unknown geotechnical conditions below the surface layers, use of drill mud such as bentonite, and the requirement of suitable onshore space for mobilization of drill rigs and equipment.

For a pipeline this size (36”), the drilling procedure would be a multi-step process. First, as the hole is bored, a steel drill string is extended behind a cutting head while drilling mud is used to cool the cutter and transmitter electronics, to flush excavated soil from the borehole and to lubricate the borehole. Once this first pass is completed and the drill head breaks the surface, the cutting head is then removed and a back-reamer attached. The pipe string is attached to the back-reamer through a swivel device. As the drill string is withdrawn to the drilling rig, the back-reamer enlarges the borehole and the pipe string is pulled into the hole. As with any pipe pulling technique, the movement of the drill string and the pipe string will be monitored. The pulling load on the polyethylene pipe must not exceed the allowable tensile load, or safe pull strength of the pipe.

Once the polyethylene pipe has been pulled through the full length of the drilled bore, then a more traditional trenching and pipe placement will resume until the pipeline reaches its proper depth. Pipeline weights will note be required for the sections contained in the drill bore.

HDD Process and Requirements

HDD technology is being used for pipeline (water, wastewater) and cable crossings for airports, highways, waterways, and elsewhere around the world.

An HDD crossing, in general, can be broken into multiple steps:

1. The first stage involves drilling a pilot hole of 3” to 10” in diameter from the shoreline along the design centerline of the proposed pipeline. The pilot hole is drilled while bentonite drilling-mud is pumped down the center of the drill rods. In the case of a jetting head, small diameter high pressure jets of bentonite slurry actually cut the soil and facilitate spoil removal by washing the cuttings to the surface where they settle out in a reception pit. In case of a drill bit, the bit is driven by a down hole mud motor which is located just

behind the drill bit and which derives its energy from the pumped drilling fluid. The bentonite also functions as a coolant and facilitates spoil removal.

2. The second stage involves enlarging the pilot hole by ‘reaming out’ the hole during several passes until it reaches the desired diameter. For this project, the drilling would likely start with a 9” or 10” pilot hole, then step-up the diameter size for each successive pass (e.g., 20”, 30”, 38”, 44”, etc). Each successive step will be a small increase in diameter because the total volume of earth that can be removed at a given time is limited. For a 36” HDPE intake pipe the hole may have to be reamed to as much as 52” diameter, but is highly dependent on soil conditions and the driller’s evaluation of risk. It would take an HDD contractor multiple passes to get to the diameter hole that is necessary for a 36” pipe (some buffer room is required between the tunnel wall and the pipe).

3. Prior to the pipeline pullback operation, the HDPE pipeline has to be fused together in one full length. The most likely way that the pipeline would be installed into the tunnel is described below:

    a. This pipeline would be fused into one long section of HDPE, filled with air, floated out, and then submerged onto the bottom in-line with the drilled hole. The HDPE pipeline is then pulled back thru the HDD tunnel until it pops out on the shore end.

Examples of a drill rig, reaming device, and other heavy equipment used in HDD are shown the figures below.

Figure 41. HDD drill rig (left) and reaming head (right).

Use of HDD technology will require an onshore area of approximately 300’ by 100’ and a source of freshwater for mixing the drill mud. In addition to the drilling rig, this space is used to house a drilling fluid cleaning and recirculation unit, drill pipe trailer, water truck, hoses, pumps, driller’s van, excavator and vacuum pump truck. The size of the laydown area for HDD may be a constraint and will have to be assessed by the project owners. An aerial view of a site performing HDD, illustrating the space requirements, is shown in the figure below.

Figure 42. Aerial view of HDD in progress.

Ideally, the tunnel would breakout as deep as is possible – as close to the required intake and discharge depths as possible – but within cost constraints. HDD and tunneling is generally costed by the meter.

Figure 43. Example of HDPE pipe being placed via Horizontal Directional Drilling.