

MELIADINE MINE – ITIVIA OUTFALL

Hazards and Operability Study

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1 Introduction

The Nunavut Impact Review Board (NIRB) has requested that Agnico Eagle Mines Limited (Agnico Eagle) perform a Hazards and Operability Study (HAZOP) and evaluate the environmental impact of the end-of-life removal of the marine outfall at the Meliadine Mine located approximately 25 km north of Rankin Inlet per Term and Condition No. 129 – New Condition for the Saline Effluent Discharge Proposal (TC129) of NIRB Project Certificate No. 006, Amendment No. 002. GreatPacifiC Consulting Ltd. (GPC) was retained by Agnico Eagle to conduct a HAZOP focused on the marine outfall and diffuser system (the outfall). This HAZOP identifies potential hazards and operability issues coupled with proposed mitigation measures to ensure safe and reliable performance of the outfall post-construction.

2 Background

The Meliadine Mine outfall forms the final component of a ~35 km effluent conveyance system that discharges treated effluent to Itivia Harbour in Rankin Inlet through a single HDPE outfall and multiport diffuser. The original outfall was designed by Tetra Tech, but Agnico Eagle engaged GPC to refine the configuration to improve “service-life, in-water performance, and constructability of the marine asset”.

The discharge system transitions from a nearshore launch site into an 84 m horizontal directional drilled (HDD) 24” diameter steel casing designed by Atkins Realis, daylighting at approximately –7.8 m in Melvin Bay (per For Permitting drawings dated April 5th, 2025, titled *Project No.6537 – Design Drawings 65-180-230-258*). GPC redesigned the weighting regime to repurpose existing precast concrete weights as underslung units with corrosion-resistant over-straps and fasteners. Post-lay doghouse weights were also added to enhance on-bottom stability and mitigate the risk of deballasting the pipeline should air be inadvertently discharged through the outfall. Construction and deployment were completed in 2025 using a conventional S-lay method with controlled flooding, tensioning, and diver-assisted placement with GPC overseeing the marine construction works at site.

The design of the outfall is as described in the Issued for Record (IFR) marine outfall drawings, titled: *Project No.6537 – Design Drawings 65-180-270-016 through 65-180-270-024*.

3 Term and Condition No.129

This HAZOP has been prepared in accordance with NIRB Project Certificate No. 006 - Term and Condition No.129 (Table 1).

Table 1 - Term and Condition 129

Term and Condition No.	129 New Condition for the Saline Effluent Discharge Proposal
Category:	Marine Environment
Responsible Parties:	The Proponent and Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC)
Project Phase:	Operations, care and maintenance, and closure
Objective:	To assess the environmental impact of the Project on the seabed and marine environment if the effluent discharge pipeline is abandoned in place or removed.
Term or Condition:	The Proponent shall conduct and submit to the Board a hazard and operability assessment of the pipeline and marine outfall system as part of the land authorization process.
Reporting Requirements:	To be provided to the Nunavut Impact Review Board at least 90 days prior to operation of the effluent pipeline and diffuser system.

At the end-of-life, the outfall is expected to be decommissioned and removed from the seabed by Agnico Eagle. This could be accomplished following this procedure (or similar):

1. Remove concrete doghouse ballasting over the pipeline via diver and surface vessel winch.
2. Remove 5 x Tideflex valves, and replace with blind flanges to seal the pipe, with offshore blind fitted with ball-valve to permit sealing of internal air once water purged.
3. De-couple pipeline at HDD daylight and seal the inshore submarine portion of pipeline.
4. Inject sealed pipeline with air from inshore end and progressively float it to the surface for collection by towboat.
5. Tow pipeline to the shore for dismantling.

Following the removal of the outfall, the habitat overlaid by the pipe should become immediately accessible to the species assemblage upon removal. Motile fish and benthic invertebrate species present within the nearby area should immediately begin re-colonizing the newly exposed habitat. The rate of re-colonization will be dependent on the species assemblage, the time of year, species reproductive cycles and migration rates.

4 Study Scope, Limitations and Assumptions

GPC prepared this HAZOP to evaluate the safe operability of the marine outfall system and identify credible hazards affecting its performance. The assessment is limited to the marine section of the

infrastructure, spanning STA 0+000 to the diffuser terminus at STA -0+145 of the marine outfall record drawings. The review does not extend to the upstream HDD section or on-land components.

Limitations of the study include the following:

- **Limited participation of stakeholders** – Participation from original engineer of record for the outfall, construction, operations, and maintenance personnel was limited, reducing the ability to validate certain operational or site-specific hazards.
- **Desktop Study** – This report was written from the desktop using available documentation provided by Agnico Eagle. A site visit was not performed with the intention of appraising potential hazards to the outfall system, although GPC did have an Engineer onsite during marine construction.
- **Post-Construction identification** - The HAZOP was completed after construction of the outfall system. As such, opportunities to influence design decisions were limited.
- **Record Information** – Record information provided was not independently verified by the authors of this HAZOP.
- **Operations and maintenance (O&M) manual** – At the time of writing, an O&M manual does not exist for the outfall system. The ability to assess maintenance related hazards is therefore limited.

The following general assumptions were made in the preparation of this report:

- The system was constructed in accordance with the IFR drawings and design specifications provided.
- In the absence of an O&M manual, it is assumed that the system will be operated and maintained in accordance with standard operating procedures and industry best practice.
- The outfall is assumed to operate in accordance with its permit(s); only during periods where sea ice is not present in Melvin Bay.
- Flow rates, temperatures, and effluent chemistry are assumed to remain within the ranges used for design.
- Bathymetry, sediment mobility, and ice gouging conditions are assumed to remain consistent with those considered during design.
- It is assumed that the owner will have seasonal access to the outfall for inspection and maintenance activities.
- It is assumed that upstream pumping, flow control, and monitoring systems function correctly and do not introduce abnormal hydraulic or pressure conditions (i.e. entrained air).
- It is assumed that Agnico Eagle staff will be the designated responding party for all hazards, mitigations, and works relating to the submarine outfall and its operation.
- It is assumed that the outfall has been demarcated on Canadian Hydrographic Service (CHS) marine charts.
- It is assumed that the shore outfall sign will remain upright and legible to mariners year-round.

- It is assumed the cautionary buoy will be seasonally reinstated as per the IFR drawings and the Transport Canada - Navigational Protection Program (NPP) approval document issued for the marine outfall.

5 Hazard and Operability Study

The HAZOP Study was completed to systematically evaluate potential hazards, failure mechanisms, and operability concerns associated with the marine portion of the Itivia outfall system. The objective of the study was to identify credible risks to system performance, structural integrity, environmental protection, and safe operation. It also aimed to document appropriate mitigation and response measures in response to those risks.

The HAZOP followed a structured review process. Each hazard was examined using a standardized breakdown that included:

- **Hazard** – the condition or event posing risk
- **Cause** – initiating factors or system vulnerabilities
- **Failure Mechanism** – the physical or operational process that occurs due to the hazard
- **Consequence** – potential impacts to safety, environment, or system function
- **Mitigation** – existing or recommended controls to reduce consequence(s)
- **Response** – actions required if the hazard occurs
- **Residual Risk** – leftover risk following implementation of the mitigation measure(s)

Hazards were recorded in table format, and are presented in Appendix A.

6 Conclusion

This HAZOP provides a structured evaluation of hazards, failure mechanisms, and operability considerations associated with the marine outfall portion of the discharge system. The review, supported by record drawings and deployment documentation, identified risks related to ballast performance, seabed interaction, diffuser function, air-management, and seasonal access, consistent with the scenarios summarized in Appendix A.

Many hazards are already mitigated through the system's design and installation approach, while others require routine inspection and maintenance during ice-free periods. The findings offer a technical basis for safe operation and ongoing monitoring and should be updated as site conditions evolve, or new operational/ inspection data becomes available.

Appendix A Completed HAZOP Table

NOTE: The mitigations and responses listed in the completed HAZOP table should not be treated as comprehensive instructions. Detailed mitigative or hazard response procedures should be addressed through an O&M Manual developed in cooperation between Agnico Eagle and a qualified marine outfall engineer.

HAZARD #	HAZARD	CAUSE	FAILURE MECHANISM	CONSEQUENCE	MITIGATION	RESPONSE	RESIDUAL RISK
1	Sea Ice Damage.	Seasonal ice develops up to several meters thick.	Ice impacts or bears on exposed subsea pipe.	A leak resulting from a pipe break may cause non-compliant discharge, system failure, and operational shutdown i.e. Tearing pipe from HDD connection and changing point of discharge. Deformation of pipe could limit discharge capacity.	A horizontal directional drill (HDD) was used to transition on-land pipe to a subsea daylight of the outfall, well below Lower Low Water Large Tide (LLWLT). With a maximum ice thickness accounted for, this places the pipe daylight below any potential sea ice draft.	None required; already addressed in design.	Negligible
2	Pipe Flotation.	Ballast weights may decouple from the HDPE (mildly buoyant in seawater) pipe.	Metallic fasteners are exposed to a saline environment.	Pipe ballasts decouple from the pipe, permitting the pipe to lift/mobilize, float to the surface and be struck by vessel (nav-hazard), or rotate from design alignment and potentially kink.	HDPE and marine-grade 2507 SDSS metallurgy are used in the design. Post-lay doghouse weights passively ballast pipe (no fasteners) to overcome a fully air-filled pipe.	None required; already addressed in design.	Negligible
3	Settlement/ Stability of concrete ballast weights.	Seabed conditions cause differential settlement beneath concrete weights.	Soft or uneven seabed substrate leads to uneven weight distribution and settlement over time. This may affect the stability of the concrete weights i.e. If one side settles more and causes the weights to topple.	Pipe stress may occur due to uneven support, potentially causing joint strain or leaks, resulting in non-compliant discharge. Stability of weights is suboptimal.	Perform regular yearly inspections early in the ice-free periods to minimize unexpected failures. Stability of ballast weights addressed in design (underslung weights: low center of gravity, doghouse weights: centre of gravity below hinge point).	None required; already addressed in design. Re-level or reposition ballast via diver during the maintenance window, if necessary.	Negligible
4	Vessel Impact.	A grounded vessel or anchor impact damages or snags and drags the pipeline.	Vessels may be unaware of the pipeline location and drag their anchor across the pipeline alignment.	A leak resulting from a pipe break may cause potential non-compliant discharge, system failure, and shutdown.	Pipeline buried in HDD portion to below typical vessel draft for region. Perform regular yearly inspections early in the ice-free periods to minimize unexpected failures. Ensure outfall sign is visible from offshore and the pipeline is marked on CHS navigation maps.	None required; already addressed in design through the outfall sign and location demarcation on marine charts. Repair damaged pipe via diver during the maintenance window, if necessary.	Low
5	Leaking pipe.	Leaks occur at pipe joints.	Pipe wall integrity is compromised. Bad butt-fusion. Gasket deterioration. Loose fasteners.	Non-compliant discharge may occur, leading to system failure and shutdown.	Perform regular yearly underwater inspections early in the ice-free periods to minimize unexpected failures. Fasteners torqued to PPI TN-38 Specs. Garloc Multiswell gasket used and no failure modes exist for in-service configuration.	Perform diver inspection to identify and repair the leak during the maintenance window, if necessary.	Low
6	Animal interference.	Marine wildlife impacts the diffuser nozzle.	The diffuser valve(s) or pipe is broken by impact.	Diffuser flow is impacted.	None - negligible risk level.	Replace or repair damaged diffuser valve via diver during the maintenance window.	Negligible
7	Animal interference.	Marine wildlife enters and blocks the diffuser nozzle.	The diffuser nozzle becomes blocked.	Diffuser flow is impacted.	None - low risk level due to presence of duckbill valve with substantial backpressure rating.	Clear the blockage and inspect diffuser nozzle via diver during the maintenance window.	Negligible
8	Corrosion of mechanical fittings.	Accelerated corrosion of fittings occurs.	Metallic fitting elements are exposed to a saline environment.	Corroded fittings leak, causing non-compliant discharge.	Perform regular yearly inspections early in the ice-free periods to minimize unexpected failures. HDPE and 2507 SDSS marine-grade metallurgy are used in the design, no mixed metallurgy, nor reliance on anodes for achieving service-life.	Replace or repair damaged fittings via diver during the maintenance window, if necessary.	Low

HAZARD #	HAZARD	CAUSE	FAILURE MECHANISM	CONSEQUENCE	MITIGATION	RESPONSE	RESIDUAL RISK
9	Substantial quantities of air are discharged through the marine outfall with the treated effluent.	Air is not effectively stripped from the effluent sent through the overland forcemain before entering the outfall.	The air coalesces and displaces water inside the pipe, resulting in buoyancy.	The outfall pipe could deballast and float to the surface, potentially being struck by a vessel (navigation hazard), and could cause an air-lock or blockage/kink.	The outfall system is overweighted to account for increased buoyancy potential resulting from accumulated air discharge.	None required; already addressed in design.	Negligible
10	Substantial quantities of air are discharged through the marine outfall with the treated effluent while a vessel is at the surface nearby.	Air is not effectively stripped from the effluent sent through the overland forcemain before entering the outfall.	A large volume of air is discharged through the diffuser nozzles and the bubbles rapidly reach the water surface, locally reducing the water density beneath a vessel.	A smaller vessel at the surface may lose buoyancy and stability due to reduced water density from rising air bubbles, posing a safety hazard to the vessel and crew.	Ensure outfall sign is visible from offshore and the pipeline is marked on CHS navigation maps to warn vessels of the discharge location. Monitor outfall system to determine when large volume air discharge may occur and ensure no vessels are nearby the diffuser. Cautionary buoy will be deployed during ice-free period.	Already addressed in design through the outfall sign and location demarcation on CHS marine charts. Address through O&M procedures.	Low
11	Weakening or lack of sea ice at ocean surface above terminus.	Mobilization of the water column above the terminus reduces sea ice formation above the discharge location.	Sea ice is weakened or does not form above the discharge location.	Weak ice presents hazards to those traversing the surface ice.	Outfall is not in operation during periods where sea ice is present. Ensure outfall sign is visible from offshore and the pipeline is marked on CHS navigation maps.	None required; already addressed through operational procedure, outfall sign and location demarcation on marine charts.	Negligible
12	The outfall is installed but discharges only low salinity effluent to the ocean and the seawater at depth within freezes the low salinity effluent solid inside the outfall pipe limiting discharge capacity.	The temperature at depth in summer may be below 0°C, and low salinity effluent sent through the outfall may freeze inside the pipe if not flushed.	Low salinity effluent discharge freezes in low ambient temperatures at depth within Melvin Bay.	Low salinity effluent inside the outfall may become permanently frozen and block the discharge capacity of the outfall pipe.	Purge the outfall of low salinity effluent during periods of low temperature, and at end of each discharge cycle. Verify temperature and site ambient conditions to determine the degree of risk. Include appurtenance and capacity for steam injection at the inshore end of HDD casing to thaw the pipeline from shore, if required.	Review site ambient conditions. Ensure low-salinity effluent is purged from system. Include flushing and steam injection capacity at the onland HDD connection.	Medium
13	Seasonal access constraints.	Sea ice prevents visual inspection or maintenance of the submarine pipe seasonally.	A combination of other potential hazard or failure mechanism may occur during this period.	A combination of potential consequences may occur, with remediation only possible once the ice melts, or through-ice dive intervention (not recommended). This may delay reinstatement of discharge operation well into the ice-free period.	Perform regular yearly inspections early in the ice-free periods to minimize unexpected failures. Only operate the outfall during ice-free periods. Consider monitoring systems such as pressure gauges and flow meter.	If a failure occurs during the ice season, suspend discharge operations until access is restored and repairs can be completed.	Medium
14	Scour Around Ballast Weights.	Local turbulence occurs around concrete weights.	Undermining causes weight settlement, leading to pipe stress.	Joint strain may occur with potential leaks, resulting in non-compliant discharge.	Perform regular yearly inspections during ice-free periods to minimize unexpected failures. Heavy-wall DR17 pipe employed in design with butt-fusions performed to ASTM-F2620.	Re-level or reposition ballast via diver during the maintenance window.	Low
15	Concrete Ballast Weight Cracking / Degradation.	Freeze-thaw cycles and sulfate attack affect the concrete.	Loss of mass or structural integrity occurs.	Pipe ballasts may decouple from the pipe, creating an uplift risk.	Marine-grade concrete (C1) is used, which is highly sulfate resistant. Concrete weights are positioned below the freeze depth.	Replace failed ballast via diver during the maintenance window.	Negligible
16	Seismic Events.	Regional seismicity.	Liquefaction or lateral spreading, extreme wave effects (tsunami).	Joint strain may occur with potential leaks, resulting in non-compliant discharge.	None - low risk level.	Repair damaged system components via diver during the maintenance window, if necessary.	Low

HAZARD #	HAZARD	CAUSE	FAILURE MECHANISM	CONSEQUENCE	MITIGATION	RESPONSE	RESIDUAL RISK
17	Sediment Accumulation / Burial.	Sediment transport and deposition occurs along the seabed.	Natural sediment migration or storm events deposit material over the pipeline and diffuser.	Diffuser nozzles become buried or blocked, reducing discharge capacity and altering flow patterns. Submarine pipe becomes obscured and therefore difficult to inspect.	Perform bathymetric surveys during yearly inspections to monitor sediment levels. Ports are >1 m off the seabed. Area appears to offer low-current speeds minimizing on-bottom sediment mobilization potentials.	Clear sediment accumulation via diver or remotely operated vehicle during the maintenance window.	Negligible
18	Diffuser instability.	Jets of effluent exiting terminus nozzles topple/ scour beneath diffuser structure.	High-velocity effluent jets induce rotational force on the pipe or cause localized scour beneath the diffuser structure, undermining its foundation.	Diffuser structure becomes unstable or topples, resulting in misdirected discharge and potential non-compliant discharge patterns.	Alternating, surface-directed diffuser nozzle pattern equalizes rotational force/minimizes seabed directed flow. Underslung weights improve on-bottom stability and increase righting moment capacity.	If diffuser toppled, reinstate during ice-free period using divers and work vessels.	Negligible
19	Biofouling / Marine Growth.	Marine organisms colonize the pipeline exterior and diffuser openings.	Barnacles, mussels, algae, and other organisms accumulate on pipe surfaces and inside diffuser nozzles.	Reduced discharge efficiency occurs due to restricted flow.	Include biofouling assessment/clearing in yearly inspections.	Remove marine growth via diver cleaning during the maintenance window.	Low
20	Thermal Expansion / Contraction.	Seasonal temperature variations cause pipe movement.	HDPE pipe expands and contracts with temperature changes between effluent and ambient seawater.	Repeated thermal cycling may cause joint fatigue or displacement, leading to potential leaks and non-compliant discharge.	None - negligible risk level for submarine pipe given design conditions and typically gradual thermal changes seasonally.	Inspect joints for signs of fatigue or displacement during yearly maintenance. Repair or replace affected components as needed.	Negligible
21	Debris Accumulation at Diffuser Nozzle.	Storm events or currents carry debris toward the outfall/diffuser.	Large debris (driftwood, fishing nets, plastic waste) becomes entangled with the pipeline or diffuser structure.	Obstructed discharge flow, potential damage to diffuser nozzles, and possible non-compliant discharge patterns.	Include debris assessment in yearly inspections. Outfall sign, cautionary buoy, and demarcation of pipeline on CHS marine charts alerts fishermen of presence of marine infrastructure risking the snagging of nets/traps.	Remove debris via diver or remotely operated vehicle during the maintenance window.	Low
22	HDPE pipe butt-fusions fail.	Butt-fusions fail and leaks develop in pipe.	Butt-fusions are not compliant and do not have adequate tensile strength.	Non-compliant discharge may occur, leading to system failure and shutdown.	Agnico Eagle employed experienced/certified HDPE butt-fusion technician for the performance of fusions onsite. Multiple portions of the outfall/diffuser assembly were pre-fused prior to shipping to site to reduce the number of fusions performed in field. Submarine pipe pressure tested prior to commissioning to ensure no leaks present/ joint integrity. Deployment of outfall to seabed is typically the most rigorous process the outfall will be subjected to during service-life. Post-lay inspection and pressure testing showed fusions to be acceptable.	Perform diver inspection to identify and repair (install external coupler) the leak during the maintenance window, if necessary.	Low