REPORT

FEASIBILITY STUDY PHASE II PEER REVIEW THUNDER BAY

Prepared for

Confederation College
1450 Nakina Drive
Thunder Bay, Ontario P7C 4W1

Prepared by

Anchor QEA, LLC
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Beverly, Massachusetts 01915

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LIST OF ACRONYMS AND ABBREVIATIONS

µg/g	micrograms per gram
AMEC	AMEC Earth & Environmental Inc.
Anchor QEA	Anchor QEA, LLC
AOC	Area of Concern
AOS	apparent opening size
BOD	biochemical oxygen demand
CAD	confined aquatic disposal
Cascades	Cascades Fine Papers Group, Inc.
CDF	confined disposal facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm	centimetre
CoC	contaminant of concern
CPT	cone penetrometer testing
CWQG	Canadian Water Quality Guidelines
DFO	Department of Fisheries and Oceans
DRET	dredge elutriate testing
EOS	enriched organic sediment
g/cm^3	grams per cubic centimetre
gpd	gallons per day
ha	hectares
HAAT	Habitat Alteration Assessment Tool
H_s	significant wave height
kg	kilograms
kg/L	kilograms per litre
km	kilometres
L/kg	litres per kilogram
m^3	cubic metres
Mill	Cascades Fine Papers/Provincial Paper Mill
MNA	monitored natural attenuation
MOE	Ontario Ministry of the Environment

NCDF	nearshore confined disposal facility
ng/g	nanograms per gram
ng/L	nanograms per litre
NSC	North/South Consultants, Inc.
PCLT	pancake column leachate test
psf	pounds per square foot
psi	pounds per square inch
PSQG	Provincial Sediment Quality Guidelines
PWQO	Provincial Water Quality Objectives
QTC	Quester Tangent Corporation
RCM	reactive core mat
SEL	severe effects levels
SMO	sediment management option
SMU	sediment management unit
Stantec	Stantec Consultants, Ltd.
STING	Seabed Terminal Impact Newton Gradiometer
TBPA	Thunder Bay Port Authority
TKN	total Kjeldahl nitrogen
TOC	total organic carbon
T_p	peak spectral period
USEPA	United States Environmental Protection Agency

EXECUTIVE SUMMARY

Anchor QEA, LLC (Anchor QEA) has prepared this Feasibility Study Phase II Peer Review for the Thunder Bay site located on Lake Superior in Thunder Bay, Ontario, for Confederation College on behalf of the Steering Committee, which is made up of representatives from Cascades Fine Papers Group, Inc. (Cascades), Environment Canada, and the Ontario Ministry of the Environment (MOE). AMEC Earth & Environmental Inc. (AMEC) submitted the Feasibility Study Phase II on January 30, 2011.

The purpose of this review is to critically evaluate the feasibility study process followed by AMEC and the feasibility study findings.

AMEC's Feasibility Study Phase II concluded that isolation capping was the preferred sediment management option (SMO) for the enriched organic sediment (EOS) based on lower complexity and cost than other SMOs that included dredging and on-site or off-site disposal of dredged material. Based on our review of the AMEC Feasibility Study Phase II, we do not believe the analysis fully supports capping as the preferred SMO. Further developing the SMO conceptual designs to a higher level of detail is recommended to reduce uncertainties that are potentially significant factors for predicting SMO performance and in estimating cost.

Our opinion is that additional information is required to characterize the geotechnical and physico-chemical properties of the EOS and underlying native sediment. A considerable amount of work was performed by AMEC during the feasibility study process to characterize the two sediment layers. However, conclusions that are based on the geotechnical characterization are not supported by the analysis. Standard laboratory testing for geotechnical index properties is not available for either EOS or the underlying native sediment. This makes typical analysis to support design concepts (e.g., consolidation test results used for cap stability analysis and contaminant fate and transport modelling) difficult.

Specific examples of where further characterization is needed include the following:

- Verifying that the EOS will support a cap
- Providing rationale for a confined disposal facility (CDF) berm foundation design

- Further evaluating the physico-chemical characteristics of the sediment, especially as they pertain to environmental risk and toxicity, to manage sources of risk and toxicity
- Evaluating the presence of debris and potential issues for the SMOs

The coastal process information included in the AMEC feasibility study report included wind/wave/current data. We re-analyzed the coastal processes evaluations and findings were in general agreement, with minor exceptions noted in the main report. The period considered for wind wave data used to model wind waves was not clear and should be better documented.

The volume of EOS is presented as a neatline volume consistent with standard engineering practice, with an assumed volume adjustment for dredging that increases the neatline volume by 50% (i.e., multiplies the neatline volume by a factor of 1.5). However, the EOS area and volume are large, and small changes in assumptions during conceptual design can result in relatively significant differences in volume and associated remedial cost. Processes such as bulking during dredging and shrinkage during drying will significantly affect the dredging, transport, and dewatering volumes. Further developing a dredge prism is more typically done during remedial design; however, the potential cost implications associated with variation in dredged material volume warrant developing a site-specific dredge prism during the feasibility study phase.

The weighting or ranking of the evaluation criteria was not defined. The criteria require detailed description, the method by which they are applied to the SMOs, and the ranking of the criteria. In general, the field programs and field data collection targeted and collected useful information (with the exception of the geotechnical characterization discussed above) but the data were not fully applied to the analyses.

The costs do not fall within the targeted 20% contingency range requested by the Steering Committee. That range is more accurate than is typical for feasibility studies in our experience. A more typical feasibility study range is +50%/-30%. We do not believe the costs necessarily fall within this range either.

The study should have included a review of the availability of specialty contractors and equipment to perform work in the Thunder Bay area. The requirement to transport equipment long distances and/or fabricate the equipment on site can be a significant cost factor. Equipment operator skill and experience for operations such as capping and environmental dredging can be a significant factor in cost and project.

The peer review of the SMO evaluation can be summarized as follows:

- SMOs that included capping:
  - The cap constructability is not adequately addressed. Additional geotechnical information (i.e., consolidation testing, geotechnical index properties, and strength measurements) is required to evaluate constructability of the cap.
  - The effectiveness of the isolation cap for chemical sequestration was not fully detailed. We could not re-create AMEC's cap modeling outcome. We recommend performing a re-analysis of isolation cap modelling.
  - Design elements that have potentially significant implications for cost were not fully addressed in the Feasibility Study, including cap construction approach to avoid destabilizing soft EOS and underlying native sediment, and sourcing of cap materials.
- SMOs that included dredging:
  - Existing column settling test (CST) results, dewatering test results, and dredge elutriate testing (DRET) results should have been used to perform a more detailed analysis of EOS properties related to potential releases during dredging, dewatering characteristics, and associated influence on dredging, dewatering, and disposal options.
  - A pilot test may be needed during a more advanced design stage to further evaluate and refine potential dredging methods, but information presently available should be sufficient for developing a feasibility study-level-of-detail conceptual dredging design. The conceptual design can better refine constructability- and cost-related issues such as dewatering rates and overdredge allowance.
  - The SMO conceptual designs did not include provisions for controls (to a level of detail that allows for evaluation of potential performance and cost) to mitigate

potential impacts during dredging and disposal operations. Available information, including CST and DRET results, can be used for this analysis.

- Design elements that have significant potential implications for cost were not fully addressed in the study, including the following:
  - Dredged material volume estimate accuracy
  - Dredging approach needs, even conceptually, and dewatering, consolidation, CDF volume, and fate and transport considerations. A worst-case or conservative/high-cost scenario could be compared to the 20% contingency carried for cost or to the more typical feasibility study cost range.
- Dredging costs were consistent with our experience on other projects but need to be associated with a more detailed conceptual design and better documented.

- SMOs that included CDF disposal:
  - We could not re-create AMEC's foundation analysis for the on-site CDF berm. The CDF containment structure was complex and expensive and we were not convinced the containment structure was constructible. Additional geotechnical information and analyses are needed to develop a feasible conceptual design for a CDF containment structure.
  - There was insufficient analysis to evaluate contaminant of concern (CoC) isolation by the CDF containment structure. We recommend evaluating CoC fate and transport within the CDF to better define the chemical isolation requirements for the CDF containment structure. Chemical isolation requirements may result in adding design features to the SMOs. Design elements that have significant potential implications for cost were not fully addressed in the study, including the following:
    - Berm construction in a complex and costly CDF containment structure approach.
    - Closure/capping costs were not included and can vary significantly depending on the site use and associated schedule and loading requirements.
    - Off-site CDF construction and disposal costs were not documented and could not be confirmed.
    - The containment of CoCs within the CDF was not addressed.

    - Dredging and CDF disposal costs were consistent with our experience on other projects but, similar to capping and dredging costs, need to be associated with a more detailed conceptual design and better documented.

- The SMO that included off-site disposal:
  - Should have included documentation of a cost-benefit analysis comparing hydraulic and mechanical dredging. details of the conceptualized dewatering system (flow rate, system capacity) are not specified and may not be adequate
  - Design elements that have significant potential implications for cost were not fully addressed in the study, including the following:
    - The dredging approach, as discussed above
    - The dewatering system, including dewatering of dredged material and treatment of dewatering effluent
    - Landfill disposal – no discussion is presented indicating the dredged material would comply with landfill disposal requirements
  - Costs were consistent with our experience on other projects but need to be better documented and evaluated relative to local availability of equipment and expertise.

We believe the following alternative SMO approaches have merit and warrant further consideration:

- Combining a smaller on-site CDF with a smaller isolation cap area, with the cap area located in management areas outside the CDF
- Using the existing mill facilities to manage dredged material
- An alternative approach for constructing an on-site CDF containment structure

Alternative SMO approaches that were considered in this peer review include the following:

- Removal and recycling of EOS
- Confined aquatic disposal (CAD) of EOS
- Removal and thermal treatment of EOS
- Filling of the sediment management unit (SMU) area to create dry land

These alternative SMO approaches are not likely feasible.

In summary, recommendations for the next steps include the following:

- The evaluation criteria definition should be more fully described, and the weighting of the evaluation criteria agreed upon.
- Further clarify remedial objectives—fully assess EOS toxicity and identify primary sources of toxicity including CoCs/EOS properties, if any, in addition to mercury to more comprehensively define sediment cleanup objectives and criteria.
- Further detail design elements to refine cost estimates. The most significant areas where we see the need for additional work include the following:
  - Defining containment requirements and construction approach for a cap
  - Refining the sediment/dredge volume estimate
  - Developing a dredging method and environmental controls during dredging
  - Identifying CDF containment structure type and construction approach
- Further evaluation of the recombined/reconfigured SMOs

In general, AMEC's feasibility study requires additional data collection, analysis of new and existing data, and developing the SMOs to a higher level of detail to recommend a preferred SMO and develop associated cost estimates to within the 20% accuracy target range. There is sufficient uncertainty in the SMO conceptual designs expected performance and estimated cost that the Feasibility Study Phase II conclusions and findings require further support.

1 INTRODUCTION

Anchor QEA, LLC (Anchor QEA) has prepared this Feasibility Study Phase II Peer Review for the Thunder Bay site located on Lake Superior in Thunder Bay, Ontario. This report has been prepared for Confederation College on behalf of the Steering Committee, which is made up of representatives from Cascades Fine Papers Group, Inc. (Cascades), Environment Canada, and the Ontario Ministry of the Environment (MOE). AMEC Earth & Environmental Inc. (AMEC) submitted the Feasibility Study Phase II to Confederation College on January 30, 2011.

The purpose of this peer review report is to critically evaluate the AMEC feasibility study. The peer review includes the following:

- Critical assessment of field work
- Critical review of all data collected
- Verification of assumptions, and evaluation of the findings, conclusions, and recommendations
- Assessment of the process followed, protocols and methodologies used, and comparison to standard engineering practices
- Expert advice on the study findings, including cost estimates, dredging volumes, confined disposal facility (CDF) configuration, and capping design considerations

Our review of AMEC's Feasibility Study Phase II is summarized in this report. Our report also includes recommendations for addressing technical issues and for next steps.

1.1 Background

Port of Thunder Bay is located on the western shore of Lake Superior in Thunder Bay, Ontario. Thunder Bay North Harbour is approximately 8.5 kilometres (km) long, extending from Bare Point to Kaministiquia River and, on average, 1.0 km wide (ranging from 0.5 km to 1.2 km). It is sheltered from Lake Superior to the east by a breakwall, which was constructed around 1884 to 1916 (the date of construction was not available in the documents reviewed) and rises approximately 2.5 metres (m) above the lake surface.

In 1987, the Thunder Bay Harbour was identified by the U.S.-Canada Great Lakes Water Quality Agreement as an Area of Concern (AOC) along with 42 other sites based on degraded surface water and sediment quality. Effluent discharge from a formerly operating paper mill resulted in the accumulation of enriched organic sediment (EOS) and contaminants of concern (CoCs). The EOS is composed of wood fibre, wood waste, and inorganic clay from the paper manufacturing process. The area of EOS is referred to as the sediment management unit (SMU) and is located within the northeast portion of Thunder Bay Harbour, adjacent to the former Cascades Fine Papers/Provincial Paper Mill (Mill) and a float plane service.

The SMU is approximately 22.2 hectares (ha) in size, and the water depth ranges from 0.5 to 4.0 m. Based on information reviewed, the area has not been dredged. Based on previous work by AMEC, there appears to be a sharp interface between the overlying EOS and the underlying native silt. The EOS reportedly ranges in thickness from 0.4 to 3.8 m, and the thickest deposit of EOS appears to be located in the general vicinity of the shoreline. The volume of material has been estimated at approximately 350,000 cubic metres (m^3).

1.2 Previous Investigations

As listed in AMEC's Feasibility Study Phase I (2010), several studies of the EOS found within the north harbour area of Thunder Bay have been completed and the results are presented in the reports below:

- Biological Effects of Mercury Contaminated Sediment in North Thunder Bay, Lake Superior (Milani and Grapentine 2002)
- Mercury Investigation in Thunder Bay Harbour Sediment (Stantec Consultants, Ltd. [Stantec] 2003)
- Biological Assessment of Sediment Quality in Thunder Bay North Harbour (Milani and Grapentine 2005)
- Biomonitoring Study of Thunder Bay Harbour in the Vicinity of Cascades Fine Paper: 2003-2004 (Fletcher and Petro 2007)
- Report on the Collection, Handling, and Analysis Results of Sediment samples from the North Thunder Bay Harbour (North/South Consultants, Inc. [NSC] and Quester Tangent Corporation (QTC) 2006]

- Sediment Geometry and Estimated Volume for the Northeast Sector of Thunder Bay Harbour (Biberhofer et al. 2007)
- Review of Mercury Investigations in the Thunder Bay Harbour (EcoMetrix 2007a)
- Thunder Bay Harbour Sediment Management Strategy: Management Screening Options (EcoMetrix 2007b)
- Feasibility Study – Phase I: Thunder Bay Harbour Sediment Management Project (AMEC 2010)
- Feasibility Study – Phase II: Thunder Bay Harbour Sediment Management Project (AMEC 2011a)

These reports were made available to Anchor QEA and were used to assess AMEC's analysis of sediment management options (SMOs). Although the peer review was limited to the review of AMEC's Feasibility Study Phase II report per the scope of the proposal, analysis of the Feasibility Study Phase I report and the documents listed above was included to more thoroughly review proposed SMOs.

2 SUMMARY OF AMEC FEASIBILITY STUDY PHASE II

2.1 Evaluation Criteria

AMEC used the United States Environmental Protection Agency (USEPA) Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) evaluation criteria to evaluate the proposed SMOs. The evaluation criteria include the following:

- Protection of Human Health and the Environment
- Compliance with Standards and Guidelines
- Short-Term Effectiveness
- Long-Term Effectiveness and Permanence
- Reduction of Toxicity, Mobility, or Volume
- Implementability
- Cost
- Community Acceptance (USEPA 1988)

The weighting or ranking of the criteria was not reported in the documents reviewed.

2.2 Proposed Sediment Management Options

SMOs were initially evaluated for the SMU by Ecometrix in March 2007. They briefly evaluated: long-term monitoring (monitored natural recovery), in situ treatment, capping, and sediment removal. They concluded that disposal of sediment within an on-site CDF or full land extension over the impacted area would be most effective SMO from the perspective of evaluation criteria short-term risk, residual risk, management controls, cost, and reliability, but cautioned that this was not a final recommendation.

Ecometrix completed a more comprehensive review in September 2007, evaluating: monitored natural attenuation (MNA), in situ remediation, in situ capping, and sediment removal by dredging. They scored the various SMOs and, based on the technical screening evaluation, on-land disposal, CDF disposal, or capping were the most desirable.

AMEC was retained by a Steering Committee in November 2008 to conduct geotechnical and marine studies in support of preparing a comprehensive Feasibility Study to evaluate the following four SMOs: sediment cap, on-site CDF, dredging and disposal at an off-site CDF, and dredging with disposal at an upland facility. In addition to these SMOs, MNA was also evaluated to serve as a base case to which the other SMOs could be compared.

This evaluation is presented in Feasibility Study Phase I, and recommended SMOs were not presented due to data gaps. Data gaps included geotechnical characterization of EOS and native sediment, data to support dredging and dewatering design, and the expected constructability/performance of a sediment cap. The following were recommended from Phase I: additional field investigations to characterize sediment geotechnical properties, and sediment volume; a dredging pilot study; a bench-scale dewatering test; and a capping pilot study.

In order to thoroughly assess the proposed SMOs, additional studies were completed in 2009. The additional studies were summarized in the Feasibility Study Phase II report and used to re-evaluate the implementation and cost criteria for each SMO.

The following SMOs were developed and evaluated in AMEC's feasibility study:

- MNA
- Isolation capping, including capping with sand and reactive capping
- SMOs that included dredging and the following disposal options for dredged material:
  - On-site CDF
  - Off-site CDF disposal, at a CDF operated by the Thunder Bay Port Authority (TBPA)
  - Off-site upland disposal

AMEC's Feasibility Study Phase II concluded that isolation capping was the preferred SMO for the EOS based on lower complexity and cost than other SMOs that included dredging and on-site or off-site disposal of dredged material.

A detailed review of AMEC's feasibility study assumptions, analyses, methods, findings, and recommendations are presented in Section 3.

2.3 Review of General Assumptions

AMEC presents several general assumptions in their Feasibility Study Phase II report. Those assumptions and our review comments are summarized below:

- Additional stakeholders, including the general public and current Mill owners/operators, will be involved in the SMO selection process. This assumption appears to be valid.
- The area of the SMU is 22.2 ha. According to the Steering Committee this area has been delineated as the area to be considered in AMEC's feasibility study.
- Noise considerations were not taken into account because the closest residential building is approximately 900 m from the proposed dewatering/laydown and dredging areas. This may be a valid assumption for the feasibility study but would require further analysis during the design stage of the project.
- The Mill will allow continual access to the site, the entrance and exit of construction vehicles through the Mill site, and the use of the Mill property (or part thereof) for all construction activities. Communication with the current owners of the Mill property that verify this assumption should be included in AMEC's feasibility study report.
- The TBPA will grant access to the harbour and the SMU at no cost, and will approve each of the SMOs carried forward. Communication with the TBPA that verify this assumption should be included in AMEC's feasibility study report.
- The Mill will not be in operation during or after the construction of the preferred SMO. This assumption is appropriate for the feasibility study but should be re-evaluated as the project proceeds.
- The harbour breakwall will remain in place to maintain a quiescent marine zone. This assumption is appropriate for the feasibility study.
- Although not explicitly referenced as an assumption in AMEC's feasibility study, the SMOs are focused on mercury. Mercury concentrations higher than the Provincial Sediment Quality Guidelines (PSQG) severe effects levels (SEL) were identified in EOS. However, additional contaminants may be contributing to site toxicity, including the EOS physico-chemical properties. Ecometrix (2007) initially presented this data gap during their review of previous mercury investigations. AMEC included discussion of the data gap in the Feasibility Study Phase I. AMEC conducted toxicity testing on the EOS porewater in the Feasibility Study Phase II. Chemical analysis was

limited to total mercury and addressed methyl mercury more qualitatively. In addition, other contaminants that have been identified above the PSQG SEL were not analyzed in the toxicity testing. In summary, although sediment cleanup objectives were not a part of the Feasibility Study Phase II report, sediment contaminants contributing to the site toxicity and risk should be evaluated to more comprehensively identify and evaluate SMOs. A clear connection between sediment CoCs, toxicity, risk, guidance, and associated cleanup objectives has not been established in AMEC's feasibility study or previous reports. If this is not done, the SMOs pose the risk of addressing mercury but not addressing another potential source of risk/toxicity. A SMO (in particular, SMOs that rely on containment of the EOS, like capping or CDF) that would work for mercury may not work for other contaminants.

The general assumptions above apply to all SMOs. Assumptions that are more specific to a subset of the SMOs are addressed in the review of the individual SMOs in Section 3.

2.4 Additional Assumptions

Additional assumptions that should have been addressed in the AMEC feasibility study but were not reported are addressed in this section.

2.4.1 Future Site Use

In the presentation of SMOs, potential future uses of the site are not assumed or discussed for either the upland Mill property or the harbour area. Construction of a sand cap, reactive core cap, or on-site CDF changes the shoreline as well as the water depths within the harbour and would impact and/or limit future site use. If a cap is installed, navigation in the harbour will be restricted or eliminated due to decreased water depths. Additionally, the potential impact of the proposed remediation on hydraulic properties (e.g., circulation in this portion of the bay) should be evaluated.

Future use of the site is particularly important in the development of the on-site CDF SMO. Construction alternatives for the CDF are dependent on potential use of the newly developed area and the overall development timeline. A more robust CDF cap design is required if the

CDF is to be used for industrial purposes, and the CDF subsurface may require stabilization, depending on loading. If no future use is identified or assumed and the CDF is only utilized to contain contaminated material, future owners of the Mill property need to be aware that the CDF has use limitations. As configured, the CDF cannot be used as additional space for operations or storage that have an associated structural load above the bearing capacity of the CDF cap. The bearing capacity is not specified for the CDF surface but is likely to be insufficient for typical industrial or waterfront operations based on the organic nature of the dredged material. The benefit of creating additional space for potential future use should be balanced with the cost of designing and constructing the CDF for such uses.

2.4.2 Local Remedial Construction Experience

Availability of local experienced remedial construction contractors and specialized equipment required for implementing the SMOs are not assumed or discussed in the feasibility study.

Due to the unique characteristics of the EOS and several of the proposed remedial option designs (e.g., capping, berm construction, and precise dredging), an experienced contractor with specialized equipment is likely to be required to minimize risk and costs. Based on communication with the Steering Committee and local engineering firms, it appears that experienced contractors and specialized equipment are not readily available in this region.

We recommend evaluating these factors in the feasibility study, and evaluating the requirements and impact to construction costs for mobilizing contractors and equipment to Thunder Bay from other areas, along with increased operating costs for non-local contractors.

2.4.3 Availability of Construction Materials

Construction material availability in Thunder Bay or surrounding communities is not discussed in the feasibility study. An assumption is included in the presentation of the capping and on-site CDF SMOs is that earthen materials (sand and stone) are readily available from an upland source for cap and berm construction. A review of potential sources for construction materials should be documented in the feasibility study. If materials and/or the volume of materials are not readily available from an upland source, additional costs may be incurred due to increased transportation fees or the need to procure specialty materials.

2.4.4 Habitat Mitigation

Mitigation for loss of shoreline access and open water is included in the discussion of the sand cap, reactive cap, and on-site CDF SMOs. No discussion regarding whether specific agencies were contacted regarding the proposed SMOs and the potential associated mitigation costs is included. A discussion with government agencies is recommended to assess potential required mitigation. Additional steps (e.g., preliminary runs of Department of Fisheries and Oceans [DFO] Habitat Alteration Assessment Tool [HAAT]) may assist in evaluating potential mitigation requirements and costs at the feasibility study level of detail.

2.5 Review of Information Collected and Used for the AMEC Feasibility Study

In this section of the peer review report, we review the information collected and used as a basis for the AMEC feasibility study. This information included field investigation data for sediment geotechnical and environmental characterization, coastal process data, and sediment volume estimation.

2.5.1 Sediment Environmental Characterization

Environmental data for site sediment were collected in accordance with standard engineering practice. Environmental investigations in the area have identified concentrations of mercury, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), and total phosphorus in sediment above PSQG SEL and methyl mercury above Canadian Water Quality Guidelines (CWQG) levels. Concentrations of total mercury within the EOS range from non-detect to 39.7 micrograms per gram (μg/g) and appear to be confined to the EOS layer.

AMEC conducted toxicity testing on the EOS porewater in the Feasibility Study Phase II. Chemical analysis was limited to total mercury and addressed methyl mercury more qualitatively. In addition, other contaminants that have been identified above the PSQG SEL were not analyzed in the toxicity testing.

Mercury in aquatic environments can undergo several transformations; one of those is the methylation of mercury to methyl mercury. Methylation is mediated by bacteria and is greatest in anoxic environments. Reported sampling and analysis of sediment focused primarily on total mercury. Methyl mercury analysis was limited to the Feasibility Study Phase I. Composite sediment sample and leachate from pancake column leachate testing (PCLT) were analyzed for methyl mercury.

The concentration of methyl mercury in the composite PCLT sample was 46.4 nanograms per gram (ng/g) and the concentration in the leachate ranged from 7.92 nanograms per litre (ng/L; pore volume 5) to 52.5 ng/L (pore volume 7). The testing was not run until the methyl mercury concentration decreased consistently; however, total mercury did decrease consistently in the last several samples. Correlation between total and methyl mercury in the PCLT results was not discussed, but is of importance in fate and transport evaluations for CDF design and should be considered in fate and transport modelling for contaminants in dredged material within the CDF. In general, additional characterization of methyl mercury is recommended for assessing risk, toxicity, and remedial cleanup levels.

In addition to PCLT and toxicity testing AMEC performed column settling tests (CSTs), dewatering testing, and dredge elutriate testing (DRET). This information is useful in feasibility evaluations and remedial design but was not fully used by AMEC in the development and evaluation of SMOs.

In the Feasibility Study Phase II, AMEC presents four sediment samples that were collected with an Eckman grab sampler from outside the study area, adjacent to the breakwater. Although the laboratory results are included in an appendix, a discussion of the implication of the results is not included in the body of the report.

2.5.2 Sediment Geotechnical Characterization

Geotechnical characterization of the sediment includes Feasibility Study Phase I and Feasibility Study Phase II field and laboratory investigation of the EOS and underlying sediment.

Based on geotechnical characterization of the EOS and underlying sediment the EOS includes the following properties:

- Comprised of wood waste, including pulp and wood chips. Clay used in the paper manufacturing process is also reportedly included in the EOS.
- Grain size results indicate the majority of the material is silt/clay size with small amounts of particles that fall within the sand and fine gravel fractions.
- Has a TOC concentration that varies from approximately 11% to 36% with an average of about 22%, indicating mineralogical material (reported to be mostly clay) comprise the balance of the solids fraction of the EOS.
- Has high water content, and has a unit weight close to that of water. In Feasibility Study Phase I, the water content was reported to be 627% (on a water weight/solids weight basis) and 86% (on a water weight/total sample weight basis).
- Has high biochemical oxygen demand (BOD), and is likely to be anaerobic based on high organic content.

The sediment underlying the EOS includes an organic layer encountered in one boring, and a silt and sand layer that more generally underlies the EOS layer in the nearshore area. The nearshore silt and sand layer, and the remaining EOS are underlain by a silt and clay layer.

The Feasibility Study Phase I geotechnical characterization of the EOS generally concluded that the EOS was a low-strength, low-unit-weight material, would require confinement when compressed under a cap, and would likely pose problems during dredging based on a tendency for the material to float once disturbed. Based on the EOS properties, standard sampling and laboratory testing were reportedly not possible. Accordingly, much of the prediction of EOS behavior is necessarily based on inference made from observation in the field during sampling and limited lab testing.

The native sediments underlying the EOS were concluded to be compressible and have low strength based on more standard geotechnical testing, including standard penetration testing, Atterberg Limits, field vane shear testing, unconfined compressive strength, and field dilatometer testing. Only one consolidation test was performed, which is insufficient for characterization of consolidation properties. Borings were not penetrated to refusal.

The Feasibility Study Phase II geotechnical characterization included field cone penetrometer testing (CPT) of deeper native sediment properties. CPT results confirmed the native sediments were soft and compressible. Additionally, CPT results were used in consolidation analyses for native sediment that indicated consolidation under the load associated with a CDF berm would result in berm settlements ranging up to approximately 4 m. Because settlements were proportional to loading, differential settlements were predicted.

We completed a review of the geotechnical analysis specifically focusing on the feasibility of the CDF berm to be constructed once EOS is removed. According to AMEC's analysis, constructing the CDF berm could result in settlements of up to 4 m in subsurface native sediment due to the consolidation of the sediments underneath the berm.

For our review, we used the same assumption as AMEC—all EOS underneath the berm footprint would be excavated before placement of berm material. Settlement calculations were only predicted from soil layers below the EOS. This review focused on the large settlement of 4 m as predicted by data from CPT04.

We were unable to reproduce consolidation results based on the CPT data provided and have reason to believe actual settlements may be less than the stated 4 m for the configuration analyzed based on our analysis and on local experience reported for Thunder Bay sediment. The documentation of settlement calculations did not provide enough information to confirm settlement magnitude or rates. We recommend further documentation be provided to support the results and for use in analysis of alternative CDF containment structure configurations. Specific issues we found in AMEC's analysis:

- Unit weight of berm material appears low for berm material specified (100 pounds per square foot [psf]).
- Documentation of settlement calculations only provide one value for important inputs such as, z, q_t, σ'_{vo}, I_c, Q_t, and σ_{vo}. The values of the inputs provided are at the 0.05 m depth interval, or within the water column.
- Documentation of calculations only provides equations entered into the computer program. There are no calculations for S_c using actual values; only the result is

posted.

Additional geotechnical testing is recommended to further characterize native sediment characteristics for CDF berm conceptual design development (and to support cap modelling and design). References to the difficulty in sampling the material using standard approaches, likely due to the soft, high water and organic material content, are included in AMEC's feasibility study reports. We believe this is a technical issue that needs to be overcome by trying different field sampling and measurement methods. Tube sampling using drilling mud (to retain soft sediment), field vane shear testing (for in situ strength measurements), and other sampling equipment (e.g., box-corer) should be further explored for collecting information that can be used in standard geotechnical laboratory testing of sediment geotechnical properties, including standard index properties, strength, and consolidation testing.

In the Feasibility Study Phase I, AMEC identified the need to conduct a debris survey to assess potential hazards involved in the implementation of the selected sediment option. A debris survey was not conducted as part of the Feasibility Study Phase II. At the feasibility level, a discussion of debris survey methods should be presented. Logging activities reportedly occurred within the site vicinity. Potential logging debris within the EOS could impact the selection of a preferred dredging method and/or slow down dredging operations. Additionally, large logs can interfere with capping and impact long-term cap performance.

Potential debris survey methods include a diver survey, probing from a small boat with a rod, and/or subaqueous test pits excavated from a barge. Diver surveys are not likely to provide much subsurface coverage, probes have the disadvantage of not visually confirming obstructions that the probe may encounter, and test pits are likely to be costly, will provide limited site coverage, and will require controls to mitigate resuspension and transport of EOS during test pit activities.

We recommend as a first step a review of the historical photographs and existing field documentation to evaluate the frequency and location of reported obstructions to subsurface investigations. After that step, a probing program set up on a grid may provide additional information regarding the presence of subsurface obstructions. A targeted test pit program could be implemented to focus on areas where review of field work and probing indicate obstructions are located. The test pits could identify the type of obstructions.

2.5.3 Coastal Process Analysis

In the Feasibility Study Phase I, information is presented regarding the coastal processes of the area to evaluate how conditions within Thunder Bay North Harbour may impact the SMOs. A combination of field measurements and numerical modelling was undertaken to assess the overall hydrodynamic environment of the area.

Although the development of a “wind/wave and current model” was apparently conducted, the modelling was not documented in the Feasibility Study Phase I or Phase II reports (we recommend the data be included in appendix to the report). The data were received under separate cover in the Marine Investigation report (AMEC 2011b).

Wind and wave data were collected from oceanographic sensors and two weather stations. Given the breakwater configuration, design wave conditions for evaluating berm stability and other SMO elements sensitive to hydrodynamic forces and sediment stability were addressed with a straightforward fetch-limited analysis. This assumes that the breakwater is maintained in perpetuity by the local authorities.

The period of observation for the wind data is not specified. If wind data were collected over the same period as the study period over which they deployed oceanographic equipment (November 2008 to January 2009), the time period within which they collected data would be too short to capture seasonal variability. If a larger dataset from a nearby wind station (as is normally done in traditional coastal process analysis to cover historical records spanning more than 30 years) was used, then that information should be included in the report.

Anchor QEA performed a fetch-limited calculation using the maximum hourly wind speed (80 km/h) from Table 3 on p. 34 of the Marine Investigation Report. Assuming a 5.5 km fetch (from the southwest), we predicted a significant wave height (H_s) of 0.84 m and peak spectral period (Tp) of 3.1 sec. AMEC recommended using a more conservative wind speed value of 100 km/h, due to the exposed nature of the project site. Re-running the calculations for this wind speed with the same fetch we came up with Hs = 1.05 m and Tp = 3.34 sec. Thus, it seems the chosen design conditions of Hs = 1.3 m, and Tp = 5 sec (see p. 35) are potentially somewhat over-estimated given the limited fetch, but may be appropriate for areas where wave transformation may result in local increases in wave height.

Armor stone size was calculated for SMOs that required protecting underlying earthen materials (e.g., CDF berms and edges of caps). The stone size estimated was 45 kilograms (kg). We performed calculations to check the size of armor stone relative to the fetch-limited wave conditions we derived, and also compared to the extreme conditions referenced in the Marine Investigation Report. Based on those calculations, it appears the 45-kg armor stone may be undersized. For the fetch-limited condition of Hs = 0.84 m, Tp = 3.1 seconds, our estimated armor stone (depending on slope stone is placed on) ranged from 100 to 200 kg. That is, approximately 100 kg for slopes of 1:2.5 and 1:2, and approximately 200 kg for a steeper slope of 1:1.5. When the same analysis is run using AMEC's extreme conditions of Hs = 1.3 m and Tp = 5 sec, the required armor stone size is 600 kg, 800 kg, and 1,300 kg, for the respective slopes of 1:2.5, 1:2, and 1:1.5.

We recommend a conservative stone sizing based on a wind-generated wave over the exposed 5 km fetch (southwest to northeast) derived for the predicted 100-year return frequency, as is customary in remediation projects.

2.5.4 Sediment Neatline Volume

We preface our review of the sediment volume estimates with the caveat that we reproduce the volumes reported in AMEC's feasibility study as they were reported. In general, references to sediment volumes require rounding to appropriate significant figures based on inherent uncertainty in estimating this relatively large volume of sediment.

The neatline volume (i.e., the estimated volume of only the contaminated sediment) of EOS was initially estimated as 341,399 m^3 by NSC (2006). Biberhofer et al. collected additional information in 2007 and, using various modelling methods, calculated a volume ranging from 295,855 to 362,961 m^3 for the organic sediment. Ecometrix presented a volume of 300,000 m^3 in their review of previous mercury investigations (2007). In the Feasibility Study Phase

I, AMEC estimates a volume of 343,000 m^3 for the EOS (303,000 m^3 from the Seabed Terminal Impact Newton Gradiometer (STING) data presented in Biberhofer et al.'s report (2007) and an estimated 40,000 m^3 in the nearshore area). AMEC refined their estimate to 351,823 m^3 in the Feasibility Study Phase II after conducting a probing study to further characterize EOS thickness in the nearshore area.

The majority of the sediment volume calculations were based on Thiessen polygons and EOS thickness. All parties assumed that the EOS maintains a constant thickness across the polygon. Biberhofer (2007), using a more complex modelling method, created fence diagrams based on a kriged model and showed that the contact between the EOS and underlying native sediment is irregular. The volume calculation methods and assumptions are appropriate for a feasibility evaluation but could be further refined with additional sampling, such as EOS thickness measurements in questionable zones.

Although the neatline contaminated volume calculations appear viable, there appears to be enough variability in thickness with current data that the Thiessen polygon method may not be accurate moving forward, especially when estimating an actual dredge volume that is based on an engineering design. With the relatively large volume of sediment requiring remediation, a change in volume could have a significant impact on project costs. It is important to factor in actual dredge volume, instead of only estimating the neatline volume. Although the sediment volume is presented as a neatline volume, additional sediment will be removed during SMOs that include dredging. Remedial dredge design volumes typically take into consideration equipment accuracy limitations, residuals management, and variability in the predicted neatline contaminated surface. Using the predicted lateral and vertical extents of contaminated sediment, a dredge prism is developed in design by taking into account these factors and design side and transition slopes and overdredge allowance.

AMEC assumes a 50% volume adjustment for the on-site CDF in accordance with standard engineering practice, off-site CDF, and dredging with upland disposal options. The 50% volume adjustment factor (i.e., multiply the neatline volume by 1.5) is appropriate at a feasibility study level to estimate the actual volume of dredged material based on the neatline volume. The adjustment takes into account overdredge allowance (typically 0.3 m) and side slopes.

However, based on the large SMU area and volume of sediment at the site, small variability in factors that are associated with sediment volume could result in significant differences in sediment volume estimates. In addition, processes such as bulking during dredging and shrinkage during drying, and dredging in areas where the EOS deposit is very thin will significantly affect the dredging, transport, and/or dewatering volumes (and, thus, are key to the initial sizing and long-term site management at CDFs). Thus, site-specific information (i.e., water contents of the sediment for in situ, differing dredge, transport, and placement methods) and development of the dredge prism (developing a dredge prism using available core data, a reasonable overdredge allowance, and incorporating considerations that include side-slopes, transitional slopes between different target depths) will allow a more accurate estimate of the actual dredge volume during the feasibility study.

Due to the relatively shallow water, protected environment provided by the breakwater, and sharp contact between the EOS and the underlying native silt, a smaller overdredge allowance may be possible at the site without significantly impacting production rate or cost, depending on available contractor equipment and experience. The EOS layer appears to thin with distance from the shoreline. Thin cuts required for dredging in this area typically result in a larger overdredge allowance in our experience. Based on the potential cost implications associated with variability in volume estimates we recommend a preliminary dredge prism design be developed during the feasibility study to further refine the potential range of sediment volumes for SMOs that include dredging.

3 REVIEW OF FEASIBILITY STUDY METHODS, FINDINGS, AND CONCLUSIONS

In this section of the peer review report the AMEC feasibility study process, methods, protocols are critically reviewed and compared to standard practices. AMEC's findings, conclusions, and recommendations are critically reviewed, including SMO configurations, conceptual designs, and cost estimates.

3.1 Monitored Natural Attenuation

3.1.1 Review of Feasibility Study Process, Methods, Protocols

The MNA SMO was presented in the Feasibility Study Phase I. No assumptions were made regarding long-term monitoring of the site. The MNA SMO was not re-evaluated in the Feasibility Study Phase II.

3.1.2 Review of Feasibility Study Analyses

AMEC's feasibility study concluded that it is unknown how long it would take for elevated concentrations of contaminants to decrease below SELs over time due to natural deposition of non-impacted sediment. Based on previous work (Stantec 2003), there is evidence that total mercury concentrations are decreasing over time, but the feasibility study concluded that it is uncertain how quickly they will decrease to an acceptable level where they do not present a risk to biota or the environment.

3.1.3 Costs

MNA was estimated at a cost of $1.5 million over 30 years ($50,000 per year). Specific information regarding the activities that will occur each year included general toxicity testing and sediment chemistry analyses. In order to accurately estimate a proposed cost for the SMO, specific survey, field investigation and sampling activities, and laboratory analyses should be presented along with associated net present value costs consistent with standard approaches for feasibility evaluations.

3.2 Isolation Capping

Two conceptual cap designs were reviewed as SMOs for the Thunder Bay site: a sand cap and a reactive cap. The containment of total mercury and methyl mercury were the basis for the cap designs.

3.2.1 Sand Cap

The sand cap SMO includes the following layers (listed from the mudline to the top of cap): a geotextile; 100-centimetre (cm)-thick layer of TOC-enriched sand (TOC = 1%); 30-cm armour layer of 4-cm gravel; and cap anchors, where necessary, consisting of 40-kg boulders.

3.2.1.1 Review of Feasibility Study Process, Methods, Protocols

AMEC's feasibility study included the following:

- A pilot constructability study would be conducted prior to final design and costing.
- Two seasons would be required for construction.
- The total SMU is 22.2 ha; an additional 3 m width around the cap perimeter would be needed for anchoring, bringing the total cap area to 22.6 ha.
- There is no information regarding ground water seepage velocity. This is a sufficiently important variable in cap modeling and analysis that additional effort should be expended to estimate seepage velocity. Seepage velocity can be better estimated using nearshore upland ground water information and/or additional field measurement. At a minimum the sensitivity of the cap model outcome to ground water seepage velocity should be evaluated.
- Annual inspections of the cap above the water would be required to verify the cap integrity as part of the cap maintenance plan.
- Mitigation would be required for the loss of shoreline access and open water.
- The private docks located immediately west of the Mill can be reconfigured with minimal disturbance.

Two models were used by AMEC to evaluate the performance of a sand cap: the guidance presented in Appendix B of the USEPA *Guidance for Subaqueous Capping* (the Palermo model) for evaluating the effective cap thickness available for the chemical containment of

CoCs; and the Lampert and Reible steady state model (2009) for predicting the time to contaminant breakthrough of the cap and the associated breakthrough concentration.

An important consideration for cap modelling is to assess the potential difference in the fate and transport behavior of contaminants in the EOS, compared to fate and transport behavior of contaminants in mineralogical sediment. Cap models are based on an assumption that sediments are comprised of mineralogical material, organic carbon, and porewater. The EOS differs from mineralogical sediment in physical and chemical makeup, and the potential differences in fate and transport of contaminants need to be more fully evaluated and understood to validate the applicability of the cap models discussed in this section.

3.2.1.2 Review of Feasibility Study Analyses

The Palermo model is used in the feasibility study to evaluate the effective cap thickness following the initial placement of the sand cap. With bioturbation and consolidation of cap materials assumed to be negligible by AMEC, the effective cap thickness is determined by quantifying the thickness of the cap affected by the release of contaminated porewater into the cap due to consolidation of underlying sediment.

The Palermo and Lampert and Reible models are assumed to have been used together in the feasibility study as a redundant check on model results.

TYPICAL SAND CAP CROSS SECTION

The elements of the conceptual sand cap design as well as questions and comments regarding each layer are presented below (listed in installation order from mudline to top of cap):

- <u>Geotextile</u> – A geotextile will be placed on the weak underlying EOS to provide added strength and stability. The reviewers agree that this layer is necessary in providing both strength and stability, as well as providing a physical separation from the underlying sediments. A geogrid bonded to the geotextile may be advantageous in distributing the sand cap load more evenly over the EOS, allowing for a less restrictive and costly cap placement that would avoid destabilizing the EOS, and would better contain the EOS. This is a detail that could be worked out in the remedial design stage, but should be referenced in the feasibility study stage because of the potential cost implications.

- Isolation Layer – a 100-cm enriched sand layer containing 1% TOC will be used for chemical isolation of contaminants from benthic and aquatic organisms. A 30% addition of material thickness from the modeled 70 cm was added as a factor of safety, presumably to include placement tolerance (if not, this is conservative). A review of consolidation rates, effective cap thickness, and modelling calculations is necessary to verify the thickness and long-term protectiveness of this isolation layer.
- Armour Layer – A 30-cm armour layer consisting of 4-cm gravel is placed over the sand isolation layer. The armour layer thickness is designed to prevent bioturbation in the sand cap and erosion of the sand cap. Use of a 4-cm gravel size was not clear—use of hydrodynamic and wave analyses (or ice effects) to size the specified material was not documented. Additional information on material sizing is required.
- Anchoring System – At the edges of the cap footprint, the design calls for 40-kg rocks to act as an anchor for the cap.

PALERMO MODEL

Using the guidance provided by the Palermo model, the input parameters presented in Table 8.1 in AMEC's Feasibility Study Phase I, and AMEC's general assumptions, the reviewers were unable to recreate effective cap thickness (L_{eff}). The calculated L_{eff} seems unreasonably low based on our experience.

Consolidation Assumption

An assumption of 50% consolidation of EOS underlying the cap (and within the CDF for the CDF-based SMOs) is made in the Feasibility Study Phase I and is used for the cap assessment. This assumption is apparently based on the engineering properties of Muskeg, an organic soil that we presume was used as a reasonable analog for the EOS. In the Feasibility Study Phase II, an additional EOS consolidation qualitative assessment was completed and was based on the pressure required to dewater EOS in dewatering studies. Based on that assessment, the EOS consolidation in the CDF was assumed to be 10%— there is no explanation for why the different consolidation values (i.e., 10 % and 50%) were used for the CDF and capping SMOs, respectively.

The physical response of the EOS to loading is also unknown and is expected to be different from the physical form taken by a typical sediment matrix (i.e., sediment consisting mostly of sand, silt, and/or clay with a lesser organics content) following consolidation. The lack of reliable geotechnical information and consolidation information for the EOS is an uncertainty in the cap design.

Determination of Effective Cap Thickness (L_{eff})

In the Palermo model, two methods are available for estimating the cap thickness affected by porewater from underlying sediment consolidation: one for non-sorbing contaminants and one for sorbing contaminants. Both calculations were completed by AMEC. Mercury is a sorbing contaminant and it is not known to Anchor QEA why the non-sorbing calculation was made; however, the calculation was reviewed for the sake of completeness.

For the non-sorbing contaminant, the thickness of the cap affected by porewater ($\text{Ä}L_{pw}$) is approximately equal to the post-consolidation underlying sediment thickness ($\text{Ä}L_{sed}$) divided by the porosity of the cap material (å). Table 8.1 in the Feasibility Study Phase I reports an $\text{Ä}L_{pw}$ value of 400 cm. Based on the input parameters listed in Feasibility Study Phase I Table 8.1, the Anchor QEA calculated a $\text{Ä}L_{pw}$ value of 320 cm (160 cm per 0.5 = 320 cm), which does not match the corresponding value reported by AMEC.

The calculation of cap thickness affected by expressed porewater of a sorbing contaminant was also calculated and is more appropriate for mercury. This calculation uses the retardation factor (R_f), a dimensionless number, which is defined in the following equation:

$$R_f = \text{å} + (n_b)(K_d^{obs}) \qquad (1)$$

Where:

å = Cap material porosity (unitless)
n_b = Bulk density of sediment (grams per cubic centimetre [g/cm^3] = kilograms per litre (kg/L)
K_d^{obs} = Sediment-porewater partition coefficient for mercury on clean cap materials (litres per kilogram [L/kg])

In this calculation, K_d^{obs} is referencing the sediment-porewater partition coefficient for the cap. In AMEC's calculations, the K_d^{obs} for the cap has been assumed to be the K_d^{obs} of the sediment. A R_f of 372,534 was reported by AMEC in Table 8.1. Anchor QEA calculated an R_f of 64,773 (R_f = 0.5 +1.1 kg/L x 58884 L/kg) using the input parameters listed on Feasibility Study Phase I Table 8.1. This results in a value an order of magnitude lower than that calculated by AMEC.

The retardation factor is used to extimate the distance that the contaminant migrates during underlying sediment consolidation ($\text{Ä}L_{sed,a}$) with the following relationship:

$$\text{Ä}L_{sed,a} \approx \text{Ä}L_{sed} / R_f$$

(2)

Where:

$\text{Ä}L_{sed}$ = The ultimate depth of consolidation of underlying sediments immediately after cap placement (cm). In the calculations, this value is estimated to be 160 cm based on the 50% consolidation of underlying sediments with the greatest thickness of underlying sediment being 320 cm.
R_f = The retardation factor calculated in equation 1 (unitless)

Based on Feasibility Study Phase I Table 8.1 and the value for retardation factor calculated by AMEC, Anchor QEA calculated an $\text{Ä}L_{sed,a}$ value of less than 1 cm (160 cm per 372,534 = 0.0004 cm). Using Anchor QEA's retardation factor with AMEC's assumption of 50% consolidation, a value of 0.002 cm is obtained for the thickness of cap affected by porewater migration due to underlying sediment consolidation. In Table 8.1, AMEC presents a value of 53.8 cm for $\text{Ä}L_{sed,a}$.

Mercury migration through cap materials is typically slow due to the strong affinity of mercury for the solid fraction. Based on this, the loss of effective cap thickness due to migration of the contaminant into the cap is expected to be minor and to be a small fraction of the underlying sediment consolidation distance (Palermo et. al 1998). The value for $\text{Ä}L_{sed,a}$ reported by AMEC contradicts this.

The final calculation presented in the portion of this guidance that was used by AMEC is to determine the effective cap thickness available for contaminant isolation from benthic and aquatic organisms. The effective cap thickness is defined by the following equation:

$$L_{eff} = L_0 - L_{bio} - \ddot{A}L_{cap} - \ddot{A}L_{sed,a} \qquad (3)$$

Where:

L_0 = The initial cap placement thickness (70 cm per AMEC design)
L_{bio} = The thickness of the bioturbation zone (assumed to be 0 cm based on AMEC design, which includes a 30-cm armour layer over the 70-cm placement of sand)
ÄL_{cap} = Consolidation thickness of cap materials (assumed to be 0 cm)
Ä$L_{sed,a}$ = Thickness of cap affected by contaminated porewater migration through cap during initial consolidation of underlying sediment (calculated above by AMEC and reviewers, respectively)

Based on the input parameters presented in Table 8.1, the assumptions listed above, and the calculated value for Ä$L_{sed,a}$ reported by Anchor QEA, we expect that a minimal thickness of the cap material (less than 1 cm) will be affected due to porewater advection during initial consolidation of sediment resulting in an effective cap thickness of roughly 70 cm.

Based on the Ä$L_{sed,a}$ reported in Table 8.1 of 53.8 cm, a value that could not be recreated by Anchor QEA, the thickness of cap available for chemical isolation is only 16.2 cm. The approximate 77% reduction in post-placement cap thickness reported by AMEC is carried into the Lampert and Reible model.

It is recommended that additional consideration be given to the application of the Palermo model and that the consolidation of underlying sediment and predicted effective cap thickness be reviewed. Overpredicting the effective cap thickness affects the overall cost and feasibility of capping as a SMO.

LAMPERT AND REIBLE MODEL

The Lampert and Reible model is used in this application to estimate total mercury porewater concentrations at the compliance point of the cap (top of cap) and time to contaminant breakthrough. Input parameters are presented in Feasibility Study Phase I Table 8.2. The assumptions made and input values used are discussed further below.

Determination of K_d and K_{oc}

The Lampert and Reible model is directly applicable for use in modelling the containment of organic hydrophobic compounds. The model can be used for other chemicals with slight modification of input parameters and assumptions as a check on the Palermo model. The relationship between the sediment-porewater partition coefficient (K_d), the fraction of organic carbon (f_{oc}), and organic carbon partition coefficient (K_{oc}) presented in AMEC's capping assessment as Equation 1 is applicable to organic hydrophobic compounds and is not valid for mercury. Mercury is an inorganic compound that partitions to organic carbon; however, organic carbon partitioning is not the only significant factor affecting the sorption of mercury. Mercury partitioning is a complex process that is affected by pH, oxidation/reduction conditions, the mineral composition of the sediments, and the speciation/formation of varying complexes and precipitates.

AMEC uses the relationship between K_d, f_{oc}, and K_{oc} to estimate a total mercury partition coefficient for a sand cap. The same process is used when modelling methyl mercury. Anchor QEA cannot reproduce the values calculated by the modeler for both total and methyl mercury. It is Anchor QEA's opinion that this method requires additional research to ensure its applicability for inorganic contaminants.

The last paragraph on page 8-8 of the Feasibility Study Phase I describes an assumption where AMEC calculates a K_{oc} based on sediment properties and the assumed TOC of the cap to compute a K_d for a sand cap. Although Anchor QEA does not agree with the use of this relationship for mercury, the calculations were reviewed for completion of this peer review.

Based on the text, the Log K_d calculated for the cap should be 3.44 Log L/kg. It appears that this value has been entered as a Log K_{oc} value in the model; however, Table 8.2 note 1 indicates that the value inserted for Log K_{oc} was calculated from the measured Log K_d value

(4.77 Log L/kg) and the use of the relationship $K_d = K_{oc}*f_{oc}$ assumes an f_{oc} for sand. If the note is assumed to be valid, the Log K_{oc} value entered into the model should be 6.77 Log L/kg. There appears to be discrepancy in how AMEC determined the model input value for Log K_{oc} and it is not obvious to Anchor QEA how this value was determined.

For modelling inorganic compounds, where the relationship between K_d, K_{oc}, and f_{oc} is not considered valid, the use of an effective Log K_d for the Log K_{oc} model input value is a valid approach (Reible 2008). If this approach is employed, the fraction of organic carbon must also be entered as 1.0 (TOC = 100%). Although the use of an effective K_d is an accepted method for simulating partitioning for cap evaluation/design, it is recognized as a simplification for mercury.

It appears that AMEC may have tried to use a combination of two approaches: 1) determining an effective Log K_d for the cap; and 2) the substitution of this effective Log K_d for the Log K_{oc} model input value. The first approach is invalid for inorganic compounds. The f_{oc} input values were not set to 1, which is a requirement of making the substitution of Log K_d for Log K_{oc} in the second approach. The reviewers also believe that, if this was the approach, an incorrect effective Log K_d value was entered as the Log K_{oc} value and the use of the K_d value of 5.44 Log L/kg measured in the PCLT is more appropriate.

Despite this uncertainty over the input value for this parameter, the sensitivity analysis conducted on the model considered Log K_{oc} values ranging from 2.74 to 6.6 Log L/kg with little change in predicted time to breakthrough and breakthrough concentration of mercury.

Determination of K_{DOC}

The input value for the colloidal organic carbon partition coefficient (K_{DOC}) listed in Feasibility Study Phase I Table 8.2 was taken to be the default value supplied in the Lampert and Reible model as the Log K_{oc} value minus 0.37. This default value is appropriate for certain organics, but is not typical for use in modelling metals including mercury. Mercury may partition to the colloidal phase; however, it is likely that the PCLT tests where they measured porewater concentration and computed a K_d accounts for this partition onto the colloidal phase. Anchor QEA therefore recommends that this K_{DOC} value be set to zero in the model because it is likely already accounted for in the PCLT-based K_d.

COMMENTS ON MODEL PREDICTIONS

Given the input values summarized in Feasibility Study Phase I Table 8.2, the model predicts that the contaminant front will reach the cap compliance point (or point of interest) in 3.6 years with a total mercury concentration of 0.0004 μg/L, which is well below the Provincial Water Quality Objectives (PWQO) for total mercury of 0.2 μg/L. However, within Section 8.2.1.2 of the Feasibility Study Phase I, there are different values reported for the total mercury PWQO and for the concentration of total mercury leaving the sand cap. Clarification regarding these two items is required.

COMMENTS ON REDUCTION OF TOXICITY, MOBILITY, OR VOLUME

In Section 8.2.6 of the Feasibility Study Phase I – Reduction of Toxicity, Mobility, or Volume, AMEC states that "an isolation cap would also reduce the volume of EOSs due to sediment compression. It is estimated that the thickness (thus the volume) of the EOS to be capped may be reduced by approximately 50%." It is important to note that while the volume of sediment is decreasing due to estimated consolidation, the actual mass of sediment or contamination is not decreasing. The change in volume is due to the expulsion of contaminated porewater from the pore space of the sediment matrix. Contaminated porewater that exits a given sediment volume after consolidation still exists in the environment as contaminant mass whether it is contained by the cap or enters the water column. The mass of contamination is not removed with capping as it is with dredging, which may be more aligned with the interpretation of "volume reduction."

OVERALL MODELING RECOMMENDATIONS

The use of the Palermo model in conjunction with the Lampert and Reible model is useful as a check in the early stages of modelling, but is not recommended for further use. The input values used for both of these modelling efforts (as listed in Feasibility Study Phase I Table 8.1 and Table 8.2, respectively) are unclear and calculations could not be recreated. Based on these issues, the reviewers could not fully confirm mercury containment by the cap.

It is recommended that additional modelling be done with revised consolidation and effective cap thickness, and that the model is reconsidered with input values representative of the contaminant(s) being modeled, with sensitivity analyses performed as needed. It is anticipated that the time to breakthrough and contaminant breakthrough concentration of both total mercury and methyl mercury may change if the cap model is revisited and alterations are made to model inputs as suggested above. Ultimately, this may affect the feasibility of capping as a SMO.

3.2.1.3 Costs

The cost for sand capping with an armor layer included in the Feasibility Study Phase II is $37.1 million. On a unit cost basis, costs are $1.67 million per ha ($676,000 per acre or $158,000 per foot per acre). In general, that is at the high end of the range of approximately $100,000 to $150,000 per foot per acre of cap thickness, based on our experience in the lower Great Lakes region. However, the higher cost may be appropriate based on availability of contractors with capping experience in the Thunder Bay area.

More detailed comments pertaining to the cost of sand capping include those listed below:

- A cap installation method should be developed in concept that minimizes point loading and potential failure of the EOS and/or underlying native sediment. The cap installation method may require installation of the cap in multiple lifts, significantly increasing cost. Overplacement of capping material should be included in the cost estimate.
- It is appropriate for the feasibility study to identify source(s) and cost of earthen materials for cap (sand) and armour (gravel), particularly to confirm the availability of a sand with 1% TOC. If sand has to be amended to provide the 1% TOC, that could increase costs significantly.
- A filter layer analysis should be documented to address the sand cap material-armour gravel transition.
- A long-term cap monitoring plan should be outlined and represented in net present worth costs.

In general, the cost implications associated with a more detailed cap conceptual design should be considered and compared to the 20% contingency included with the cost estimate. The details provided do not appear to support a cost estimate within a 20% contingency. In our experience, a feasibility study should be between -30% and +50%. However, the

Steering Committee required a target accuracy range (accuracy refers to comparison to actual cost to construct) for SMO cost estimates of 20 %. Based on the uncertainty regarding cap effectiveness and constructability, the cost estimate cannot be verified to fall within either the standard feasibility study or target ranges.

3.2.2 Reactive Cap

A reactive cap is also considered in AMEC's feasibility study. The reactive cap option is similar in the cross section to the sand cap described above with the substitution of a reactive core mat (RCM) as the base layer of the cap over the EOS and installed in place of a geotextile liner.

3.2.2.1 Review of Feasibility Study Process, Methods, Protocols

Assumptions for isolation capping were reviewed in Section 3.2.1.1 and those review comments also apply to reactive caps.

3.2.2.2 Review of Feasibility Study Analyses

The reactive core cap consists of an RCM containing either activated carbon or organoclay for mercury containment. Modeling was not conducted by AMEC to evaluate the added value of the RCM; rather, the RCM placement was assumed to substitute for sand cap thickness to achieve a 1.3 factor of safety. Anchor's QEA experience is that RCM is an expensive cap component and typically provides increased sorptive capacity that needs to be justified by comparing to the added cost. We recommend that an appropriate material that is capable of effectively containing mercury be identified for the RCM, and that additional modelling be conducted to understand the benefit of using the RCM over the sand cap.

As mentioned in review of the sand cap cross section, we recommend considering placing a geotextile or filter layer between the sand and armor layers of this cap. Also we recommend considering an additional earthen material layer or geotextile for placement under the RCM consistent with manufacturer's installation recommendations and previous experience. The layer underneath the RCM is considered to be a protective layer placed to eliminate, to the extent possible, variability in the sediment prior to RCM placement. A debris survey also is also recommended during the feasibility study to provide information regarding the potential for damage to the RCM during and after placement.

A variant of this remedial option might be considered where amendments are added as bulk media to the sand rather than included as a RCM. Material available at the Mill may be suitable as an amendment, but would require testing and evaluation. The placement of geotextile under the RCM is redundant from a geotechnical perspective alone, and the amendment placed in the sand could provide additional sorptive capacity that the RCM provides without concerns for RCM damage from debris.

3.2.2.3 Costs

The comments presented in Section 3.2.1.3 pertaining to sand cap costs are relevant here. The reactive cap costs increase to approximately $43.3 million, with associated unit costs of $1.95 million per ha ($790,000 per acre). The difference in cost is attributable to the addition of the RCM layer. Review of the additional cost compared to our experience on other RCM capping jobs indicates the additional cost is representative. However, we recommend the feasibility study includes a discussion of the benefit of adding the RCM compared to the sand cap alone. The approximately $7 million increase in cost should be supported by increases in factor of safety and/or long-term performance of the cap. At least one RCM vendor (CETCO) has performed sorptive capacity studies for organoclay and mercury that could be used for such an analysis.

It is also important to note that, if constructed, this would be the largest RCM-based cap to date, and reactive caps for mercury sequestration are in pilot/experimental stages.

3.3 Dredging and Disposal at an On-site Confined Disposal Facility

This SMO includes constructing a CDF over a significant portion of the EOS deposit, hydraulically dredging the remaining EOS, and placing the dredged material in the CDF. The CDF would be constructed from earthen berms founded directly on native sediment underlying the EOS. Assumptions and analysis are presented below.

3.3.1 Review of Feasibility Study Process, Methods, Protocols

AMEC's feasibility study included the following:

- A pilot dredge study is needed to establish the type of dredging (mechanical or hydraulic) and production rates, and to determine solids and liquids handling details and the effects of dredging on water quality. We do not believe a pilot study is required to select a dredging method for developing a more detailed conceptual design for analysis in the feasibility study stage. A pilot study may be appropriate for a subsequent design stage. This review comment applies to all dredging-related SMOs.
- Two and a half seasons or 17.5 months are estimated to be needed for CDF construction and dredging.
- The amount of EOS to be dredged was reported to be 49,001 m^3 for the footprint of the berm and 112,209 m^3 of material outside of the footprint of the berm times a 1.5 overdredge factor and was totaled to 217,315 m^3, an apparent discrepancy (the reported volumes multiplied by the overdredge allowance is about 242,000 m^3 – it appears the overdredge factor was not applied to the volume of material that would be removed under the proposed CDF berms).
- Assumed dredging production rate of 1,000 m^3 per day, which equates to approximately 217 days (see comment above on volume).
- All materials needed for construction (sand, gravel, etc.) will be readily available from an upland source. This is typically verified in a feasiblility study but was not in AMEC's.
- Additional capping materials and construction will be required after construction of the CDF due to the anticipated consolidation and settlement of the cap placed on the CDF fill. A CDF cap can be a considerable expense depending on the design details, but was not addressed in AMEC's feasibility study.
- Mitigation will be required for the loss of 11.6 ha of open water.

3.3.2 Review of Feasibility Study Analyses

Our review of the conceptual design, assumptions, and analysis presented in AMEC's feasibility study is summarized below. The on-site CDF SMO includes the complex components of containment structure design and construction, dredging, consolidation of dredged material, and capping. These are discussed in detail below.

3.3.2.1 Dredging

Dredging includes a recommendation for a pilot test. We agree that a pilot study could provide additional information for a detailed dredging design given the unique nature of the EOS. However, we do not agree a pilot study is necessary to develop a dredging conceptual design for use in a feasibility evaluation.

The dredging method is driven by the preferred disposal option. Once a disposal option is selected, the dredging method is selected to comply with disposal requirements. Disposal options are typically a key consideration in dredging method. Disposal options that require extensive dredged material management and/or lack space for management typically require limiting generation of water during dredging – for these options, mechanical dredging may be preferred. For disposal options where dredged material management is not as extensive and higher productivity is not required hydraulic dredging may be preferred.

Potential environmental impacts associated with dredging were included in the feasibility study stage. Selecting a dredging method is based on the dredged material disposal option, and also on evaluation of potential impacts during dredging, equipment availability, and contractor experience.

We recommend a more detailed conceptual dredging design be developed based on a proposed disposal method, controls to mitigate potential impacts, and availability of equipment and experience in the Thunder Bay region to develop a more detailed cost estimate that is consistent with the feasibility study expectations for the 20% cost range.

An important consideration of a dredging conceptual design is estimating the volume of water requiring treatment that is generated during dredging. The Cumberland Bay project has similarities to the Thunder Bay project including a relatively larege volume of wood waste mixed with sediment. Hydraulic dredging was used for the Cumberland Bay sediment remediation project. The percent solids ranged from 3% to 7% below the percent solids assumed by AMEC in the dewatering analysis for hydraulic dredging of EOS. This comparison to experience with dredging a similar material using hydraulic dredging indicates the amount of water requiring treatment assumed for EOS hydraulic dredging may be underestimated in AMEC's Feasibility Study Phase II analysis.

An additional concern associated with dredging includes resuspension and residuals management. A conceptual design developed for evaluation should include a range of options for protecting water quality by minimizing resuspension. Options range from the more costly and labor intensive (e.g., working within structural enclosures) to lower cost and less labor intensive (e.g., monitoring and modifying the dredge cycle). Costly/labor-intensive and lower cost/less labor-intensive options should be compared on a cost-benefit-risk basis. Resuspension and residuals concerns are based on the following:

- In the Feasibility Study Phase I, concern is expressed regarding the EOS low unit weight and potential for floating material during dredging. We agree that is a concern, and the video documenting conditions during field sampling further validates that concern.
- Feasibility Study Phase I geotube dewatering results indicate the dewatering effluent remained turbid even after passing through the 0.1-micron apparent opening size (AOS) in the geotube, likely attributable to the EOS clay content.

In addition to concerns associated with resuspension and residual for particulates, the DRET referenced in the Feasibility Study Phase I indicates dissolved phase mercury is likely problematic during dredging due to the presence of dissolved mercury in the test effluent (that is supposed to replicate water near the dredging site) in excess of regulatory PWQOs.

Two types of barriers are proposed in the Feasibility Study Phase II to manage residuals and dissolved phase during dredging: 1) impermeable flexible barriers assumed for CDF-related dredging, and 2) RCMs configured in turbidity curtains for dredging associated with off-site upland disposal. It is not clear why the two different types of barriers are proposed.

For residuals management post-dredge placement of 0.3 m of clean fill is assumed, but low unit weight and possible resuspension of residual EOS during clean fill placement should be considered—a diffuser or similar approach may be required for clean fill placement, which could impact cost.

3.3.2.2 Dredged Material Management

Dredged material management includes providing adequate capacity in the CDF for dredged material placement, including consideration for fill material bulking (and eventual shrinkage), and ponded water above the dredged material throughout the construction sequence. A comparison of CDF berm crest elevation and final ponded water evaluation was not included.

Additionally, an analysis of the volume requirements of the CDF was not fully detailed in accordance with typical feasibility study level of detail. In addition to the consideration of actual dredge volumes (not only neatline volumes), factors that should be included in the CDF volume evaluation include the following:

- The potential for the volume of material to significantly increase during dredging (i.e., the "bulking" factor). This consideration should be further evaluated.
- Geotubes for placement in CDF were deleted, but no explicit explanation was provided—we assume this was because of the high applied pressure (100 pounds per square inch [psi]) required to dewater the material through the geotubes.
- Consolidation of dredged EOS is not fully addressed, and is assumed to be addressed in a future pilot test. An assumed value of 10% consolidation is presumably based on the required high pressure to dewater the material but still poses an uncertainty—additional volume will remain in the CDF if consolidation is greater than 10%, and the CDF would be undersized if consolidation is less than 10%. The basis for the 10% assumption should be explicit, given the implications. So what should be done to estimate the consolidation of dredged EOS?

Additional considerations related to CDF volume are described in the dewatering section below.

3.3.2.3 Dewatering

Discussion of water management in the CDF is not documented. The berm crest and temporary weir elevation should be configured to meet freeboard requirements for the final stages of dredging when dredged material elevation and ponded water elevation above the dredged material will be relatively high. Effluent water quality, discharge standards, and contingent approaches for potentially required treatment should be addressed, particularly for hydraulic dredging. This analysis would require the more detailed conceptual dredging design recommended above to generate theoretical water production during dredging. A discussion of CDF berm construction is presented below.

Additional considerations related to dewatering and the fate and transport of contaminants in the CDF are discussed below.

3.3.2.4 CDF Construction

The CDF construction sequence should be further detailed. A concern not addressed in the feasibility studies is the requirement for management of EOS removed to accommodate constructing CDF berms on the native sediment. In our experience, this can present logistical and cost implications and should, therefore, be addressed, even if preliminarily, in the feasibility study development.

CDF berm foundation construction is complex and costly. The combination of sand drains and gabion mats are a large cost (gabion mats are referenced as potentially prohibitive in terms of constructability) and may be reconsidered based on performance of sand drains in low permeability sediment, and possible alternate approaches. Alternate approaches (e.g., Triton marine armor mattresses, constructing rock mats, and building the berm on the mattresses and/or rock mat combined with removal of unsuitable material) may be considered for distributing load and accommodating settlement.

Additional construction details for the CDF berm should be conceptualized, including the number and thickness of lifts to construct. Constructing the first lift of the CDF berm, particularly in the more shallow water so that the top of the lift is above water would reduce the need for barge-based equipment and would be a significant cost savings. This approach was used at the nearby TBPA Chippewa Bay CDFs and is generally preferred if feasible. The soft native sediment may preclude this option, particularly in deeper water. However, because of the cost implications associated with CDF containment structure construction, we believe a more detailed conceptual design is required to develop cost estimates within the 20% target accuracy range.

3.3.2.5 Fate and Transport Considerations

Fate and transport modelling was not explicitly referenced, but is appropriate for a feasibility study, given the potential implications for cost and constructability associated with the need to construct a reactive core or internal layer within the CDF. A reference to sand with 1% TOC installed in geotubes is used as an internal sequestration layer but may be more complex and costly than a sand berm core.

The PCLT result referenced in the Feasibility Study Phase I indicates methyl mercury decreases with time/pore volume passage through the sample, but does not correlate fully with total mercury. Methyl mercury may be problematic in the CDF if the environmental conditions within the CDF change compared to the environmental conditions in the sediment prior to dredging, such that more mobile (compared to elemental mercury) methyl mercury is generated and becomes problematic from a fate and transport perspective. This possibility should be further addressed in the feasibility study, even if only conceptually.

3.3.3 Costs

The cost for on-site CDF disposal included in the Feasibility Study Phase II is $58.4 million. On a unit cost basis, costs are $166 per m^3 ($127 per cubic yard). It is difficult to compare that cost to other CDFs due to the complexity of the dredging process and CDF containment structure design and construction. Most CDFs are constructed within a slip and require only a containment berm at the mouth of the slip. The proposed CDF requires a perimeter berm on three sides, with the fourth side bounded by the shoreline. The estimated unit costs compare reasonably well to two recent Canadian CDF designs of which we have knowledge.

Review of the individual line items in the cost estimate indicates that the line item costs fall within the range consistent with experience. However, as described above, the basis for the costs includes uncertainties that have potentially significant cost implications, and additional analysis is recommended to better bound the costs. The following summarizes the points above as they pertain to cost:

- The CDF containment structure construction should be further evaluated given the difference in consolidation/settlement analysis outcomes and the potential for a less complex and costly CDF containment structure approach.
- The dredging approach needs to be further detailed, even conceptually, and linked to the dewatering, consolidation, CDF volume, and fate and transport considerations. A worst-case or conservative/high-cost scenario could be compared to the 20% cost estimate accuracy target range carried for cost.
- As discussed above, the CDF capping is dependent on the time rate of consolidation and future site use requirements.

The cost estimate for this option could be further refined by further evaluating conceptual design elements that are significant cost items (including CDF construction and dredging), developing alternate conceptual design approaches based on those outcomes, and comparing costs associated with those alternate approaches to the general 20% contingency included with the cost estimate. The remedial design approach for this SMO and other SMOs does not have the level of detail to support a 20% contingency.

3.4 Dredging and Disposal at an Off-site CDF

This SMO includes mechanical dredging of the EOS, rather than hydraulic dredging as described above for the on-site CDF. The mechanically dredged material is loaded into barges and transported approximately 12 km to the TBPA CDF. The SMO includes general assumptions that the TBPA will provide infrastructure improvements required for segregating dredged material during placement and will perform long-term operation, maintenance, and monitoring, in exchange for a tipping fee.

3.4.1 Review of Feasibility Study Process, Methods, Protocols

AMEC's feasibility study included the following:

- Assumed dredging production rate of 1,000 m^3 per day, which equates to approximately 2.5 seasons or 528 days.

- The TBPA would approve disposal of the EOSs within the CDF. Although there is sufficient capacity within the existing CDF to contain the dredged sediments, the TBPA will be responsible for constructing a berm partition to close the cell, and maintain the partition in exchange for disposal fee (i.e., tipping fee) of $11 per m^3. This assumption is not verified/documented in the feasibility study.
- No loss-of-use mitigation costs are included.
- The close proximity of the campground and residential neighbourhoods to the proposed cell is of concern as it raises both water quality and short-term odour and noise impacts. Mitigation is not included, but this approach is acceptable for the feasibility study.

3.4.2 Review of Feasibility Study Analyses

Except for dewatering, review comments for dredging associated with this SMO are similar to those expressed above for hydraulic dredging associated with on-site CDF disposal of dredged material. We do not agree a pilot dredging study is needed at this stage of the project. Instead, additional bench-scale testing should be conducted during design to fully evaluate the design aspects (including column testing to further evaluate contaminant fate and transport) for the selected remedy. Based on the outcome of those studies, the need for a pilot test can be evaluated during design.

CoC fate and transport is an issue that should have been addressed. Filter/reactive layers are not included in assumptions—these are a significant cost component in the on-site CDF and should, therefore, be tested against the estimated cost range, based on the statement in AMEC's feasibility study that it is unlikely TBPA CDF berms were designed to contain dissolved phase CoCs.

3.4.3 Costs

The cost for off-site CDF disposal included in the Feasibility Study Phase II is $85.9 million. On a unit cost basis, costs are $244 per m^3 ($187 per cubic yard). However, the cost in the spreadsheet cannot be reproduced with the information presented, and the actual cost requires clarification. Final site closure is not confirmed in the SMO description and does not appear to be included in the cost estimate.

Even when considering costs adjusted for the apparent spreadsheet discrepancy, the estimated costs seem inconsistent with on-site CDF disposal, when the elimination of the complex/costly on-site CDF structure is considered.

Review of the line item costs indicate that the more significant cost factors include the following:

- Dredging – approximately $17 million. The unit cost is the same as was used for hydraulic dredging and appears high based on our experience and the higher volume of EOS removed via mechanical compared to hydraulic, but may be appropriate for the Thunder Bay region. The source of this cost should be included in the feasibility study.
- Barge transportation to the CDF – approximately $12 million. The unit cost for this is $23 per m^3, which appears high based on experience, but again may be appropriate given the available equipment in the area, and our interpretation that transport of the dredged material and offloading from the barge into the CDF were combined in the cost estimate; the cost source should be documented. Hydraulic unloading (e.g., with a low solids pump) of the barge should be compared to the assumed clamshell unloading.
- CDF disposal fee – approximately $6 million based on a unit cost of $11 per m^3, which is consistent with our experience for CDF disposal. However, there is no documentation that this fee has been discussed with the TBPA, or that the infrastructure improvements associated with the CDF and assumed to be covered by the fee have been agreed to by the TBPA.

This SMO provides advantages and benefits compared to the on-site CDF, but requires further evaluation and coordination with TBPA even in the feasibility study stages to verify key cost-related assumptions.

3.5 Dredging and Upland Disposal

This SMO includes hydraulic dredging of EOS, dewatering, dewatering effluent treatment, and off-site upland disposal of dredged material solids at a nearby landfill.

3.5.1 Review of Feasibility Study Process, Methods, Protocols

AMEC's feasibility study included the following:

- Assume dredging will be accomplished by hydraulic methods at a production rate of 1,000 m^3 per day, which equates to 2.5 seasons or 528 days.
- Hauling activities will be conducted 12 hours a day, 6 days per week. All other work (i.e., dredging and dewatering) will be conducted 24 hours a day, 7 days per week.
- Approximately 300 m^3 of solids and 5,700 m^3 of liquids will be produced per day (feed rates for filter press requires a minimum of 2:1 dilution).
- Dewatering will be accomplished using a filter press based on the results of the dewatering study presented in Section 3.
- Chemical additives (polymer) will be used to aid dewatering.
- Wastewater from the filter press will require treatment prior to discharge back into the harbour (details of the treatment train will be determined during pilot study).
- Dewatered sediment will be transported by truck to the John Street Landfill.
- The volume of dredged sediment is expected to decrease by 70% during dewatering.
- Dewatered sediment will pass the slump test required for disposal in the landfill without any additional material treatment or handling.
- The John Street Landfill will accept the material and will provide extended working hours. This assumption is not documented/verified.
- Trucks will not affect public or private roads; therefore, no road maintenance has been considered.

3.5.2 Review of Feasibility Study Analyses

Concerns regarding dredging for this SMO are similar to the other SMOS that include dredging and are described above.

Dewatering effluent production might be slightly underestimated. The assumed production rates and dewatering/effluent treatment are similar to reported Cumberland Bay project averages—998 m^3 per day and 6.3 million litres per day for Cumberland Bay (compared to assumed 1,000 m^3 and 5.8 million litres per day). It is worth noting that Cumberland Bay included 10-inch and 12-inch horizontal auger dredges operating 24 hours per day.

The dewatering effluent treatment system is not detailed. Some details (e.g., four filter presses assumed by AMEC, compared to eight used on Cumberland Bay) and minimal pretreatment (Cumberland Bay used extensive pretreatment) are provided. We suggest a conservative treatment system be conceptually designed and costed to compare to $0.01 per litre cost, and compare to the 20% contingency. The $30 million treatment costs included in the cost estimate are a significant portion of the total SMO cost and associated contingency and changes in the treatment process could therefore have significant cost implications.

Additionally, we recommend using the results of the dewatering test performed by AMEC to compare dewatered filter cake percent solids achievable to the percent solids required to pass the slump test required by the landfill. Additional cost to stabilize with admixtures could be in the $25 to $50 per m^3 range, a potentially significant additional cost.

Alternate approaches could be considered where mechanical dredging and/or dredged material is dewatered via gravity drainage. This approach would likely decrease water treatment requirements. Admixtures could be blended with the solids to pass the slump test for transport and acceptance at the landfill, or arrangements could be made to transport wet dredged material to the landfill for disposal. This type of approach would have to be compared to the Feasibility Study Phase II SMO approach, which includes larger scale dewatering and resultant treatment.

3.5.3 Costs

The cost estimated for this SMO was approximately $139.4 million with an approximate unit cost of $396 per m^3 ($303 per cubic yard). These costs compare reasonably well with recent project experience for efficient projects in the lower Great Lakes and elsewhere.

The Cumberland Bay project includes similarities to the Thunder Bay site with regard to sediment type, volume, environmental setting, working conditions, and approach. Cumberland Bay involved hydraulic dredging in 1999 to 2000 of approximately 170,000 m^3 of pulp and paper waste, off-site upland disposal of solids after dredged material dewatering (in plate and frame filter presses), effluent treatment, and discharge of effluent into Lake Champlain. The costs for the Cumberland Bay project were approximately $36.1 million and associated unit costs of $213 per m^3 ($163 per cubic yard). Those costs are in 1999 and 2000 U.S. dollars and require adjustment for inflation, and are also a result of a pool of experienced contractors located in close proximity to the site. Accordingly, we believe the costs presented in the Feasibility Study Phase II are reasonable when these factors are considered.

Significant line item costs that require further detailing include the following:

- Dredging (approximately $16.8 million) – see comments above regarding similarity in unit cost for mechanical and hydraulic dredging, and for dredging differing volumes associated with the SMOs.
- Filter press equipment and operation (approximately $18.4 million) – the unit cost presented for this is $34,881 per day, and requires additional basis, particularly given that power consumption, polymer addition, and water treatment are addressed as separate line items.
- Chemical additives/polymer (approximately $6.7 million) – the unit cost for this is $12,684 per day and requires additional basis.
- Water treatment (approximately $30.5 million) – unit cost is $0.01/L. See comments above regarding water treatment design.
- Landfill disposal ($6.8 million) – unit cost is $43 per m^3, consistent with experience, but requires documentation of correspondence with landfill regarding cost and compliance with permit requirements.

Similar to the cost estimates presented above, we understand and agree with the recommendation for a pilot test during the design phase of the work to better refine elements of the design. However, the cost estimate for this option at the feasibility study level of analysis could be further refined by developing alternate conceptual design approaches for dewatering and treatment based on those outcomes, and comparing costs associated with those alternate approaches to the 20% cost estimate accuracy target.

4 EVALUATION OF ALTERNATIVE SEDIMENT MANAGEMENT OPTIONS

In this section of the report we present a description and assessment of alternative SMOs for the site. The SMOs include reconfigured/recombined combinations of existing SMOs and new SMOs.

4.1 Recombining/Reconfiguring Remedial Options

The following are remedial approaches that involve recombining/reconfiguring the elements included in the general SMOs included in the feasibility study reports:

- A smaller CDF (than configured in Feasibility Study Phase II) combined with a smaller sediment cap (also smaller than the cap configured in Feasibility Study Phase II)
- Dredging and use of former Mill facilities for dredged material management and on-site landfill disposal
- CDF containment constructed using an alternate approach

A description of these SMOs is summarized below, and a general discussion of potential merits and disadvantages follows.

<u>Combined Smaller CDF/Sediment Cap</u>

With this approach, a small CDF would be constructed in the nearshore area surrounding the more contaminated sediment. EOS that is not contained in situ within the CDF footprint would either be dredged and placed in the CDF or capped. The footprint and CDF volume, extent of dredging, and cap extent would have to be evaluated based on balancing the merits/disadvantages discussed below.

The potential general merits for this approach include the following:

- Combining a CDF with capping provides a contingency for EOS remediation in the event the EOS volume is underpredicted (the volume of dredged material is often underestimated during the planning and design stages) due to inherent survey limitations, bulking, or other factors. If the CDF volume is filled prior to expectation and EOS that had been planned for dredging remains outside the CDF, that EOS can be included in the EOS proposed for capping.

- Dredging would be generally confined to areas where the EOS deposit is thicker, and CoC concentrations are higher. It is likely that dredging the EOS deposit in areas where the layer is thicker will result in less overdredge and water requiring management and treatment. The lower dredge volume may also better support a mechanical dredging production rate to fill the CDF and further reduce the requirement for water management/treatment within the CDF.
- The cap can be placed over the SMU areas more distant from the shoreline where the EOS layer is thin and in deeper water. Because the EOS layer is thin in this area, there is a higher probability that overdredging will result in volumes higher than estimated, increasing cost, and possibly exceeding CDF capacity (for the Feasibility Study Phase II conceptual design that relies on CDFs for disposal of all EOS).
- An additional advantage for placing the cap in areas with a thinner EOS layer is that there is a lower mass of CoCs that require chemical containment under the cap, and the cap design requirements (including cap thickness) may be less than those in other areas where the EOS is thicker. The cap service life may require a more complex and expensive cap design if there is a larger mass of CoCs. Also, consolidation is expected to be less of a concern when capping thinner EOS deposits.
- Construction of a smaller CDF containment structure may decrease complexity and risk associated with constructing a larger CDF, is expected to reduce cost compared to constructing a larger CDF, and is likely to require less mitigation because less habitat is transformed or lost.

Potential disadvantages associated with this approach include the following:

- The CDF containment structure, while smaller for this option, still requires construction in a geotechnical setting where soft native sediment underlies the EOS.
- Capping of the sediment still poses some of the issues regarding placement of the cap material, consolidation of the EOS and underlying native sediment under the cap, and CoC containment under the cap.
- Capping sediment adjacent to the CDF limits the potential future uses of the site. Navigational dredging would be limited due to the presence of the cap.

Accordingly, this approach presents potential advantages, but limitations discussed in the feasibility study reports, our comments applicable to CDF containment structure design and construction, and our comments applicable to capping still apply to this alternative SMO. We recommend this approach be further evaluated, including with that evaluation the additional analyses recommended for CDF and capping that are included elsewhere in this report.

Dredging and Use of Former Mill Facilities for Dredged Material Management and On-site Landfill Disposal

This alternative SMO is similar to the dredging and off-site upland disposal SMO included in the feasibility study reports. This approach includes dredging of EOS within the SMU, transport of the dredged material to the former Mill facility for storage and dewatering, treatment of dewatering effluent in the former Mill wastewater treatment plant, discharge of the treated effluent to site waters, and disposal of dredged material solids in the on-site landfill.

The former Mill has space, facilities, and equipment for dredged material management. The equipment was formerly used in paper manufacture handling and processing materials similar to the EOS and has apparently been out of service for several years. It is expected that the equipment would require repairs, upgrades, and modifications for use in a sediment remediation project. Pilot testing may be necessary to assess if the Mill equipment can be modified to process the EOS. Additionally, a commitment for use of the facility and equipment would be required before expending significant effort and expense to pursue this option.

Equipment and facilities reportedly potentially available at the former Mill include the following:

- Two clarifiers used previously for solids removal (volumes of 2,150 m^3 and 4,300 m^3, respectively)
- One belt filter press with a capacity of 35 metric tons per day operating with a sludge input/output solids content of 4%/40%
- Ten serpentine lagoons including 5 aerated with both underwater headers and surface aerators. The lagoon system was reportedly used to treat 25,000 to 45,000 m^3 per day

(about 6.6 million gallons per day [gpd] to 11.9 million gpd) of effluent containing elevated BOD with a removal efficiency of about 90%. Typical yearly wastewater treatment operating costs were in the range of $1.5 to $2.0 million.

- A sludge landfill reported to have 250,000 to 350,000 m^3 volume capacity is located north of the Mill building. Both clay sludge from clarifiers and secondary sludge from lagoons were landfilled there since the 1980s, with groundwater monitoring results documented through 2006.

The volume of wastewater generated during hydraulic dredging according to the analysis presented in the Feasibility Study Phase II is predicted to be about 1,000 m^3 per day at 5.7 m^3 of water generated for each m^3 of in-place sediment. As discussed above, we believe that flow rate may be low based on water generation reported for other projects. However, based on that prediction, estimated water generated per day by hydraulic dredging per this analysis is 5,700 m^3 per day (about 1.5 million gpd), which compares reasonably with former Mill operating volumes and flow capacities reported above.

Treatment options for the removal of mercury from the effluent need to be assessed in order to discharge the effluent to site waters and achieve discharge standards. This is a process not previously required during the previous Mill operations.

Resolving uncertainties regarding potential system choke points during the initial and subsequent stages of dewatering effort, and required repairs, upgrades, and modifications to provide adequate system flow is needed to fully explore water treatment requirements. Additional resolution of uncertainties regarding dredged material solids and associated required moisture content and volume is also required. The in situ volume of SMU EOS including the 1.5 overdredge factor is greater than 500,000 m^3, which is significantly higher than the reported volume capacity available in the former Mill landfill. The change in volume of the EOS after dredging and dewatering, therefore, requires further analysis. Dredged material solids will include elevated mercury concentrations and other potential CoCs and would, therefore, require comparison to leaching potential and landfill construction requirements.

A conceptual design including treatment train setup and requirements, compared to Mill equipment treatment potential and upgrade, repair, and modification costs is beyond the scope of this report. However, we recommend this conceptual design be further explored because of potential efficiencies in dredged material transport and cost savings.

The potential general merits for this approach include the following:

- Transport and disposal fees for this approach are likely to be significantly lower than off-site transport and disposal fees.
- The cost to upgrade, repair, and modify former Mill equipment should be compared to procuring and mobilizing new equipment, and may be advantageous.
- As discussed above for the dredging and off-site landfill disposal SMO included in the feasibility study reports, alternate dredging methods should also be explored for this approach—mechanical dredging or use of a high solids pump may significantly reduce dewatering requirements. A lower dewatering effluent flow rate will likely reduce the requirement to upgrade, repair, and modify Mill equipment, and reduce associated costs.
- The facility includes significant areas of open space to accommodate sediment remedial operations.

Potential disadvantages, other than uncertainties previously referenced, associated with this approach include the following:

- Depending on the future use of the former Mill, the space, equipment, and facilities may not be available for use during sediment remediation.

In general, we recommend further evaluating this alternate approach because of the potential for significantly reduced project cost.

<u>CDF Containment Constructed Using an Alternate Approach</u>

The CDF containment structure included in the Feasibility Study Phase II includes a complex construction sequence developed conceptually based on CPT measurements that indicate native sediments underlying EOS are very soft. The construction sequence includes installation of sand drains in native sediment to increase the native sediment consolidation rate and to assume some of the berm load. The softer, compressible EOS are removed prior to berm placement. We recommend evaluating alternative approaches including:

- Constructing the berm on an installed rock mat
- Constructing the CDF containment from steel sheetpile

Constructing the CDF berm on an installed rock mat simplifies the construction sequence and, if feasible, would also be expected to reduce construction cost.

Placing rock serves to displace the underlying EOS material, and/or compact the native sediment to the degree that sufficient bearing capacity is obtained to then build the berm to the design grade. Some examples of this are the Port of Long Angeles Pier T CDF, Port of San Diego Campbell Shipyard remediation, and the Port of Everett (Washington) nearshore confined disposal facility (NCDF). In most cases, as would likely be required in Thunder Bay based on available subsurface information, unsuitable subsurface materials would be removed and replaced with coarser materials. This would increase bearing capacity and would also reduce the potential for differential settlement and damage to the berm, and decrease the time required for consolidation of sediment located under the berm.

Steel sheetpile requires evaluation of subsurface conditions, structural design, and associated construction cost. Additionally, the environmental factors associated with a steel sheetpile wall would require further evaluation. If a sealed sheetpile wall is used to limit migration of CoCs beyond the CDF, a low permeability cap would likely be required to limit infiltration and buildup of groundwater within the CDF. If groundwater was allowed to discharge from the CDF, treatment of the ground water would likely be required.

The sheetpile wall could be installed through a berm to increase support for the wall, reduce resuspension of EOS, and provide a location for reactive core material to manage CoC migration in groundwater. Sheetpile walls will require maintenance and eventual replacement. There are numerous examples of nearshore sheetpile walls used to retain fill and create shoreline. Sheetpile containment structures were used for CDFs in the Island End River in Boston and in New Bedford Harbor, Massachusetts.

Additional subsurface investigation is required to more fully evaluate native sediment geotechnical properties, depth to a more competent sediment layer and/or bedrock, and the feasibility of an alternate approach for CDF containment.

To more fully evaluate potential merits and disadvantages, both alternative structures require resolving the uncertainties described above. If both alternatives are feasible following resolution of the uncertainties, a cost-benefit analysis can be conducted to assess the preferred alternative. However, the potential merits associated with both alternate CDF containment structure approaches include improved constructability and lower cost.

4.2 Alternative Sediment Management Options

Alternative remedial options include approaches that were not referenced in the previous project documents. We did not include innovative approaches that have not been demonstrated on a full scale.

Alternative remedial SMOs considered include the following:

- Removal and recycling of EOS
- Confined aquatic disposal (CAD) of EOS
- Removal and thermal treatment of EOS
- Filling of the SMU to create dry land

These additional remedial options are discussed below.

<u>Removal and Recycling of EOS</u>

Pulp waste can be recycled/beneficially reused, including reuse in paper manufacture, agriculture, and to generate energy via burning or co/burning. However, this is likely not a feasible option for the EOS because of the following:

- The presence of mercury in the EOS would likely require treatment prior to and/or during recycling. The high clay content would likely create difficulties for reuse in the paper products manufacturing process. The clay is not of sufficient quality to be separated and reused.
- The EOS thermal content is likely low due to high clay content, and would require

extensive dewatering prior to co-burning.

Generally, the costs to dewater and transport the EOS are likely to be high. Recycling is not expected to be a viable option and is not recommended for further evaluation.

Confined Aquatic Disposal of EOS

CAD generally includes subaqueous disposal of dredged material either in a natural bathymetric depression or in a cell constructed by dredging sediment (typically, deeper sediment is removed to create the CAD cell and the material is beneficially reused).

CAD disposal was evaluated for the site, but is not considered feasible for the following reasons:

- There are not sufficient natural bathymetric depressions in the site vicinity, requiring a CAD cell to be constructed by dredging native sediment. Available information for native sediment underlying the EOS indicates the sediments may require significant slopes to support CAD cell sides without slumping, which would consume CAD cell volume.
- The EOS has a low unit weight and would likely require some form of containment (e.g., pumping into geotubes) for the EOS to be placed in the CAD cell without potential for releases of EOS to the water column with the potential for subsequent transport and redeposition of the EOS. This is an approach that has been implemented successfully at other non-submerged sites, but has not been implemented at a large scale on submerged sites..
- Capping the CAD cell would require accommodating potentially significant consolidation of a thick EOS layer and long-term degradation of the EOS. Cap repairs would potentially be required.

Additionally, there is not sufficient information regarding the depth of soft native sediment and depth to bedrock to evaluate possible constraints on CAD siting. Shallow bedrock or hard sediment would limit CAD siting.

CAD is not expected to be a viable option and is not recommended for further evaluation.

Removal and Thermal Treatment of EOS

This alternative SMO would include removal of the sediment, processing of the dredged material to remove water, and incineration of the solids. Because the EOS includes a significant fraction of wood waste, the dredged material may have thermal potential and could be co-burned for energy generation, but may require additional processing to reduce clay content and maintain thermal content.

However, thermal technologies typically require a relatively low moisture content (in our experience, thermal treatment generally requires about 90% solids and 10% water content). Dewatering studies indicate achieving this water content may not be practically achievable. The potential effect on incineration of a significant volume of clay in the material is not known. Additionally, incineration is generally not recommended for wastes containing mercury.

Thermal treatment is not expected to be a viable option and is not recommended for further evaluation.

Filling the SMU to Create Dry Land

This alternative SMO would include filling of the SMU to an elevation above the water table that would develop in the fill (e.g. a dry cap). This approach would confine the EOS and associated CoCs in a manner similar to a cap, but this cap would not be submerged and would, therefore, not have a direct exposure pathway to water or to benthic habitat. Containment of CoCs would be required at the cap margins, similar to a CDF. Unlike the CDF, dredging would either not be required or would be limited to areas around the perimeter of the SMU to limit the area/volume of fill required.

More than 750,000 m^3 of fill would be required assuming the following:

- The fill would cover the entire 22-ha SMU (an average water depth in the SMU of about 2.5 m).
- The fill would extend approximately 1m above the water line (water line is presumed about equal to the lake level).
- An associated average fill thickness of 3.5 m (not including accounting for consolidation and settlement of material under the fill).

Consolidation of the EOS and underlying sediment will likely result in a need for additional fill material to maintain the elevation of the filled area above water. Long-term degradation of the EOS may also result in settlement of the fill and the need to add material to maintain the grade. The edge of the fill would require containment via a berm or similar structure, raising issues similar to those discussed previously for the CDF. Mitigation requirements for eliminating the 22 ha of habitat via filling are not known, but may be partially mitigated by creating an alternate habitat on the filled area.

Uncertainties involving placement of the fill, fill stability, construction of a containment structure, and mitigation requirements exist for this approach. The volume of fill required could exceed 750,000 m^3, requiring evaluation of potential sources and cost for procuring, transporting, and placing the fill.

Based on the alternate SMOs listed above, we recommend further evaluation of the recombined/reconfigured SMOs referenced above. We do not recommend further evaluating the alternative SMOs.

5 CONCLUSION

Conclusions and recommendations are based on our review of the information presented in the feasibility study reports.

5.1 Conclusions

Anchor QEA has prepared this Feasibility Study Phase II Peer Review for the Thunder Bay site located on Lake Superior in Thunder Bay, Ontario. The following SMOs were developed and evaluated in AMEC's feasibility study:

- Monitored natural attenuatio.
- Isolation capping, including capping with sand and reactive capping
- SMOs that included dredging and the following disposal options for dredged material:
  - On-site CDF
  - Off-site CDF disposal, at a CDF operated by the TBPA
  - Off-site upland disposal

AMEC's Feasibility Study Phase II concluded that isolation capping was the preferred SMO for the EOS based on lower complexity and cost than other SMOs that included dredging and on-site or off-site disposal of dredged material. Based on our review of the AMEC Feasibility Study Phase II, we do not believe the analysis fully supports capping as the preferred SMO.

Our peer review included evaluation of field work, data collected, feasibility study analysis, methods, findings, and conclusions.

Our assessment of the field work was that it was performed in accordance with standard practices.

Environmental characterization of the site is not adequate for the feasibility study. A significant amount of information was collected for environmental characterization including sediment chemistry, dewatering, DRET, and PCLT. However, although sediment cleanup objectives were not a part of the Feasibility Study Phase II report, sediment contaminants contributing to the site toxicity and risk should be evaluated to more comprehensively identify and evaluate SMOs. A clear connection between sediment CoCs, toxicity, risk, guidance, and associated cleanup objectives has not been established in AMEC's feasibility study or previous reports.

The geotechnical characterization of the EOS and underlying native sediment was not sufficient for developing the feasibility study conceptual designs. Standard laboratory consolidation, strength, and geotechnical index properties are not available for either EOS or the underlying native sediment. This makes typical analysis to support design concepts (e.g., consolidation test results used for cap stability analysis and contaminant fate and transport modelling) difficult and results in uncertainty in the SMO conceptual designs for capping and on-site CDF disposal.

An additional consideration is the presence of debris in the sediment. The presence of debris in the area was not addressed in the feasibility studies. Debris poses issues for both capping and dredging.

The coastal process information included in the AMEC feasibility study report included wind/wave/current data. Using the same wind and bathymetric data we re-analyzed the coastal processes evaluations that AMEC included in the Feasibility Study Phase II. Our findings were in general agreement with the AMEC findings, with minor exceptions noted in the main report. The period considered for wind wave data (used to model wind waves) was not clear and should be better documented.

The volume of EOS is presented in AMEC's feasibility study as a neatline volume. Consistent with standard engineering practice, AMEC assumes a 1.5 multiplier volume adjustment for the neatline volume for SMOs that include dredging. However, the EOS area and volume are large and small changes in assumptions during conceptual design can result in relatively significant differences in volume and associated remedial cost. Processes such as bulking during dredging and shrinkage during drying will significantly affect the dredging, transport, and dewatering volumes.

Based on our review of the evaluation of SMOs our general findings were that the weighting or ranking of the evaluation criteria was not defined. Our opinion is that the criteria require detailed description, how they are applied to the SMOs, and the ranking of the criteria. The ranking is in our experience developed with input from project stakeholders and can vary depending on the site, surrounding area, and potential future use(s) of the site.

Cost estimates for the SMOs were at the higher end of the range of costs for comparable projects, but are in the general range for remedial projects given the site location, conditions, limitations, and level of detail in the feasibility study to support the cost estimates. However, we do not believe the costs are supported by the SMO conceptual designs and are not within the targeted 20% contingency range required by the Steering Committee. That range is more accurate than is typical for feasibility studies in our experience. A more typical feasibility study range is +50%/-30%. We do not believe the costs necessarily fall within this range either, based on some of the uncertainties described in this report.

An additional general comment on cost is that the AMEC feasibility study should have included a review of the availability of specialty contractors and equipment to perform this work in the Thunder Bay area. The requirement to transport equipment long distances and/or fabricate the equipment on site can be a significant cost factor. Equipment operator skill and experience for operations such as capping and environmental dredging can be a significant factor in cost and project outcome and should be addressed in the AMEC feasibility study.

Peer review comments specific to the SMOs include the following:

- SMOs that included capping:
  - The cap constructability is not adequately addressed. Additional geotechnical information (consolidation testing, geotechnical index properties and strength measurements) is required to evaluate constructabilty of the cap. This addresses a basic question of implementability for capping, i.e., can the cap be placed without destabilizing and mobilizing the underlying EOS? A feasibility study-level-of-detail conceptual design can be developed using available information, with the additional geotechnical investigation data to be collected. A pilot test may be needed to advance the design further.

  - The effectiveness of the isolation cap for chemical sequestration was not fully detailed. We could not re-create AMEC's cap modelling outcome. We recommend performing a re-analysis of isolation cap modelling, based on specific comments provided in the report.
  - Design elements that have potentially significant implications for cost were not fully addressed in the feasibility study, including cap construction approach to avoid destabilizing soft EOS and underlying native sediment, and sourcing of cap materials. Our comparison of the cost estimate for capping to other projects, normalized on a unit cost basis (i.e., capping cost per square metre of capping area) indicated the costs were at the high end of the range. However, the costs are not supported by the study analyses, and the uncertainties associated with constructability and effectiveness, need to be addressed before the cap cost estimate can be refined to the 20% contingency range.

- SMOs that included dredging:
  - Existing column settling test (CST) results, dewatering test results, and DRET results should have been used to perform a more detailed analysis of EOS properties related to potential releases during dredging, dewatering characteristics, and associated influence on dredging, dewatering, and disposal options.
  - Dredging method selection for the candidate SMOs should have been based on a more detailed characterization of sediment disposal options to aid in selecting a dredging method. Disposal options are typically a key consideration in dredging method. Disposal options that require extensive dredged material management and/or lack space for management typically require limiting generation of water during dredging – for these options, mechanical dredging may be preferred. For disposal options where dredged material management is not as extensive and higher productivity is not required hydraulic dredging may be preferred. A pilot test may be needed during a more advanced design stage to further evaluate and refine potential dredging methods, but information presently available should be sufficient for developing a feasibility study-level-of-detail conceptual dredging design. The conceptual design can be discussed with contractors during the

feasibility study to better refine constructability- and cost-related issues such as dewatering rates and overdredge allowance.

- The SMO conceptual designs did not include provisions for controls (to a level of detail that allows for evaluation of potential performance and cost) to mitigate potential impacts during dredging and disposal operations. Available information, including CST and DRET results, can be used for this analysis.
- Design elements that have significant potential implications for cost were not fully addressed in the study, including:
    - As discussed above, dredged material volume estimate accuracy and the potential cost implications.
    - The dredging approach needs to be further detailed, even conceptually, and linked to the dewatering, consolidation, CDF volume, and fate and transport considerations. A worst-case or conservative/high-cost scenario could be compared to the 20% contingency carried for cost or to the more typical feasibility study cost range.
- On a unit cost basis dredging costs were consistent with our experience on other projects but need to be associated with a more detailed conceptual design and better documented.

- SMOs that included CDF disposal of dredged material:
    - As discussed above, we could note re-create AMEC's foundation analysis for the on-site CDF berm. The CDF containment structure developed by AMEC was complex and expensive. We were not convinced the containment structure conceptualized during the AMEC feasibility study process was constructable. Additional geotechnical information and analyses are needed to develop a feasible conceptual design for a CDF containment structure.
    - For both the on-site and off-site CDFs there was insufficient analysis to evaluate CoC isolation by the CDF containment structure. We recommend evaluating CoC fate and transport within the CDF to better define the chemical isolation requirements for the CDF containment structure. Chemical isolation requirements may result in adding design features to the SMOs. This is required for both the on-site and off-site CDFs.

- Design elements that have significant potential implications for cost were not fully addressed in the study, including:
    - For the on-site CDF, berm construction results in a complex and costly CDF containment structure approach that raises questions regarding the feasibility of the containment structure.
    - Closure/capping costs were not included and can vary significantly depending on the site use and associated schedule and loading requirements.
    - For the off-site CDF, construction and disposal costs were not documented and could not be confirmed, raising uncertainty.
    - For both CDFs, the containment of CoCs within the CDF was not addressed and may require additional cost to address.
    - On a unit cost basis dredging and CDF disposal costs were consistent with our experience on other projects but, similar to capping and dredging costs, need to be associated with a more detailed conceptual design and better documented.

- The SMO that included off-site disposal of dredged material:
    - This SMO should have included documentation of a cost-benefit analysis comparing hydraulic and mechanical dredging. Hydraulic dredging was selected, but generates a significant volume of water that requires management. Mechanical dredging would generate less water. The trade-off between production rates and dewatering requirements/costs should have been evaluated.
    - Some of the details of the conceptualized dewatering system (flow rate, system capacity) are not specified and may not be adequate compared to experience on similar projects.
    - Design elements that have significant potential implications for cost were not fully addressed in the study, including:
        - The dredging approach, as discussed above.
        - The dewatering system, including dewatering of dredged material and treatment of dewatering effluent.
        - Landfill disposal – no discussion is presented indicating the dredged material would comply with landfill disposal requirements.

  - On a unit cost basis costs were consistent with our experience on other projects but need to be better documented and evaluated relative to local availability of equipment and expertise.

Recommendations regarding the recombined/reconfigured SMOs and the alternative SMOs are presented below.

5.2 Recommendations

In addition to specific and detailed recommendations included in the text above, a summary of general recommendations made throughout this report includes the following:

- The evaluation criteria definition should be more fully described, and the weighting of the evaluation criteria discussed. The evaluation of the SMOs compared to the criteria could be more detailed as described below, but requires more detail in the conceptual designs used to describe SMOs. A summary of our review of the evaluation of SMOs is presented below.
- Complete the assessment of sediment toxicity and identify primary CoCs, if any, in addition to mercury to more comprehensively define sediment cleanup objectives and criteria.
- Further detail significant line item costs to refine cost estimates.
- Perform a more detailed geotechnical investigation to evaluate subsurface conditions and native sediment and EOS properties to further develop on-site CDF design.
- Based on the alternative approaches developed for this review, we recommend further evaluation of the recombined/reconfigured SMOs including: the smaller CDF and cap combination; EOS removal and on-site management and disposal using former Mill facilities and equipment; and alternate CDF containment structure. We do not recommend further evaluating the alternative SMOs, except for possible additional discussion of SMU filling to create dry land.

In general, the feasibility study requires additional analysis and detail to select a preferred SMO. There is insufficient uncertainty in the SMO conceptual designs to support the Feasibility Study Phase II conclusions. Further developing the SMO conceptual designs to a higher level of detail is recommended to reduce uncertainties that are a potentially significant factor for predicting SMO performance and in estimating cost.

Uncertainties that require resolution, even in the feasibility study stage, and recommended approaches to resolve the uncertainties include the following:

- SMOs that included dredging:
  - Disposal method – using available information, perform a more detailed analysis of EOS properties and associated influence on dredging and disposal options.
  - Dredging method – perform a more comprehensive characterization of disposal options for sediment to aid in selecting a dredging method. A pilot test may be needed during a more advanced design stage to further evaluate and refine potential dredging methods, but information presently available should be sufficient for developing a feasibility study-level-of-detail conceptual design. The conceptual design can be discussed with contractors to better refine constructability- and cost-related issues such as overdredge allowance.
  - Potential impacts to the water column during dredging and disposal operations – using available information, develop a conceptual design (to a level of detail that allows for evaluation of performance and cost) for controls to mitigate potential impacts during dredging and disposal operations.
- SMOs that included capping:
  - Containment requirements for a cap – perform a re-analysis of isolation cap modelling, based on comments provided in Section 3.2. Combined with the more detailed remedial objectives discussed above, the ability of a cap to contain CoCs from chemical and physical perspectives is an uncertainty.
  - Stability of EOS during capping – using available information and additional geotechnical information (consolidation testing data, strength characteristics, geotechnical index properties) for the underlying native sediment, develop a conceptual design for cap placement on the soft EOS. This addresses a basic question of implementability for capping, i.e., can the cap be placed without destabilizing and mobilizing the underlying EOS? A pilot test may be needed during a more advanced design stage to further evaluate this important part of a

capping approach, but information presently available, supplemented with additional geotechnical investigation data, should be sufficient for developing a feasibility study-level-of-detail conceptual design.

- CDF-related SMOs:
  - CDF containment structure construction approach – collect additional geotechnical information to supplement existing information and develop alternate approaches for CDF containment structure
  - CoC isolation properties of the CDF containment structure – Using available information, perform an evaluation of fate and transport of EOS CoCs within the CDF to better define the chemical isolation requirements for the CDF containment structure. This is required for both the on-site CDF and the TBPA options.

Much of the information required to further detail the SMOs conceptual designs has been collected. However, a more detailed analysis and use of that data, combined with collection of additional data as described above, are required to develop conceptual designs to a level of detail that reduces uncertainty, allows cost estimates to be developed that are closer to the target accuracy range and recommend a preferred SMO.

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