June 2018

NEW SOO LOCK ECONOMIC VALIDATION STUDY

APPENDIX B ECONOMIC ANALYSIS

GREAT LAKES AND OHIO RIVER DIVISION
PLANNING CENTER OF EXPERTISE FOR INLAND NAVIGATION
AND RISK-INFORMED ECONOMICS DIVISION, HUNTINGTON DISTRICT
NAVIGATION PLANNING CENTER BRANCH (CELRH-PX-NC)

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EXECUTIVE SUMMARY

This appendix outlines the economic evaluation performed in support of the 2018 New Soo Locks Economic Validation Study. According to EC 11-2-208 *Corps of Engineers Civil Works Direct Program Development Policy Guidance Fiscal Year 2017*, this type of study is "a reexamination of project justification, including the economics and/or environmental effects, that does not require reformulation of alternatives." This analysis evaluates the benefits and costs associated with constructing a second "Poe-sized" Lock at the Soo Locks complex.

This project was authorized by Section 3091 of the Water Resource Development Act (WRDA) 2007, amending Section 1149 of WRDA 1986. Guidance outlined in ER 1105-2-100 (*Planning Guidance Notebook)* was used throughout this analysis. All benefits and costs were computed using the Fiscal Year (FY) 2018 federal discount rate of 2.75 percent (EGM 18-01), a 50-year project life with a base calendar year of 2027, and dollar values displayed at Q1 FY 2018 price levels.

The new lock would be constructed in place of the existing Davis and Sabin locks (**Figure ES 1-1**), providing redundancy and improving the flow of waterborne transportation throughout the Great Lakes Navigation System.

Figure ES 1-1—Soo Locks Complex Major Features

Navigation economists working for the U.S. Army Corps of Engineers' Planning Center of Expertise for Inland Navigation and Risk-Informed Economics Division (PCXIN-RED) in Huntington, WV updated project benefits. Huntington District engineers developed cost estimates, which were reviewed and certified by the Walla-Walla Cost Engineering Mandatory Center of Expertise (MCX).

Benefit-cost analyses were based on anticipated transportation cost savings (benefits) and the estimated implementation investment costs of constructing a second Poe-sized lock at the Soo Locks complex.

Project benefits include the annualized value of net reductions in service disruption impact costs and in scheduled project costs, as well as gross benefits such as recreation and labor resource benefits.

Scheduled project costs include project investment costs, maintenance costs, and both the investment and maintenance costs for alternative transportation modes, including unmet demand proxy modes.

[redacted].

Benefits resulting from net costs (service disruption and scheduled project costs) were evaluated by comparing annualized costs in the without-project condition and with-project condition. When the with-project condition results in a net reduction in costs, the cost reduction is considered a benefit of the with-project condition. **Figure ES 1-1** itemizes Soo Locks Validation Study benefit subcategories. They include service disruption impacts avoided, unmet demand impacts avoided, without-project costs avoided, recreation benefits, and labor resource benefits. Analysts anticipate that constructing a second Poe sized lock would provide approximately $58.2 million in average annual benefits over the 57-year period of analysis (FY 2018 price levels, 2027 base year, 2.75 percent discount rate).

Table ES-1-1—Average Annual Benefits by Category, 2020–2076, Q1 FY18 Dollars, 2.75 Percent Discount Rate

Benefit Category	
Service Disruption Impact Costs Avoided	
Diverted Traffic Costs	$1,592,843
Vessel Transit Time Costs	$1,949,303
Poe-restricted Vessel Layup (wait at port)	$1,331,584
Sub-Total Service Disruption Costs Avoided	**$4,873,730**
Unmet Demand Proxy Transportation Impacts Avoided	
Taconite - via conveyor system	$1,123,263
Taconite - via expanded stockpile	$7,437,006
Taconite - via expanded Escanaba	$31,189,087
Sub-Total Unmet Demand Impacts Avoided	**$39,749,357**
Without-project Costs (WOPC) Costs Avoided (benefits)	
Normal Operations & Maintenance	$0
Scheduled Maintenance	$3,033,975
Escanaba (existing)	$1,016,227
Davis / Sabin decommissioning	$781,433
Service Disruption Repair Costs	
Engineering Reliability Components	$5,508
Accidents	$0
Major Maintenance/Component Replacement	
Project Level Components	$678,772
Poe Lock Components	$1,566,202
MacArthur Lock Components	$1,890,659
Sub-Total WOPC Costs Avoided	**$8,972,776**
Recreation Benefits	
Visitor Center	$2,902,500
Recreational Craft	$800
Tour Boats	$66,400
Sub-Total Recreation Benefits	**$2,969,700**
Labor Resource Benefits	
Labor Resource Benefits	$1,607,854
TOTAL PROJECT BENEFITS without Labor Resource Benefits:	**$56,565,563**
TOTAL PROJECT BENEFITS with Labor Resource Benefits:	**$58,173,417**

The service disruption impacts avoided category accounts for vessel capacity issues. These include diverted traffic costs, vessel transit time costs, and Poe-restricted vessel layup (wait at port) delay costs. This category accounts for approximately $4.9 million per year, or 8.4 percent of the total project benefits.

The unmet demand impacts avoided category accounts for taconite transportation constraints case of a Poe lock closure. This category includes three alternatives for accommodating the unmet transportation demand for materials: a conveyor system, expanded stockpiling operations, and an expansion at Escanaba. The use of these alternatives due to lock component failures and/or vessel accidents account for approximately $39.7 million per year, or 68.3 percent of the total project benefits.

The without-project condition costs avoided category quantifies the expected costs avoided associated with existing lock components if a new lock is not constructed. This category includes normal operations and maintenance, scheduled maintenance, existing costs at Escanaba, the decommissioning of the Davis and Sabin locks, service disruption repair costs, and major maintenance/component replacement. This category accounts for approximately $8.9 million per year, or 15.4 percent of the total project benefits.

The recreation benefits category accounts for enhanced recreation activities resulting from the construction of a new lock. This category includes opportunities afforded by the visitor center, recreational craft lockages, and tour boats. This category accounts for approximately $2.9 million per year, or 5.1 percent of the total project benefits.

The final benefit category is labor resource benefits, which is defined as the economic effects of the direct use of otherwise unemployed or underemployed labor resources during project construction or installation. This category accounts for approximately $1.6 million per year, or 2.8 percent of the total project benefits.

The costs, benefits, net benefits and benefit-to-cost ratios of the investment alternatives are summarized in Table ES-1-2. These net benefit and benefit-cost ratio calculations are shown at both the current FY18 discount rate of 2.75 percent, as well as a 7.0 percent rate. In summary, the construction of a new lock at the Soo Locks complex would result in an average annual benefit of $58.2 million at an average annual cost of $32.7 million, producing an average annual net benefit of $25.5 million and a benefit to cost ratio (BCR) of 1.78 at the FY18 federal discount rate (2.75 percent). This analysis validates the economics for the re-authorization of the new, Poe-sized lock.

Table ES-1-2—Benefit-to-Cost Evaluation, 2020–2076, Q1 FY18 Dollars

Cash Flow Category	New Poe-Size Lock	
	2.75% Discount Rate	7.0% Discount Rate
Total Average Annual Project Costs	$32,708,888	$69,480,408
Total Average Annual Project Benefits	$56,565,563	$103,795,851
BASE NET BENEFITS	$23,856,675	$34,315,443
BENEFIT-TO-COST RATIO (BCR)	**1.73**	**1.49**
Base Net Benefits	$23,856,675	$34,315,443
Allowable Labor Resource Benefits	$1,607,854	$3,145,301
NET BENEFITS	$25,464,528	$37,460,744
BENEFIT-TO-COST RATIO (BCR)	**1.78**	**1.54**

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10 – Poe Lock System Risk Analysis Report (1994)
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Section 1. Introduction

This economic appendix summarizes the reevaluation of benefits and costs, which reflect changes in the vessel fleet, alternative transportation modes, commodity forecasts, construction costs and the impacts of a deteriorating lock system.

1.1 Study Procedure

The study procedures outlined in the ER 1105-2-100 *Planning Guidance Notebook (PGN)* apply to all USACE planning studies. What makes a validation study different from other USACE planning studies is the limited scope. According to EC 11-2-208 *Corps of Engineers Civil Works Direct Program Development Policy Guidance Fiscal Year 2017*, this type of study is "a reexamination of project justification, including the economics and/or environmental effects, that does not require reformulation of alternatives." These analyses seek to evaluate and inform the benefits and costs associated with potential project alternatives, as compared to the future without-project condition.

The USACE Detroit District followed the benefit procedure outlined in Appendix E, Section II, of the PGN to develop this analysis. **Figure 1-1** displays an overview of the study framework. Where possible, risk-based estimates are incorporated in the commodity forecasts, alternative mode costs, reliability of existing and proposed structures, and system delays associated with capacity constraints. The uncertainty surrounding these estimates, evaluations, and outputs are described throughout this document.

Figure 1-1 - Soo Locks BCR Validation Study Framework

1.2 Prior Studies and Reports

After reviewing existing reports and studies, relevant data and information taken from the following documents have been used in this Report, which are listed descending chronological order:

Soo Locks Major Rehabilitation Evaluation Report (MRER), U.S. Army Corps of Engineers, Detroit District (2017). The major rehabilitation evaluation report (MRER) examined components within the Poe Lock and MacArthur Lock [redacted] This plan has an estimated total cost of $57,581,000 with a BCR of 2.92. The report was approved in December 2017.

Geotechnical Analysis, U.S. Army Corps of Engineers Detroit District (2016). The geotechnical analysis report dated March 2016 was initiated as a result of concern over a potential failure mode (PFM) identified in the periodic assessment report. The study team conducted an in-depth geotechnical analysis of the potential failure modes and identified internal erosion of materials as the primary risk. The geotechnical analysis report ultimately discounted all of the PFMs that identified internal erosion as a higher risk driver. The in-depth analysis determined and verified that the north and center dikes are constructed with rock fill, not earth fill, and therefore, are not susceptible to internal erosion at the critical unit flow rate.

2016 Traffic Statement, St. Mary's Falls Canal, Michigan, United States Army Corps of Engineers, 2016. The purpose of this statement was to provide updated information on delays, vessel passages, lockages, and net tons of cargo that passed through the MacArthur and Poe Lock.

The Perils of Efficiency: An Analysis of an Unexpected Closure of the Poe Lock and its Impact, U.S. Department of Homeland Security, October 2015. The purpose of this report is to discuss the impact of an unexpected 6-month closure of the Poe Lock on the iron mining—integrated steel production—manufacturing supply chain. The report addresses the challenges facing alternative modes of transportation to support the supply chain and finds there is no single strategy which can compensate for the negative effect to the North American economy.

Semi-Quantitative Risk Assessment (SQRA), U.S. Army Corps of Engineers, Detroit District
An Army Corps of Engineers cadre of experts completed an SQRA on the Soo Locks complex in 2014. Its report addressed issues from the preceding reports and inspections and set the stage for the issues suitable for MRER consideration. Appendix A-2 of the SQRA identifies potential failure modes that were non-risk-drivers for the SQRA but had potential performance issues over time that warranted evaluation under an MRER. The complete SQRA report is provided as a reference to the MRER. Many members of this cadre stayed on to develop the MRER.

Partial Benefits Evaluation—Soo Locks, Michigan (2014). This study addressed concerns voiced by the Great Lakes maritime community regarding the inadequate accounting of benefits in the 2005 *Soo Locks Limited Reevaluation Report* (LRR). The report addressed these concerns through a "sensitivity analysis" to determine if a reexamination of potential lock closure impacts might result in a significantly different BCR for the construction of a second Poe-sized lock if a new benefits evaluation study was conducted. Three interrelated components of the study included 1) a stakeholder response analysis entailing interviews with Great Lakes shippers and operators involved primarily in taconite and coal movements; 2) an expert elicitation workshop involving industry representatives (e.g., mining, manufacturing, utilities, railroads) focusing on lock closure scenarios and the ability/feasibility of alternatives that could move coal and taconite around the locks; and 3) a feasibility test that involved constructing and running economic models to quantify the impacts of a lock closure. Each of these study components examined, in detail, five alternatives for moving taconite and coal in case of a lock closure: reroute through Escanaba, Michigan; reroute to rail/rail to vessel transloading; lightering; foreign sourcing; and reroute to trucking.

The Economic Value of Iron Ore Transiting the Soo Locks, Peter Kakela, June 2013. The purpose of this report is to highlight the importance of taconite moving through the Soo Locks and quantify its direct, indirect, and induced economic value. The report found that the total dollar value of taconite shipped through the Soo Locks in 2012 amounts to $500.4 billion, or 3.2 percent of the U.S. gross domestic product (GDP). Additionally, this report estimates over 650,000 jobs depend on these taconite shipments. Further, the report highlights a history of the significance of taconite to national security.

2008 Great Lakes Navigation System Transportation Rate Update for Great Lakes Water Movement, University of Toledo. The University of Toledo conducted this study on behalf of USACE to update transportation rates for the Great Lakes and St. Lawrence Seaway System. Using 2006 commodity tonnage data for 51 origin-destination-commodity (O-D-C) triples on the Great Lakes St. Lawrence Seaway, this study developed detailed transportation rate estimates for the existing water routing as well as the lowest cost alternative land routing. These O-D-C

triples were selected from the 2006 Waterborne Commerce Statistics Center (WCSC) data. For estimating cost, the study depended upon the data collected in the 2005 Tennessee Valley Authority (TVA) referenced below. Cost data was adjusted using 2006 Waybill data and published cost and inflation information. The study found that the water route was the cheapest route in all but one case. The least-cost land-only alternative transportation route always included railroad transportation for at least part of the route. Where the land route had a lower cost than the corresponding waterborne shipping route, the distance of travel was substantially smaller for the land-only alternative. Finally, this study estimated that the 51 moves resulted in $904.5 million in transportation rate savings through use of the waterway system.

Assessing the Capacity of Class I Railroads as Related to Soo Locks Navigation Traffic, Center for Transportation Research, the University of Tennessee (2008). This report focused on rail movements for the four most prevalent commodities moving over the Soo Locks – coal, taconite, limestone, and grain. It considers both infrastructure and variable input constraints under scenarios involving the closure of the Poe Lock and the closure of both the Poe and MacArthur Locks. The study found that any closure of the Poe Lock would be extremely disruptive to the shippers that depend on this infrastructure and to the vessel operators that provide transportation over the Great Lakes. A closure resulting in traffic diversions would also significantly impact rail carriers in the Great Lakes region, potentially forcing them to add the daily capacity equivalent to 50 trains per day. The study's key findings included the following: the effort by the railroads to respond to this scenario would not be instantaneous and would require a tremendous level of cooperation among railroads, shippers, organized labor, equipment suppliers, and the public sector; a service expansion of this magnitude has not been experienced since World War II, so the ability to understand the full impact of costs to providing railroad services is limited; and even a remote possibility of closure should be met with significant contingency planning in order to meet the potential shift in transportation modes.

Transportation Rate Analysis: Great Lakes & St. Lawrence Seaway, the Tennessee Valley Authority (2005). This study was conducted by the Tennessee Valley Authority on behalf of USACE to facilitate the calculation of the National economic development (NED) benefits attributable to the Great Lakes and St. Lawrence Seaway navigation. A second purpose was to measure the transportation cost effect of alternative short-term unplanned navigation structure closures. The study provides a full range of transportation rates and supplemental costs for 857 waterborne commodity movements in 2002. Freight rates for each movement were calculated based on the actual water-inclusive routing. It also calculated the competing all-land alternative and a set of closure durations (15, 30, 90, or 180 days) of the Soo Locks,

Welland Canal, or St. Lawrence Seaway. This report estimated that the users of this navigation system saved more than $2.66 billion in transportation and handling charges when available vessel costs were compared to the next-best, all-land transportation alternatives. This and other rate studies have been used to estimate the transportation rates and associated savings for this 2018 validation study.

Sault Ste. Marie Lock Traffic Study, U.S. Army Corps of Engineers, Detroit District, May 1991. This report documented revisions to the 1985 Soo Locks traffic forecast from the feasibility report. The revisions are based on actual tonnage recorded between 1985 and 1990, general market conditions, and the opinions of industry experts on future market conditions.

Periodic Inspection Reports, U.S. Army Corps of Engineers, Detroit District
Periodic inspections occur regularly at the Soo Locks. This effort includes a risk assessment of PFMs judged to be risk-drivers. Periodic inspection reports are available from 1968 to 2012 and describe the then-current condition of a feature, identify deficiencies, and provide recommendations for improvement. These include separate periodic inspection reports for the Poe Lock, MacArthur Lock, and the compensating works. The periodic inspection report for the hydropower facilities, dams, and dikes are covered under a separate report.

Operational Condition Assessments (OCAs), U.S. Army Corps of Engineers, Detroit District.
Operational condition assessments are periodic reviews of all major components and subcomponents at a project site. In an OCA, letter grades (A through F) are assigned to components through professional judgment and visual inspection which allow for components to be ranked. The December 2015 OCA report was used to support and help to inform the analysis in the recent *Soo Locks Major Rehabilitation Evaluation Report*. Major features assessed in this OCA included the Poe Lock, MacArthur Lock, and the Compensating works.

Final Interim Feasibility Report and Environmental Impact Statement Great Lakes Connecting Channels and Harbors, U.S. Army Corps of Engineers, Detroit District, March 1985, revised March 1986. This report documented the engineering and economic feasibility of constructing a replacement lock on the site of the Davis and Sabin Locks, as well as rehabilitating the Sabin and Davis Locks. The report concluded that both alternatives are economically justified. Since the replacement lock alternative had greater net benefits, the report recommended its construction.

Soo Replacement Lock Limited Reevaluation Report, U.S. Army Corps of Engineers, Detroit District, August 2005. This report addressed an updated design and the associated increase in

costs for a replacement lock. The report reevaluated the recommendations from previous studies and documented changes in the taconite industry and general economic conditions around the Great Lakes. Under assumptions about alternative transportation modes of commodities which have since proven to be inaccurate, the report concluded that the replacement lock alternative was not economically justified. In addition, no outages due to reliability concerns were projected for the study.

Section 2. Great Lakes Vessel Fleet and Historic Traffic

2.1 U.S. and Canadian Fleet

A total of 139 U.S. and Canadian dry bulk cargo carrying vessels were operating on the Great Lakes in 2012. The U.S. fleet contained 73 vessels, while the Canadian fleet numbered 66. These fleets are different in size and methods of unloading (**Table 2-1**).

Table 2-1 – U.S. and Canadian Fleet Composition (2012)

Major Bulk and Self Unloading Vessels in the Great Lakes Fleet (2012)											
Vessel Class	Vessel Class Definition (length)	United States				Canada				Total	Percentage of Total Fleet
		Self-Unloader	Self-Unloader (ITB)	Bulk Freighter	Subtotal	Self-Unloader	Self-Unloader (ITB)	Bulk Freighter	Subtotal		
I	Less than 400	-	1	7	8	6	-	3	9	17	12%
II	Between 400 and 499	-	-	5	5	-	-	3	3	8	6%
III	Between 500 and 549	-	1	2	3	-	-	-	-	3	2%
IV	Between 550 and 599	-	-	1	1	1	-	-	1	2	1%
V	Between 600 and 649	15	2	-	17	4	-	1	5	22	16%
VI	Between 650 and 699	7	-	-	7	3	1	-	4	11	8%
VII	Between 700 and 730	4	1	1	6	20	-	17	37	43	31%
VIII	Between 731 and 849	10	1	1	12	6	-	1	7	19	14%
IX	Between 850 and 949	1	-	-	1	-	-	-	-	1	1%
X	Greater than 950	12	1	-	13	-	-	-	-	13	9%
	Total Vessel Count:	49	7	17	73	40	1	25	66	139	100%
	Percentage of Total Fleet:	35.3%	5.0%	12.2%	52.5%	28.8%	0.7%	18.0%	47.5%		

**ITB = Integrated Tug Barge*

The figures below provide examples of Class X and Class VII vessels. **Figure 2-1** and **Figure 2-2** display the *Paul R. Tregurtha* (Class X vessel), a self-unloading bulk carrier, which is the longest vessel on the Great Lakes at 1,013' 06." **Figure 2-3** and **Figure 2-4** display the *American Mariner* (Class VII vessel), a self-unloading bulk freighter.

Figure 2-1—Paul R. Tregurtha (Class X) – Unloading Coal (Marquette, Michigan)

Figure 2-2—Paul R. Tregurtha (Class X) – Port Side Profile

Figure 2-3—American Mariner (Class VII) – Unloading Coal (River Rouge, Michigan)

Figure 2-4—American Mariner (Class VII) – Loading Grain (Duluth, Minnesota)

Self-unloading vessels have on board machinery that allows the vessel to be unloaded, which eliminates the need for shore side personnel and unloading equipment. Vessel holds funnel bulk cargo to a series of conveyors that move the commodity to a discharge conveyor boom located above deck. The boom conveyor (up to 250 feet in length) can be lifted and swung hydraulically left or right to position the cargo on the dock or into a receiving hopper as

specified by the customer. Virtually all U.S.-flag Lakers are equipped with bow and/or stern thrusters, devices which increase maneuverability and thus minimize the need for tugs.

2.2 Commodity Grouping

Commodity groupings used in this analysis are consistent with previous Soo Locks studies, and include five primary commodity groups: taconite, coal, grain, limestone, and "others." For any waterway analysis, data must be aggregated in a way that is manageable for analytic and modeling purposes. Commodities are typically grouped with consideration to the transportation equipment used, as well as industry characteristics that drive the projected tonnage demand into the future. Commodities at the Soo Locks complex serve select major industries that process significant tonnage volumes, such as the iron and steel industry, the coal-fired electric generating industry, and the export grain market for consumption. These industries typically use transportation equipment consistent with the commodity being transported. For instance, taconite will typically move in a self-unloader on the water, and an ore jenny on a rail line. Grain will move via seaway-capable, ocean-going vessels (or Salties) in order to serve countries overseas. The characteristics of these large-scale industries make the commodity groupings at the Soo Locks complex fairly concise.

It should be noted that 100% of the iron ore transported on the Great Lakes is in the form of taconite pellets, which have an iron ore content of approximately 65%. Although not 100% pure, the Waterborne Commerce Statistics Center (WCSC) still classifies 1 ton of taconite as 1 ton of iron ore. By definition, the taconite tonnage estimates displayed in **Section 2.3** represent total taconite tonnage, which is less than 100% pure iron ore.

Originally thought to be of little value, taconite deposits were considered waste in the days when high grade iron ore was mined. The iron content, magnetite, is only 20-30% compared to 50-60 % iron content in red ore. As high grade ore deposits became depleted, the Great Lakes mining industry became reliant on taconite.

The process for converting taconite deposits (20-30% ore) into taconite pellets (65% ore) is a very labor and capital intensive. Holes are drilled and taconite ore is blasted out of the ground. It is then transported to a processing plant in large trucks and placed into machines where it is crushed, mixed with water, and ground into a fine powder. Next it goes to separators where iron ore is extracted using strong magnets. This iron concentrate is rolled with clay inside rotating cylinders called agglomerators to develop taconite pellets, which are dried and baked to form the final product.

2.3 Historic Traffic

The historic tonnage for the Soo Locks complex, from 2007 thru 2017, is presented in **Table 2-2**. From 2007–2017, the Soo Locks complex accommodated more than 72.5 million tons on an average annual basis, including taconite (57 percent), coal (21 percent), grain (11 percent), aggregates (6 percent), and other (5 percent). The maximum tonnage during this period was 81.1M tons (2007), while the minimum tonnage was 52.8 million tons (2009); representing a range of 28.3M tons. In 2017, 89 percent of the total tonnage transiting the Soo Locks complex passed through the Poe Lock.

Table 2-2—Soo Locks Tonnage by Commodity Type and Year, 2007–2016

Soo Locks Tonnage by Commodity Type and Year						
Year	**Taconite**	**Coal**	**Grain**	**Aggregates**	**Other**	**Total Tonnage**
2007	43,453,000	19,757,000	9,832,000	4,079,000	3,973,000	81,094,000
2008	43,622,000	22,228,000	7,109,000	4,354,000	3,319,000	80,632,000
2009	21,766,000	17,363,000	7,772,000	3,084,000	2,782,000	52,767,000
2010	39,506,000	18,076,000	8,148,000	4,492,000	3,161,000	73,383,000
2011	46,059,000	13,485,000	7,891,000	4,515,000	2,880,000	74,830,000
2012	46,598,000	13,707,000	7,597,000	4,496,000	2,847,000	75,245,000
2013	42,533,000	14,580,000	6,570,000	4,761,000	3,373,000	71,817,000
2014	44,124,000	14,003,000	8,624,000	4,896,000	4,431,000	76,078,000
2015	38,605,000	13,270,000	8,812,000	4,563,000	4,343,000	69,593,000
2016	39,754,000	10,490,000	8,471,000	4,263,000	4,269,000	67,247,000
2017	47,709,500	10,266,733	8,890,157	4,703,283	3,762,195	75,331,868
Average:	**41,248,100**	**15,202,300**	**8,156,000**	**4,382,400**	**3,558,200**	**72,547,100**

*Data Source: USACE Waterborne Commerce Statistics Center (WCSC)

Figure 2-5 provides a graphical summary of total Soo Locks complex tonnage, by commodity type.

Figure 2-5—Soo Locks Complex Tonnage by Commodity Type and Year, 2007—2017

*Data Source: USACE Waterborne Commerce Statistics Center (WCSC)

Eleven integrated steel mills in the Great Lakes region are dependent upon domestic taconite production from mines in northern Minnesota and the Upper Peninsula of Michigan. Eight facilities are located in the United States, and three are in Canada. Ten of these mills rely on taconite shipments that transit the Soo Lock Complex, the exception being Essar Steel's Algoma facility which it is located on Lake Superior in Sault Ste. Marie, Ontario. The eight U.S. steel mills account for 40 percent of domestic steel production, and all of the advanced high strength steel used for the manufacture of products like automobiles and appliances. An unscheduled Poe Lock closure of any duration during the navigation season, could result in significant regional and National economic impacts due to the idling of steel plants.

Multiple coal-fired power plants are reliant on coal shipments which transit the Soo Locks; however, they are less dependent than steel mills because many power plants have the required infrastructure to receive shipments via rail.

Table 2-3 displays the maximum overall dimensions of vessels permitted to transit the Poe and MacArthur Locks, pursuant to 33 CFR 207.440; St. Mary's Falls Canal and Locks, Mich.; use, administration, and navigation. These dimensions apply when the Poe Lock is operational. However, if the Poe Lock is out of service for a period exceeding 24 hours, the District Engineer may allow vessels greater than 730 feet in length, but not exceeding 767 feet in length, to navigate the MacArthur Lock.

Table 2-3—Maximum Vessel Dimensions by Lock

Soo Locks - Physical Characteristics								
Lock	Lift	Depth (ft.)	Width (ft.)		Length (ft.)		Year Open	Status
			Actual	Usable	Actual	Usable		
Poe	22	32.0	110	105	1,200	1,100	1969	Operational
MacArthur[1]	22	31.0	80	75	800	730	1943	Operational
Davis	22	23.1	80	75	1,350	1,271	1914	Closed
Sabin	22	23.1	80	75	1,350	1,271	1919	Closed

[1]Per 33 CFR 207.440, if the Poe Lock is out of service more than 24 hours, the USACE Detroit District Engineer may allow vessels up to 767 ft. in length and 75 ft. in width with special handling procedures.

Table 2-4 provides a summary of Poe-restricted vessels by vessel class. The summary was developed using the Lock Performance Monitoring System (LPMS) data from 2012, 2013, 2014, and 2016. Data from 2015 was excluded from this summary since there was a significant unscheduled MacArthur Lock closure on July 29, 2015, due to a misalignment of the miter gates.

- 367 unique commercial vessels transited the Soo Locks complex, and 124 were Poe-restricted based on vessel dimensions. Of them, 113 were Class II vessels, which is high due to the various unique combinations of towboats/tugs and barges that can occur.

- Vessel Classes V–X represent the primary cargo movers; 211 vessels fell within this class range, and 118 were Poe-restricted (56 percent). Although the majority of vessel classes 1 through 7 meet the length requirements of the MacArthur Lock, some of them are unable to transit this lock due to width constraints. This includes two Class II barges with widths exceeding 76 feet that are commonly moved by three towboats. This results in six unique Poe-restricted vessel combinations in the Class II category.

- Poe-restricted vessels handled approximately 51.6M of the 72.6M tons that transited the Soo Locks complex, representing 71 percent of the total tonnage.

- There are 13 Class X vessels, known as "1,000-footers," which are the largest vessels that utilize the Great Lakes Navigation System. These vessels transported 30.8M tons of the 72.6M tons that transited the Soo Locks complex, representing 42 percent of all movements.

Table 2-4—Poe-Restricted Vessels

Vessel Class	Vessel Class Definition (length)	Unique Vessels[1]	Poe Restricted Vessels[2]	Poe Restricted Tons	Total Tons	Percentage of Poe Restricted Tons
I	1'-399'	17	0	-	45,174	0%
II	400'-499'	113	6	161,897	1,130,891	14%
III	500'-549'	15	0	-	421,600	0%
IV	550'-599'	11	0	-	92,209	0%
V	600'-649'	69	32	901,995	5,512,662	16%
VI	650'-699'	56	39	1,570,570	3,628,092	43%
VII	700'-730'	36	6	3,641,818	10,286,117	35%
VIII	731'-849'	34	25	11,016,129	17,158,341	64%
IX	850'-949'	3	3	3,481,608	3,481,608	100%
X	>950'	13	13	30,839,434	30,839,434	100%
TOTAL:		**367**	**124**	**51,613,450**	**72,596,128**	**71%**

Based on average LPMS Data from the years 2012, 2013, 2014, and 2016

[1] Accounts for complete tow length for unique vessel and barge combinations

[2] The definition of Poe-restricted is a length exceeding 767'or a width exceeding 76'

Based on an analysis of 2012-2016 seasonal traffic patterns provided by the Soo Area Office, Class 10 vessels were located below the Soo Locks for 77% of the average annual navigation season, and Class 7 vessels were located below the Soo Locks for 80% of the average annual navigation season. During a typical navigation season, a significant percentage of taconite vessels are located on the lower Great Lakes, so if a significant unscheduled outage occurred, it is reasonable to assume that sufficient vessel capacity would exist to transport taconite through the Port of Escanaba.

2.4 Shipment List

A shipment list is a table listing the tonnages and other information for any movement using the Soo Locks. For this Soo Lock study, a shipment list was created by combining several different data sources. While USACE Lock Performance Monitoring System (LPMS) was the main data set, the following data sources were used to fill in gaps: 1) USACE Waterborne Commerce Statistics domestic vessel data, 2) USACE Waterborne Commerce Statistics foreign vessel data (which comprised data from the Port Import Export Reporting Service, the U.S. Bureau of the Census, and the U.S. Customs and Border Protection), 3) U.S. Coast Guard data, and 4) Boat Nerd.

The LPMS data was provided by The U.S. Army Corps of Engineers Detroit District Soo Area Office (SAO) for 2012, 2013, 2014, and 2016. The LPMS data for 2015 because it contained a lock closure event. By excluding 2015 data, the team ensured that the shipment list represents normal shipping pattern and also that lock reliability was not captured in the shipment data since lock reliability is modeled within the Soo-Reliability Economic Model (Soo-REM). The LPMS data was evaluated by the PCXIN-RED and SAO for any data discrepancies. The team discovered that vessel identification information (e.g. U.S. Coast Guard numbers and International Maritime Organization numbers) and vessel dimension information in the data set were not entirely reliable. To solve the issue, the PCXIN-RED and the team at USACE Buffalo District (LRB) developed ancillary data sets containing vessel identification numbers and dimensions.

To reconcile the data, the team used code in Standard Query Language (SQL) Server Management Studio 2012, which is software for database management that easily allows multiple data sets to be joined and reconciled against each other. Using the same software, the team also identified vessel classes, determined what vessels are restricted to the Poe Lock, what vessels are restricted under special MacArthur lock operations, and the origin country of the vessel.

Table 2-5—Soo Locks Complex Shipment List Data Fields and Sources

Field	Source
CHMBR_NO	LPMS
ORIGIN	LPMS
DESTINATION	LPMS
ARRIVAL_DATE	LPMS
SOL_DATE	LPMS
END_OF_LOCKAGE	LPMS
VESSEL_FUNCTION_TYPE	LPMS
OPS_ID	LPMS
DIRECTION	LPMS
NUM_LIGHT_BOATS	LPMS
NUM_REC_BOATS	LPMS
VESSEL_NAME	LPMS
VESSEL_FLAG	LPMS
COMM_CODE	LPMS
COMMODITY_TONS	LPMS
BARGE_ID	LPMS
Vessel_Length_FT	Developed
Vessel_Breadth_FT	Developed
Barge_Length_FT	Developed
Barge_Breadth_FT	Developed
Vessel_Class	Developed
Poe_Restricted	Developed
730ft_Restricted	Developed
Country	Developed

The shipment list serves as the analysis baseline for determining arrival patterns, lockage times, historical composition of vessels by class and commodity, and other important facets of the vessel fleet. It is used in the ARENA® model simulation, used to help develop water transportation costs, and used by the Soo-REM to help determine vessel accident frequency for a given traffic forecast year.

Section 3. Commodity Forecasts

As part of this study, analysts developed commodity forecasts (**attachment 1**). Those commodity forecasts are shown in **Figure 3-1** in terms of total tonnage. These forecasts were necessary for estimating cargo flows moved by vessels utilizing the locks. The study team analyzed and forecasted five primary commodity groups—taconite, coal, grain, aggregates, and 'other'—and forecasted over a 60-year period of analysis (2021–2080). To better understand and account for forecast uncertainty, three future scenarios were developed for each of the five commodity groups.

The future scenarios are low, medium, and high tonnages. These future scenarios were developed by using tonnage reports from the Soo Locks complex, data from other government

agencies, and qualitative input from stakeholders and industry experts. Future projections vary between commodities given their end uses and the factors that affect their demand. The high and low scenarios are developed based on reasonable assumptions of the upper and lower bounds of tonnage expectations, respectively. The medium scenario is developed around the best available information to attempt to identify realistic future tonnage expectations.

Taconite represents over half of the total tonnage transported through the Soo Locks complex. This commodity is sensitive to economic shocks since it is used as an intermediate input for durable products such as automobiles and appliances. Taconite tonnage fluctuates from year to year depending on the business cycle. Over the last 15 years, Soo Locks complex taconite tonnage has been range bound, between 38 and 46 million short tons annually. These numbers are restricted for the economic recession in 2008 and are not industry driven. Specifically, the demand for taconite is driven by the demand for steel produced in integrated steel mills. Both steel imports and steel manufactured by other less iron-ore-intensive production methods are factors impacting historical and projected tonnage levels.

Coal is the second largest commodity group, in terms of tonnage, evaluated for this study. Two types of coal are moved through the locks—Powder River Basin (PRB) and Appalachian—which have different end uses. Tonnage trends differ depending on the PRB destination. Over the last decade, tonnage for Canadian-bound PRB has declined significantly as a result of Ontario's power initiative to eliminate coal-fired power generation. This same downward trend has been underway in the U.S., with utilities also phasing out old, coal-fired power generation plants. In contrast, most of Appalachian coal shipped through the Soo Locks complex is utilized at a steel facility located just upstream of the locks. Given the different trends for coal shipped through the Soo Locks complex, separate sub-forecasts were developed for PRB coal and Appalachian coal.

Grain, grown in the U.S. heartland and on the Canadian prairies, is transported by train to Lake Superior ports for export to European and Middle Eastern markets. Most of this grain is loaded onto vessels in Thunder Bay, Ontario; and Duluth, MN, before being transferred to larger ocean-going vessels at Canadian ports located at the mouth of the St. Lawrence River. It should be noted grain exports vary significantly from year-to-year as a result of currency fluctuations, freight rates, and the global supply of grain.

Limestone is one of the few commodities that moves through the Soo Locks complex in a westerly (or up-bound) direction. Through interviews with Lake Carriers Association representatives, it was identified that nearly two-thirds of aggregate tonnage is utilized for manufacturing taconite pellets; 15 percent of this tonnage is attributed to flue gas

desulfurization at coal-fired facilities, and the remaining 20 percent of tonnage is employed for a variety of uses. This leaves limestone tonnage susceptible to other industry headwinds as well as positive economic drivers.

The remaining commodities, such as salt, animal feeds, and fertilizers, were aggregated into one commodity group for simplicity. This mix of bulk commodities represent approximately 5 percent of the total tonnage transported through the Soo Locks complex.

Figure 3-1—Economics Rehabilitation Alternatives

Three future tonnage projections range from the low of 50 million short tons long term, to a high of 105-110 million short tons long term. The medium scenario falls in the 70-75 million short ton range, with stabilization identified in 2033 due to flat expectations for taconite and declining coal tonnage being offset primarily by higher grain tonnage forecasts.

Section 4. Soo Locks Complex Service Disruption Risk

4.1 Accident Risk

The analysis of risk of accidents for this study effort was based on the 1994 report *Poe Lock System Risk Analysis* by Planning and Management Consultants for the Institute for Water Resources (**attachment 10**). The intent of the report was to analyze the probabilities of system accidents that result in closures of the Poe Lock. This report had been the basis for

computation of accident risk in the previous 2014 Partial Benefit Analysis (PBA) as well as the 2005 Limited Rehabilitation Report, and the same general approach has been incorporated into Soo-REM for this analysis.

[redacted]

[redacted]

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

4.1.1 Per-Transit Accident Probabilities

To evaluate future accident risk, probabilities were estimated at the per-vessel-transit level. Event-tree probabilities described above were validated based on the respective observed frequencies [redacted] and ultimately adjusted so that computed final accident probabilities matched observed frequency. [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

4.1.2 Probabilities of Severe Closure

[redacted]

[redacted]

[redacted]

4.1.3 Updates to 1994 Analysis

For this analysis, several modifications were made to these estimated probabilities to incorporate more recent data. First, data from the LPMS database on both recorded cargo vessel transits and recorded accidents by type for the period 2012–2015 was appended to the dataset used in the 1994 analysis. This additional LPMS data allows a slightly more refined estimate of per-vessel-transit risk. For this additional period, additional lockages occurred at the project, with no additional recorded accidents at the respective chamber/chambers measured in the previous analysis (four additional gate impacts were recorded in LPMS; however, none occurred at the Poe Lock), leading to slightly reduced per-transit probabilities of accident occurrence. [redacted]

[redacted]

[redacted]

Finally, the computed total probabilities of severe events (P(Accident) * P(Severe)) were adjusted using the same Bayesian updating process, given the 50 years of observed history in which none of these analyzed severe events have occurred. Essentially, with the probabilities as estimated in the 1994 analysis, the probability given historic traffic of one or more accident events occurring is 4.54 percent per annum. Evaluated as a binomial process, the probability of

one or more severe accidents to have occurred in the 50 years since the opening of the current Poe lock chamber in 1968 ($1-(1-0.0454)^{50}$) is greater than 90 percent. Conversely this means the observed history of zero severe accident events in this period is less than 10 percent likely given these estimates of severe accident probability. The purpose of this Bayesian updating calculation is to update our prior estimate of these probabilities based on the observation of no observed events in the past 50 years.

[redacted]

4.1.4 Accident Service Disruption Durations

[redacted]

[redacted]

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

[redacted]

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

[redacted]

Table 4-4—Lockages-Per-Ton by Commodity and Vessel Type

Commodity Type	Poe Restricted Lockages (Poe) per Ton	Non-Poe Restricted Poe Lockages per Ton	MacArthur Lockages per Ton
Taconite	0.00002081	0.00003828	0.00003868
Coal	0.00002056	0.00005157	0.00005544
Aggregates	0.00003385	0.00004207	0.00004842
Grain	0.00004169	0.00004479	0.00004807
Other	0.00005472	0.00008988	0.00008216

This computation results in an annual number of vessel passages, dependent on forecast year. To compute a given simulation year's probability of an accident, a binomial distribution using the computed vessel passages as the number of trials was used to determine the probability of one or more accidents occurring. [redacted]

A limitation of the Soo-REM implementation of this risk is that only one accident of any type is possible in a given year. Since Soo-REM is an annual simulation, intended to represent annual risk to the project rather than per-vessel passage risk, this simplification was necessary. Given that under the medium traffic forecast scenario, however, the computed probability of more than one vessel accident of any type in a single simulation year is less than one tenth of a percent (without accounting for the decreased risk of subsequent accidents since the first accident's service disruption would reduce the availability of the lock and thus the total remaining accommodated vessel passages in that year), this simplification will not substantially impact the model's accounting for vessel accident risk. If a [redacted] accident is sampled to occur in a simulation year, service disruption impacts are randomly sampled from a beta distribution defined by the parameters provided in the *Poe Lock System Risk Analysis* report (shown in **Table 4-2** and **Table 4-3** above).

4.2 Component Reliability Risk

[redacted] These service disruptions can take the form of closures of either the Poe or MacArthur Locks for varying durations, simultaneous closures of both locks leading to a total project closure, or increased vessel transit times.

This component level risk can be defined as the monetized consequence of these service disruption events, modified by the probability of component unsatisfactory performance resulting in these disruptions. [redacted]

[redacted]

[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

Each of the [redacted] components has a specific rate of failure, and each service disruption (lock closure or lock slowdown) has a different likelihood of occurring. Rate of failure is defined by a hazard function, and the likelihood of experiencing any given service disruptions is defined by an event-tree, where each branch represents a different level of severity. The combination of these two types of data (hazard functions and event-trees) produce a distribution of closure durations and slowdowns. As an example, **Figure 4-1** displays the distribution of the worst failure that is likely to be experienced at the Poe Lock over the planning period, across 10,000 model iterations. A full navigation season closure is extremely unlikely to occur, in the planning period. The most-likely worst-case closure of the Poe lock that occurs over the planning period is approximately 50 days, which is an expected value. **Section 9.1** describes this figure and the calculations behind it in greater detail.

Figure 4-1 - Maximum Poe Lock Closure Duration, Histogram, Baseline Condition

The engineering team did not identify the reliability of the remaining [redacted] components as likely to cause direct service disruption events. As such, no benefits relating to these components would be realized from increased reliability or redundancy in the future with project condition.

[redacted]

[redacted]

[redacted]
[redacted]
[redacted]
[redacted]
[redacted]
[redacted]
[redacted]
[redacted]
[redacted]
[redacted]
[redacted]

[redacted] reliability of the [redacted] components identified to cause direct service disruption events is modeled by a combination of hazard functions. These define a given component's chance of any failure state in a given year. Event-trees define the array of that component's possible failure states with associated conditional probabilities. The event-trees also define the consequences of each of these failure states in terms of the repair costs, service disruption description (type and duration), and a post-repair reliability adjustment. Through the economic modeling of this engineering reliability data (hazard functions and event-trees) life-cycle repair costs and transportation impacts can be estimated. This is done for both the future without-project condition and in the future with project condition. The differences between the two represent impacts avoided (benefits) for the investment analyzed.

The hazard functions for each component define failure probabilities as a function of component age. As components age throughout the analysis period, they become less reliable and the hazard rate increases. When a component is repaired following a failure event, the component age and associated future failure probabilities are altered accordingly. Likewise, as

a component is replaced, either as part of an investment strategy or following a catastrophic failure event, the component age is reset and reliability is assumed 100 percent for the remainder of the analysis period. The severity and associated probabilities of component failures, as well impacts associated with each in the form of service disruption types and durations, repair costs, and the aforementioned effects of repairs on future component reliability, are captured in component specific event-trees. [redacted]

4.3 Risk Characterization

The FWOPC risk of closure at the Soo Locks Complex prompting consideration of constructing a new Poe sized lock can be characterized as a relatively low likelihood of events with a very high consequence in terms of economic impacts. As many types of closure are evaluated, this broad characterization however misses some nuance and does not fully describe risk at the project. For example a relatively high likelihood exists, in particular early in the planning horizon, of a closure of short duration, primarily resulting from Poe and MacArthur component failures. Risk also changes significantly over the planning horizon, as component risk (risk of components failing leading to chamber or project closures) reduces incrementally as components are replaced as part of scheduled OMRR&R work, or as components with a high annual probability of failure are replaced following these failures. [redacted]

Risk is a function of both probability and consequence, and consequence in the context of this analysis is largely derived from duration of project closures. It should be noted however that consequence does not scale linearly with duration. **Table 4-7**, **Table 4-8**, and **Table 4-9** illustrate the probability of closures at the Poe and MacArthur locks, as well as coincident closures of both, by duration.

Table 4-7 – Poe Lock - Frequency of Closure Exceeding in Simulation Year

Closure Duration (days)	Frequency of Closure Exceeding, by Simulation Year				
	2020	2024[1]	2027	2043[2]	2050[3]
0	24.24%	18.23%	11.61%	3.48%	3.99%
10	2.06%	6.96%	6.71%	2.54%	2.91%
20	1.28%	5.88%	5.60%	1.90%	2.23%
30	1.02%	3.31%	3.07%	1.13%	1.19%
40	0.90%	0.97%	1.06%	0.78%	0.91%
50[4]	0.77%	0.76%	0.88%	0.67%	0.75%
60	0.67%	0.64%	0.78%	0.55%	0.66%
70	0.57%	0.55%	0.63%	0.44%	0.54%
80	0.48%	0.46%	0.52%	0.40%	0.49%
90	0.42%	0.37%	0.43%	0.34%	0.38%
100	0.33%	0.32%	0.34%	0.26%	0.31%
150	0.09%	0.12%	0.08%	0.03%	0.08%
200	0.01%	0.02%	0.01%	0.00%	0.00%
300	0.00%	0.00%	0.00%	0.00%	0.00%

[redacted]

Table 4-8- MacArthur Lock - Frequency of Closure Exceeding in Simulation Year

Closure Duration (days)	Frequency of Closure Exceeding, by Simulation Year			
	2020	2025[5]	2027	2050
0	20.20%	11.97%	0.03%	0.17%
10	0.05%	0.06%	0.02%	0.17%
20	0.01%	0.01%	0.00%	0.00%
30	0.01%	0.00%	0.00%	0.00%
40	0.01%	0.00%	0.00%	0.00%
50	0.01%	0.00%	0.00%	0.00%
60	0.00%	0.00%	0.00%	0.00%
70	0.00%	0.00%	0.00%	0.00%
80	0.00%	0.00%	0.00%	0.00%
90	0.00%	0.00%	0.00%	0.00%
100	0.00%	0.00%	0.00%	0.00%
150	0.00%	0.00%	0.00%	0.00%
200	0.00%	0.00%	0.00%	0.00%
300	0.00%	0.00%	0.00%	0.00%

[5] [redacted]

Table 4-9 – Poe and MacArthur Lock - Frequency of Closure Exceeding in Simulation Year

Closure Duration (days)	Frequency of Closure Exceeding, by Simulation Year		
	2020	2027	2050
0	0.76%	0.64%	0.84%
10	0.44%	0.40%	0.33%
20	0.31%	0.26%	0.21%
30	0.15%	0.11%	0.13%
40	0.04%	0.06%	0.05%
50	0.01%	0.04%	0.03%
60	0.01%	0.01%	0.02%
70	0.00%	0.01%	0.00%
80	0.00%	0.00%	0.00%
90	0.00%	0.00%	0.00%
100	0.00%	0.00%	0.00%
150	0.00%	0.00%	0.00%
200	0.00%	0.00%	0.00%
300	0.00%	0.00%	0.00%

Risk at the project is overwhelmingly driven by risk at the Poe lock, resulting from component failure and accident risk. The figure below illustrates the changing risk at Poe for closures of various durations. Durations and year inflection points where chosen, as in the tables above, to correspond to planned future OMRR&R actions and to inflection points in the duration/impact cost curve. The blue line represents closures of any duration (greater than zero days). The annual probability of a closure of any duration begins the planning horizon at near 25%, driven primarily by [redacted], which has a greater than 97% chance of failure in year 2020 (not all failures result in closures). As the simulation progresses, the probability of this and similar high probability/low consequence failures diminishes as components are replaced in scheduled replacement actions or following unscheduled repair work resulting from failure events. The total risk at the Soo Locks Complex however is overwhelmingly driven by very low probability/high consequence events, as stated previously, which are in turn driven primarily by accident risk. [redacted] These accidents can result in closures of varying durations, however most are significant in duration. As illustrated in **Figure 4-2**, this risk remains mostly unchanged over the planning horizon.

Figure 4-2- Poe Lock Closure Frequency and Duration, by Year

Section 5. Planning Models

EC 1105-2-412 (*Assuring Quality of Planning Models*), dated 31 March 2011, defines planning models as*:*

> …any models and analytical tools that planners use to define water resources management problems and opportunities, to formulate potential alternatives to address the problems and take advantage of the opportunities, to evaluate potential effects of alternatives and to support decision-making.
>
> These include but are not limited to models used to define the future without-project condition, models used for plan formulation, models used to compute economic benefits, models used to assess the environmental impacts of alternatives, conceptual models that represent relationships among natural forces and factors, and human activities (intended or not) that are believed to impact, influence, or lead to a target condition (mostly ecological models) and any other models essential to the planning process.

Four planning models were developed for the New Soo Lock Economic Validation Study economic analysis:

1. Soo-REM
2. ARENA® Vessel Delay Model
3. Annual Operational Contribution GDP Impact Model
4. Vehicle Manufacturing GDP Impact Model

Technical experts at USACE reviewed these models and approved them for single use in accordance with EC 1105-2-412. All models met standards for technical quality, system quality, and usability.

5.1 General Purpose of an Inland Navigation Economic Model

For a navigation project investment, NED benefits are composed primarily of the reductions in transportation costs attributable to the improved waterway system. These reductions are achieved through increased efficiency of existing waterway movements, shifts of waterway and overland traffic to more efficient modes and/or routes, and/or shifts to more efficient origin-destination combinations. Further benefits can accrue from induced (new output/production) traffic that is transported only because of the lower transportation cost derived from an improved project. Benefits can also come from creating or enhancing the potential for other productive uses of the waterway, such as the generation of hydropower. National defense benefits can also be realized from regional and National growth, and from diversity in transportation modes. In many situations, lower emissions can be achieved by transportation of goods on the waterway.

In the case of this validation study, NED benefits are derived through avoiding increases in transportation costs from unscheduled service disruptions. Regardless, the conceptual basis for the "… basic economic benefit of a navigation project is the reduction in the value of resources required to transport commodities"[6].

Traditionally, this basic economic benefit for ship/barge transportation is calculated as the difference in costs between waterway shipment and the long-run least-costly all-overland alternative routing. This benefit estimation is referred to as the waterway transportation rate savings. The waterway transportation rate savings covers the movement of a commodity from ultimate origin to ultimate destination including costs arising from loading, unloading, trans-loading, demurrage, and other activities.

The primary benefit for federal investment in commercially navigable waterways (benefits with a plan as opposed to benefits without a plan) ends up as a transportation cost reduction. In the case of the Sault Ste. Marie project, however, the issue is not a long-run capacity problem but

[6] Planning Guidance Notebook, ER 1105-2-100, U.S. Army Corps of Engineers, 22 April 2000, page 6-55.

rather a short-run condition problem causing unscheduled service disruptions where taconite cannot be delivered overland to water-served steel mills, causing severe economic consequences when stockpiles are exhausted.

5.2 Gross Domestic Product/Regional Economic Development Impact Models

Two separate GDP spreadsheet models were developed in support of this study. A*nnual Operational Contributions to Economy* is an assessment of the economic contribution of the operations of the Soo Locks complex based on a standard economic multiplier analysis. This entails all the activities and associated economics of those activities that can be directly attributed to the Soo Locks complex as it relates to shipping commodities through the Great Lakes Navigation System. As such, this framework is broken out into multiple parts: 1) the economic contribution of Soo Locks complex operations, 2) the economic contribution of ports and shippers shipping through the Soo Locks complex, and 3) the economic contribution of commodity production being shipped through the Soo Locks complex.

The second framework, *Detailed Assessment of Industry Dependence of the Soo Locks: A View from the Vehicle Manufacturing Sector*, recognizes that the Soo Locks complex is a means to an economic-related end. By this, the operations of the Soo Locks complex facilitates production value chains that would likely be hindered should the Soo Locks complex experience an unanticipated shut-down. Because of the wide-breadth of commodities and goods flowing through the Soo Locks and the even wider breadth of value chains for which these flows contribute, the frame of assessment is limited to a single commodity value chain, from taconite raw materials to final goods for consumption.

Attachment 5 provides the details of these two analyses, which are also summarized below.

5.2.1 Annual Operational Contributions to the Economy

This GDP/regional economic development evaluation provides an estimate of the economic contributions of the Soo Locks to the Great Lakes (GL) regional economy, which is made up of eight states bordering the Great Lakes.[7] More specifically, this analysis provides estimates of the level of economic activities facilitated by the Soo Locks that include 1) shipping activities of Great Lakes port regions that ship commodities through the Soo Locks, 2) operations and maintenance of the existing lock system, and 3) production of commodities shipped through the Soo Locks. It is important to recognize that this is an economic contribution analysis, which estimates the *existing* economic activity (output, labor income, value added, and employment) associated with an *already occurring* economic stimulus. As such, the estimates differ from those that would underlie a regional economic impact analyses, where impact estimates are

[7] States include: Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, Wisconsin

based on the expected *change in* economic activity associated with *new* economic stimulus to an economy.

Impact summaries for each analysis are included in **attachment 5**, and aggregate impacts are included in **Table 5-1** below. This analysis shows that the Soo Locks are directly or indirectly tied to $46.4 billion in output for the eight-state Great Lakes region and $58.2 billion for the Nation. This is associated with 142,000 full- and part-time jobs in the Great Lakes region and 237,000 for the Nation, with wage and salary disbursements of $10.1 and $15.1 billion, respectively. From a social accounting framework, the Soo Locks is associated with just over $17 billion in Gross Regional Product (GRP) in the Great Lakes region and about $25.5 billion in Gross Domestic Product for the Nation. GRP is defined as gross industry output (i.e., sales or gross revenues) less the cost of intermediate inputs (i.e., the consumption of goods and services purchased from other US industries or imported. The difference between GRP and GDP is geographic; GRP quantifies gross industry output for a subset of the National economy.

Table 5-1—Regional and National Total Economic Contribution of the Soo Locks

	Contribution Region	
Contribution	**8 Great Lakes States**	**Nation**
Output	$46,355.9 m	$58,189.1 m
Jobs	142,366	237,080
Labor Income	$10,103.9 m	$15,082.2 m
GRP	$17,026.4 m	$25,544.3 m

5.2.2 Vehicle Manufacturing

This regional economic development evaluation provides an estimate of the economic contributions of the Soo Locks to the National economy, as measured by the contribution of taconite shipped through the Soo Locks for use in the vehicle and vehicle parts manufacturing and distribution sectors. This is a value chain assessment of taconite from mining through transformation into steel, including contributions toward vehicle and vehicle parts value-added, and final distribution for retail purchases, which is traced using the table of National transactions underlying the Regional Economic System (RECONS) model. The standard RECONS model is also used to estimate economy-wide impacts as they relate to secondary industry transactions and purchases through changes in income that give rise to standard economic impact multipliers.

Table 5-2 displays net economic impact estimates for this analysis. The total impact of an unscheduled 12-month disruption in the Soo Locks would result in a temporary reduction of

employment of about 8.5 million U.S. jobs with total labor income declining by $451.1 billion. Gross domestic product would likely see a temporary decline of about $666.5 billion while economic activity, measured by output (gross sales) would decline by about $1.1 trillion. Much of these results depend on how firms would respond to an expected temporary disruption, in that firms may choose to under employ their workforce, lest risk losing long-term employees. They may also make temporary transitions to other markets, further mitigating the overall economic effects of an unexpected lock closure.

Table 5-2—Net Economic Impacts by Value Chain Leg

Value Chain Leg	Employment		Labor Income ($2016 Million)	
	Direct	Total	Direct	Total
Mining	–15,000	–67,000	–1,791	–4,869
Iron and Steel Production	–24,000	–217,000	–2,261	–13,870
Motor Vehicle Production	–573,000	–3,750,000	–51,656	–244,918
Motor Vehicle Sales	–3,246,000	–4,436,000	–157,556	–187,439
Aggregate Impact	**–3,858,000**	**–8,470,000**	**–213,264**	**–451,095**
Value Chain Leg	**Gross Domestic Product ($2016 Million)**		**Output (Sales) ($2016 Million)**	
	Direct	**Total**	**Direct**	**Total**
Mining	–4,113	–9,596	–7,264	–17,329
Iron and Steel Production	–1,807	–21,872	–21,009	–58,560
Motor Vehicle Production	–74,746	–391,740	–365,144	–1,023,678
Motor Vehicle Sales	–156,531	–243,248	–11,890	–29,404
Aggregate Impact	**–237,197**	**–666,456**	**–405,307**	**–1,128,971**

5.3 ARENA® Vessel Simulation Model

The Baird, Inc. ARENA® Delay Model is a vessel level simulation model of the Soo Locks complex. Developed as part of the CELRE 2014 PBA study, the simulation tracks vessel arrivals by vessel type for processing through the project's lock chambers. With a service disruption (e.g., closure) of a chamber and/or addition of a second Poe-sized lock chamber, the simulation queues and processes vessels. It tabulates vessel delay time, queued Poe-restricted vessel hours, and annual tonnage throughput. Comparison of the without-project and the with-project conditions are used to estimate diverted tonnage, vessel delay costs, and layup vessel costs. In general, it analyses the following:

- Random vessel arrivals by vessel type based on historical vessel arrival data
- Scaling of random vessel arrivals to achieve the USACE specified throughput for each forecasted traffic scenario

- Stoppages of vessel transits in the St. Marys River due to weather events such as fog, based on historical data

- Stoppages of the locks due to various operational items, based on historical data

- Tug assistance, based on historical data

- Lock assignment for each vessel, based on the lock assignment rules understood to be in place at the Soo Locks complex

- Locking procedures, such as entries, fill/discharge, exit, and turnbacks, based on the procedures understood to be in place at the Soo Locks complex

- Lock processing durations (entry, fill/discharge, exit), based on historical data

- Tracking vessels' origin to destination during certain disruption scenarios utilizing turn time distributions, developed from historical data

5.3.1 Model Purpose

The ARENA® simulation was run for a series of tonnage levels and service disruption scenarios. **Table 5-3** summarizes the number of disruption scenarios developed by the model, with each scenario representing a different closure duration or increase in lock processing time. Each disruption scenario was modeled assuming ten different tonnage levels spanning from 10M tons per annum (tpa) to 110M tpa to cover the anticipated forecasted tonnage levels over the planning horizon. This resulted in a total of 1,820 combined scenarios.

Table 5-3—Disruption Scenarios

Disruption Scenarios					
Lock	**Without-project 730' MacArthur Limit[1]**	**Without-project 767' MacArthur Limit**	**With Project 730' MacArthur Limit[2]**	**With Project 767' MacArthur Limit**	**Total**
Poe Closure	16	16	16	16	64
Poe Processing Increase	9	9	9	9	36
MacArthur Closure	16	16	0	0	32
MacArthur Processing Increase	10	10	0	0	20
Combined Closures	15	15	0	0	30
				Grand Total Disruption Scenarios:	**182**

[1] The average transit duration for commercial vessels during a single season, excluding idled time

[2] The total idled hours for domestic vessels that are Poe-restricted during a single season

See **attachment 7** for a more comprehensive summary of the ARENA® model.

5.3.2 Model Output

Given the number of various tonnage volumes by year and by forecast scenario, given the probabilistic nature and number of service disruption types, and given multiple service disruption events can occur and/or overlap in a given year, simulations are made and summarized for 1,820 different service disruption types and tonnage levels. In effect, these produce a series of service disruption tonnage-performance curves (e.g., Without-Project Condition throughput tonnage at various tonnage levels given a 2-month closure of the Poe Lock). The Soo-REM (specifically the SOO-AffectedTons.xlsx workbook) then uses these performance curves to interpolate and estimate the performance metric for the given traffic level and service disruption sequence.

5.4 Soo Reliability Economic Model

The Soo-REM model uses Monte Carlo-style simulation to determine the number and type of service disruptions associated with component failures or accidents at the project which are estimated to occur over the planning period. It determines the tonnage throughput expected to be impacted by these service disruptions, as well as the associated expected increase in transportation costs relative to the cost of moving through the project.

Monte Carlo simulation uses repeated random sampling within user-defined distributions to determine a range of potential outcomes for the analysis, accounting for uncertainty due to

knowledge uncertainty and natural variability regarding both the existing and future conditions. The Soo-REM model uses a sampling technique similar to Monte Carlo known as Latin Hypercube. The Latin Hypercube sampling technique does not use completely random sampling, but rather divides input distributions into N equivalent probability partitions, where N is the number of performed iterations, and samples randomly (uncorrelated) from these partitions. This approach to sampling is intended to produce the same general result as Monte Carlo random sampling, but by ensuring a more even spread of sampled input values to do so in fewer iterations.

These calculations are performed for the with-project and without-project conditions of this validation study. Incremental transportation costs and other impacts are essentially a function of component reality and associate service disruption impacts, traffic levels at the project, tonnage that cannot be delivered via water routing through the project due to service disruptions, and finally the incremental cost and capacity of alternate modes. Output distributions are presented and discussed in **Section 9.1**.

Benefits result from reductions in these incremental transportation costs and other impacts through reduction in either the incidence or duration of service disruptions by increasing component reliability. This reduction in transportation costs represent NED benefits to the Nation.

5.4.1 Model Layout

The model comprises a series of linked EXCEL workbooks which handle separate components of the analysis. Below, the workbooks are categorized into the 1) Input, 2) Calculations/Model, and 3) Outputs/Summary workbooks. The suite of workbooks include:

- Inputs
    - SOO-RatesAndModalCapacity.xlsx
    - SOO-TrafficForecasts.xlsx
    - Soo-Costs.xls
- Calculations/Model (Soo-REM)
    - SOO-ServiceDisruptionSim.xlsm
    - SOO-AffectedTons.xlsx
    - SOO-AltCostImpacts.xlsx
- Outputs/Summary
    - Soo-REM-SimulationResults-Forecast-Low.xlsx
    - Soo-REM-SimulationResults-Forecast-Medium.xlsx
    - Soo-REM-SimulationResults-Forecast-High.xlsx

- Soo-CostBenefit_Forecast-Low.xlsx
- Soo-CostBenefit_Forecast-Medium.xlsx
- Soo-CostBenefit_Forecast-High.xlsx
- Soo-CostBenefit_Forecast-Compare.xlsx

While all workbooks were required to complete the analyses required for this report, the "model" is contained in the three workbooks itemized under the Calculations/Model subcategory. While only one workbook actually simulates, the other two serve as separable calculation steps which were easier to compartmentalize rather than include in a single large workbook model. When the model is run (simulated), all three workbooks must be open. The Calculations/Model workbooks are

SOO-ServiceDisruptionSim.xlsm—The SOO-ServiceDisruptionSim workbook is the first in sequence and performs the Monte Carlo style analysis. This workbook uses the EXCEL add-in @Risk (v7.5), developed by Palisade Corporation, to perform simulations to estimate when the project may experience service disruptions over a user-defined study period based on individual component reliability. If one or more service disruptions occur within a simulation year for a given model iteration, the model determines the total days of service disruption by category. During a given iteration of the model this is done for each simulation year, and this information is exported to the SOO-AffectedTons workbook.

SOO-AffectedTons.xlsx—The SOO-AffectedTons workbook determines the total tonnage affected by this series of service disruption events in each simulation year (tonnage unable to be delivered by water routing given the service disruption and vessel capacity constraints), as well as vessel delay and layup costs resulting from service disruption events. This workbook then exports the series of annual affected tons for the study period to the SOO-AltCostImpacts workbook.

SOO-AltCostImpacts.xlsx—The SOO-AltCostImpacts workbook uses rate and capacity data from SOO-RatesAndModalCapacity and traffic forecast data from SOO-TrafficForecasts to compute the incremental increase in transportation cost for tons affected in each simulation year, relative to a full operations (no service disruptions) scenario. As such, rates in SOO-AffectedTons do not represent the total transportation costs, but rather the difference in rate between alternate modes and full operations water routing. The results of these calculations are then exported back into SOO-ComponentReliability, along with vessel-related costs (delay and layup) from SOO-AffectedTons.

Here, it is aggregated into total impact costs of sampled service disruption events by study year. This is done for each model iteration, and all results are stored as output distributions for each study year. A depiction of the inputs and model flow for Soo-REM is shown in **Figure 5-1**.

Figure 5-1—Soo-REM Framework

The model calculation components, including the service disruption simulation performed in SOO-ServiceDisruptionSim.xlsm, the affected tonnage and vessel-impact calculation in SOO-AffectedTons.xlsx, and the alternate mode cost and unmet demand calculations performed in SOO-AltCostImpacts.xlsx, are explained in-depth in **attachment 9.**

Section 6. Project Alternatives Defined

Since this report is a validation study, a reformulation of alternatives is not required. Therefore, the analysis compares the without-project condition (continued operation and maintenance of the Poe Lock and MacArthur Lock) with the with-project condition (construction of a new Poe-sized lock and continued maintenance of the existing Poe lock).

6.1 Without-project Condition

The without-project condition entails the continued operation and maintenance of the Poe and MacArthur Locks and associated support features. Engineering and economic analyses focused on the potential impacts to navigation associated with the continued aging and degradation of critical lock components. They include several facility features (such as the facility steam plant) that support lock operations. Nineteen major components have general plans for repairs/replacement based on information related to component reliability and risk of failure due to age, fatigue, etc. This future maintenance plan, assumed in both the without-project and with-project conditions, reflects the historic trend in O&M funding for the project. Minor variations exist in the timing of individual scheduled component replacements between the without-project and with-project condition.

6.2 With Project Condition (New Lock)

The future with project condition is the most likely scenario associated with construction of a redundant, Poe-sized lock and prioritized major maintenance on the existing Poe Lock. In this scenario, a new lock would be built by 2027, and the O&M program would continue routine and prioritized major maintenance on the Poe Lock; this would be to maintain the navigation mission and meet the congressional intent of redundancy. [redacted]

There are also operational benefits to maintaining an operational lock in both canals. The MacArthur Lock would be placed in a standby but ready status once the new lock is completed. However, it would be briefly placed back into service as needed to allow for major maintenance and/or replacement of certain Poe Lock components. In anticipation of the idle status of the MacArthur Lock, O&M expenditures for major maintenance on the MacArthur Lock would be held to a minimum. It is anticipated that by 2041, the MacArthur Lock would be placed into permanent "caretaker" status, with minimal usage and minimal O&M to prevent it from decaying into ruin.

It should be noted that the recently completed the major rehabilitation evaluation report for the Soo Locks used a different WOPC. Analysts considered the same major components for both studies, however the MRER, which analyzed the potential benefits of advanced maintenance, repair, or replacement of these components, was evaluated against a baseline of a fix-as-fails (FAF) future, one in which no preventative actions would be taken outside of routine maintenance. In contrast, the validation study WOPC was determined to be the "most likely," as specified in the planning guidance notebook (ER 1105-2-500)[8].

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[8]The Planning Guidance Notebook (ER 1105-2-100) defines the WOPC as *"… the most likely condition expected to exist in the future in the absence of a proposed water resources project. … Forecasts of future without project*

Section 7. National Economic Development Benefits

The purpose of a U. S. Army Corps of Engineers planning analysis "… is to estimate changes in national economic development that occur as a result of differences in project outputs with a plan, as opposed to national economic development without a plan." This is accomplished through a federally mandated National economic development analysis which is "… generally defined as an economic cost-benefit analysis for plan formulation, evaluation, and selection that is used to evaluate the federal interest in pursuing a prospective project plan." National economic development benefits are defined as "… increases in the net value of the national output of goods and services, expressed in monetary units …."

Traditionally, the conceptual basis for the basic economic benefit of a navigation project is the reduction in the value of resources required to transport commodities. In the case of this validation study analysis, benefits are derived more from the avoidance of unscheduled service disruptions and the risk of unmet demand to the region's steel industry. These benefits are measured in a wide range of cost avoidance categories, which are outlined in the sections below.

With the majority of vessel traffic at the Soo Locks project only being able to transit the large Poe Lock chamber, intermittent closures of the large lock can cause severe disruptions to traffic. Benefits for the construction of a second Poe-sized lock chamber come from avoiding these impacts. To estimate the benefits of this second Poe-sized chamber, risk exposure for the existing project and the recommended project are quantified and compared.

The risk exposure estimation involves a Monte Carlo style simulation of Soo Locks performance over a 57-year planning horizon given engineering reliability data, vessel accident probabilities, transportation costs, and traffic demand forecasts. **Section 9.2.2** includes a description of the planning horizon. The model (Soo-REM) simulates random structural, electrical/mechanical, and vessel accident lock service disruption events and estimates consequent transportation delay and diversion costs. The transportation benefits of a new Poe-sized lock are the transportation cost savings from reduced delay and transit times and the avoidance of more costly traffic diversions. The analysis also takes into account reduced repair, maintenance, and

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conditions shall consider all other actions, programs that would be implemented in the future to address the problems and opportunities in the study area in the absence of a Corps project."
EP 1130-2-500 (27-DEC-1996) Chapter 3 Major Rehabilitation Program describes the base, or WOPC, for an MRER as a "*base condition"* that *"… assumes that the project will be operated in the most efficient manner possible without the proposed rehabilitation.*" The EP also notes that *"Considerable risk and uncertainty is inherent in the base condition."*

rehabilitation costs with a new lock as estimated by CELRE. Additional benefits include recreation and area redevelopment.

The average annual benefit of a new Poe-sized lock is estimated with a present worth and amortization valuation of the 57-year benefit stream at different discount rates. At the current federal discount rate of 2.75 percent and price level (FY18), the total average annual benefit of a new lock at Soo complex is $58.2 million. The breakdown of the benefits are: 71 percent diversion costs avoided; 6 percent delay reduction; 15 percent repair, maintenance, and rehabilitation costs avoided; and 8 percent recreation and area redevelopment. The majority of benefits are diversion costs avoided because of inadequate overland rail infrastructure around the Soo project and lack of alternative means to deliver taconite to the Great Lake integrated steel mills via Class X vessels without the Poe Lock. Several billion dollars' worth of capital investment would be necessary to deliver Poe taconite to the mills during an extended Poe closure. To estimate the impacts of unmet shipments, capital costs for this additional overland capacity were translated into alternative transportation rates and costs. These constructed rates are considered an appropriate methodology to estimate the NED value of unmet shipments and the diversion impacts of the existing Poe Lock.

7.1 Soo Locks Economic Analyses – Historical Comparison

Table 7-1 provides an economic analysis comparison of the 1986 Interim Feasibility Report, 2005 Limited Reevaluation Report, and 2018 New Soo Lock Economic Validation Study.

Table 7-1—Comparison of Soo Locks Economic Analyses

Category	1986 Feasibility[1]	2005 LRR[2]	2018 VS
STUDY METRICS			
Price Level:	Jan-85	FY 2000	FY2018
Federal Discount Rate:	8.375%	5.625%	2.75%
PRIMARY BENEFITS			
Disruption Costs Avoided:			
Stockpile Drawdown Costs[3]:	-	$1,226,000	-
Diverted Traffic Costs:	$5,549,000	$2,740,000	$1,592,843
Vessel Layup Costs[4]:	-	$1,702,000	$1,331,584
Safety Costs:	-	$416,000	NC
Unmet Demand Transportation Costs:	-	-	$39,749,357
Stockpile Inventory Savings:	$8,017,000	-	-
Reserve Fleet Costs:	$2,340,000	-	-
Emission Abatement Costs Avoided:	-	$381,000	NC
Rehabilitation Costs Avoided:	-	$3,723,000	$4,135,633
Scheduled Maintenance Costs Avoided:	-	-	$3,033,975
Repair Costs Avoided:	-	-	$5,508
Vessel Delay Savings[5]:	$13,116,000	$3,013,000	$1,949,303
Recreation Benefits:	-	$2,235,000	$2,969,700
Decommissioning Cost Savings:	-	$948,000	$781,433
SUPPLEMENTAL BENEFITS INCLUDED IF BCR > 1.0			
Labor Resource Benefits[6]:	$2,284,000	$1,775,000	$1,607,854
Terrorist Disruption Avoided:	-	$1,382,000	NC
Subtotal Primary Average Annual Benefits:	**$29,022,000**	**$16,384,000**	**$56,565,563**
Total Average Annual Benefits (all categories):	**$31,306,000**	**$19,541,000**	**$58,173,417**
COSTS			
With Project Total First Cost:	N/A	$310,000,000	$903,158,305
Total Average Annual Cost[7]:	**$24,056,000**	**$22,564,000**	**$32,816,273**
COST-BENEFIT ANALYSIS:			
Net Incremental Annual Benefits:	$7,250,000	($6,180,000)	$25,464,528
Benefit-Cost Ratio:	1.3	0.73	1.78

[1] Benefit Reference: 1986 Soo Locks Final Interim Feasibility Report, Economic Appendix, Page I-54

[2] Benefit Reference: 2005 Soo Locks LRR, Economic Appendix, page B-91

[3] Included in the stockpiling component of unmet demand transportation costs

[4] Benefit category was named "idle vessel costs" in the 2005 Soo Locks LRR

[5] 2005 LRR estimate is an aggregation of two benefit categories; lock delay costs ($445,000) and vessel delay savings ($2,568,000)

[6] Category was named "area redevelopment benefits" in previous studies (1986 Feasibility and 2005 LRR)

[7] Includes Interest During Construction (IDC) and Operations and Maintenance (O&M) Costs

7.2 2005 LRR – Major Economic Updates from 1986 Feasibility Study

The sections below summarize major updates included in the 2005 analysis, as referenced in the 2005 LRR, Appendix B – Economic Analysis, Section 3.

7.2.1 General Updates

The 2005 analysis updated a number of factors. It modified its traffic forecasts to reflect current market trends. It also updated the least-cost overland route transportation rates to reflect current price levels. Additionally, the analysis revised vessel interference times (as a function of annual tonnage) and reexamined the composition of the Poe Lock restricted fleet. Finally, the analysis included accident closure probabilities cited in the 1994 Poe Lock system risk analysis.

7.2.2 Economic Modeling Updates

Soo Locks Waterway Analysis Model (SOOWAM)—the 1985 feasibility report relied on a queuing model to develop tonnage/delay relationships at the Soo Locks complex. The 2005 LRR relied on a simulation model developed by the Navigation Planning Center to simulate the unique operating characteristics of the Soo Locks Navigation System and estimate vessel delay savings. The SOOWAM is a stochastic simulation model that simulates the operation of a real-world facility or process and contains one or more random variables. The WAM was originally developed to determine the impact of tow movements on the inland waterway system. A deep-draft version of the WAM was developed by the Navigation Planning Center in 1993 for use in analyzing alternatives for the Panama Canal and then modified in 1996 and 1997 for the Soo Locks complex.

Expected Disruption Costs Model (EDC Model)—given the probabilities of Poe Lock closures from accidents, and given the consequences (e.g. delay costs, diversion costs, idle vessel costs) estimated by SOOWAM, an expected cost needed to be developed for each cost avoided (benefit) category. This was accomplished by the development of an EXCEL workbook simulation model utilizing a Palisade Corporation add-in called @RISK.

Benefit-Cost Uncertainty Model (BCU Model)—the more detailed traffic forecasts and the uncertainty qualified in them necessitated the development of a new model to capture (weight) their probabilistic nature. Basically, the results from the EDC Model were used to build a lookup table displaying the impacts (disruption costs avoided) for the various annual traffic levels. The expected disruption costs avoided for any of the new forecast scenarios could then be estimated by pulling appropriate results from this lookup table. Since each forecast scenario could have a different weight (probability), the @RISK add-in was again utilized in an EXCEL workbook. In addition to simulating the expected disruption costs under the forecast scenarios, the workbook was also designed to include the various cost categories (construction, rehab

savings, etc.) and the ability to model uncertainty in their estimates. In other words, this model combines the benefits and costs taking into account the variability in each. As a result, benefits, costs, net benefits, and benefit-cost ratios can be expressed probabilistically.

7.2.3 Benefit Categories Removed from Consideration

Reserve Fleet Cost Savings—although the 1986 interim feasibility report identified 15 vessels that could be activated for service if the Poe lock was inoperable for a prolonged period of time, there is no reserve fleet at this time nor will one exist in the future. This information became known after contact with the shipping industry, including the Lake Carriers' Association. Therefore, this benefit category was removed from the 2005 LRR analysis.

Stockpile Inventory Cost Savings—the 1986 interim feasibility report indicated the construction of a replacement Poe-sized lock would reduce the volume of taconite or coal kept in stockpiles as a raw material supply source. However, a 1997 survey of shippers (2005 Soo LRR, addendum 3) indicated no additional amount of inventory is kept as insurance against a possible interruption of service at the Poe Lock. Consequently, this benefit category was removed.

7.2.4 Benefit Categories Added to the Analysis

Lock Delay Costs Avoided—the lock delay cost component of the disruption costs avoided benefit category applies to the vessels that would continue to transit the Soo if the Poe Lock was closed by passing through the MacArthur Lock exclusively. Since only one lock (the MacArthur Lock) would be available under the without-project condition, all remaining commercial vessels would have to pass through the MacArthur Lock. This cost component accounts for additional delay and processing times at the MacArthur Lock during Poe closures, as well as queue drawdown time after Poe service is restored.

Stockpile Drawdown Costs Avoided—for closures of 30 days or less, the 2005 LRR analysis assumed that scheduled shipments would not divert. It also assumed the affected steel mills and electric power plants would consume stockpile reserves. These plants maintain a minimum level of stockpile with the intent of preventing an interruption in production. During short duration closures, stockpiles would be drawn down to accommodate the shortfall in shipments. It was assumed that after 30 days agreements with other shippers would be in place, and any future raw material needs would be able to be delivered via either a Mac-sized vessel, an Escanaba, or all-rail routing.

Analysts assumed that once the lock reopened, all vessels would be engaged in moving tonnages for the remainder of the navigation season. Therefore, delivery by water of the restocking tonnages would not be available. Thus, restocking was assumed to occur during the remaining year by an all-overland routing.

Idle Vessel Costs Avoided—a service disruption at the Poe Lock would result in a loss of income for the vessels restricted to Poe Lock use. There are 27 vessels with this restriction, assuming relaxing the vessel size restriction currently imposed on the MacArthur Lock. The assumption is that during the first 30 days of an unannounced closure, the vessels would not have opportunities for reemployment. Consequently, all Poe-restricted vessels would be idled for any closure duration up to and including 30 days.

Safety Costs Avoided—Poe and MacArthur closure events necessitate overland tonnage diversions which have higher probabilities of accidents, leading to an increase in property damage, injuries, and death.

Emission Abatement Costs Avoided—Poe and MacArthur closure events necessitate overland tonnage diversions which emit a higher level of pollution (Nitrogen Oxide, Sulfur Oxide, and Particulate Matter at 10µm and 2.5µm).

Rehabilitation Costs Avoided—if a new Poe Lock was constructed, the MacArthur Lock would not need to be rehabilitated, and the old Poe Lock could be rehabilitated more efficiently (constrained less during the winter closure season).

Recreation Benefits—these benefits are based upon a slight increase in both visitation and value of recreational users' experience of the Soo Locks complex. Recreation benefits were calculated for three user groups: recreationists visiting the Soo Locks visitor center, recreationists on private recreational craft that transit the locks, and recreationists on tour boats that transit the locks. **Section 7.7.5** presents the recreation benefit evaluation.

Decommissioning Costs Avoided—if a new Poe-sized lock is built in the Davis/Sabin footprint, the Davis and Sabin Locks would not have to be decommissioned, which is a cost avoided benefit.

Terrorist Disruption Costs Avoided—Disruption costs avoided were assumed to equal 20 percent of the total disruption cost avoided benefit in an attempt to account for the probability of a Poe Lock terrorist attack.

7.3 2018 VS – Major Economic Updates from 2005 LRR

7.3.1 General Updates

The 2018 Soo Locks Validation Study analysis applies numerous updates, including:

(1) The federal discount used in cash flow calculations; 5.625% (2005 LRR) vs. 2.75% (2018 VS).

(2) Recognizes and quantifies impacts due to the lack of overland capacity and the capability restrictions to move taconite from Duluth to steel mills on the Lower Great Lakes. There have been substantial overland developments, including the continued degradation of rail lines, many of which are now not suitable to move a full loaded iron ore jenny, and also the closure of a large trans-modal port at Escanaba. The potential for large quantities of unmet demand exists in the event of lock failures.

(3) Considers risk due to lock component failures. Previous studies only analyzed the likelihood that vessel accidents could occur.

(4) Considers benefits of avoided lock closure impacts resulting from scheduled closures of the Poe lock during miter gate replacements. These closure impacts are mitigated in the with-project condition by the presence of the new lock.

(5) Modifies traffic forecasts to reflect current market trends.

(6) Updates least-cost overland route transportation rates to reflect current price levels.

7.3.2 Economic Modeling Updates

Three models were developed to support the New Soo Lock Economic Validation Study: Soo-REM, the ARENA® Vessel Delay Model, and the GDP/RED Impact Models. Descriptions of each model can be found in **Section 5.**

7.3.3 Benefit Categories Removed from Consideration

Safety Costs Avoided and Emission Abatement Costs Avoided—given study budget constraints and the realization that this benefit category was expected to be small relative to other major categories, they were not considered for 2018 validation study inclusion.

Terrorist Disruption Costs Avoided—this category was determined to be too subjective for inclusion during the Dec 2015 New Soo Locks Validation Study kickoff meeting.

7.3.4 Benefit Categories Added to the Analysis

Unmet Demand Proxy Impact Costs—in some cases, such as taconite, the study team was unable to identify sufficient existing alternative modal capacity to dispatch all tonnages that could be displaced by a long duration lock closure. To estimate the economic impact of these unmet tonnages (or, unmet demand), the study team developed proxy alternative transportation costs. These proxy methods of transportation are not actual proposed

alternatives, but rather serve as a surrogate to value the existing methods of transportation against a next-best, least-cost alternative. See **Section 7.6** for additional information.

Repair Costs Avoided—Soo-REM simulates component unscheduled engineering reliability failure events, and a repair cost is pulled along with the service disruption specification (type and duration) from the engineering reliability event-tree. See **Section 8.1** for additional information.

Scheduled Maintenance Costs Avoided—this category analyzes the difference in scheduled maintenance costs for with and without-project conditions. See **Section 8.1** for additional information.

7.4 Transportation Cost Savings Benefits

Calculating the cost of moving commodities through the Soo Locks complex presents several challenges. Since a dock is not necessarily the exact starting or ending point for a commodity, the first step is to determine the exact origin and destination of each commodity movement. The next step involves deriving the actions necessary for the commodity to follow the path from start to end, including the loading and unloading methods and storage options. Once the paths and steps are known, costs must be estimated for each task within each movement. Another challenge is that shippers and operators are often reticent to provide cost estimates because of concerns regarding proprietary information as well as the difficulty that comes with making assumptions about cost estimates. Yet another challenge comes with compiling, analyzing, and summarizing the large amount of cost per movement data. However, USACE and other agencies have completed several rate studies, providing some key data points which were relied upon for this study.

One particular challenge in constructing transportation rates for this study is that the alternative methods for transporting commodities are limited when the Soo Locks complex is unavailable. There is a significant amount of tonnage passing through this location and the alternative modes are not expected to be able to transport the entire tonnage. For this reason, several theoretical, or conceptual, alternatives were developed to better understand the true cost savings produced by the Soo Locks complex. These alternatives are discussed in the following sections.

Once transportation costs have been estimated, the next step involves estimating the transportation rate savings. Transportation rate savings (or losses) can most easily be defined as the difference in cost between the actual water-inclusive route and the least-costly all-land

alternative route. Since the waterway costs were calculated previously, the missing information is the cost of the least-costly all-land alternative route. Calculating the cost of the overland routes for each commodity movement requires determining the potential alternate paths that a commodity could take and gathering the relevant rail and truck rates for those paths.

When tonnages divert off the waterway, the economic impact is calculated by using these transportation cost savings. For these diverted tonnage costs, the New Soo Lock Economic Validation Study analysis builds upon work done by a Baird/ URS Joint Venture as part of the Partial Benefits Analysis Report, dated October 27, 2014 (herein, PBA). This analysis included three interrelated study components: 1) a stakeholder response analysis entailing a series of interviews with Great Lakes shippers and operators involving primarily taconite and coal movements;, 2) an expert elicitation workshop involving a range of industry representatives (e.g. mining, manufacturing, utilities, railroads); and 3) a feasibility test that involved constructing and running economic models to quantify, under various scenarios, the impacts of lock closure.

Table 7-2 - Alternate Transportation Mode Summary, by commodity and direction

Commodity	Direction	Alternative transportation mode	Maximum annual capacity[4/]	Incremental cost per ton	Incremental cost per ton including expanded capital costs
Coal	upbound	Mac Vessel Backhaul	Dynamic[1/]	$0.44	$0.44
		Vessel to Truck	1,100,000	$132.11	$132.11
		Least Cost All-Overland Route[3/]	Not Limited	$16.16	$16.16
	downbound	Direct Rail to Coal Plants[3/]	3,900,000	$11.00	$11.00
		Rail to Toledo, OH	4,300,000	$22.58	$22.58
Iron Ore	downbound	Current Port at Escanaba	5,000,000	$5.94	$86.22[2/]
		Canadian Sourcing	50,000	$18.81	$18.82
Iron Ore (unmet demand)	downbound	Conveyance	4,468,800	$0.62	$77.07[2/]
		Stockpiling	2,565,000	$4.41	$145.72[2/]
		New Port at Escanaba	Not Limited	$26.00	$590.89[2/]
Limestone	upbound	Mac Vessel Backhaul	Dynamic[1/]	$0.29	$0.29
		Least Cost All-Overland Route[3/]	Not Limited	$34.67	$34.67
Grain	downbound	Least Cost All-Overland Route[3/]	Not Limited	$28.97	$28.97
Others	both	Least Cost All-Overland Route[3/]	Not Limited	$62.55	$62.55

[1/] The amount of upbound Mac-sized vessel capacity depends upon the forecast year, since the amount of empty return trips is driven by the amount of downbound tonnage and vessel trips.

[2/] Includes the additional capital invesment and maintenance costs based on expected (average) Soo-REM results made over 10,000 simulation iterations. Values reflect the cost per ton using the medium traffic forecast scenario under the most-likely planning scenario. Capital investments are made upfront, in 2020, and are calculated by using the highest observed diverted tonnage need throughout the 57-year period of each Soo-REM simluation iteration. The expected investment and maintenance costs are then converted to average annual values, by capitalizing them over 57-years using the current federal discount rate of 2.75%. The average annual invesment and maintenance costs were then divded by the average tonnage moved by each mode throughout the 57-year period to derive the rate per ton for the capital expenditures. The additional capital investment rate per ton was then added to the current rate per ton to derive the total rate per ton that includes the expanded modal capacity.

[3/] Rates are derived from transportation rate data sets developed by rate experts at the Tennessee Valley Authority and the University of Toledo.

[4/] Total capacity (throughput) is annualized for this summary table. But the total throughput for some modes is limited to a daily capacity based on the length of lock closure. For example, the conveyor has a daily throughput restriction. See the individual diversion write-ups for additional detail.

During the PBA, the study team examined the existing modal options available for taconite and coal, and made capacity and rate estimates for those existing options. The PBA team also analyzed potential methods for transporting taconite and coal that do not existing currently. Additional analysis was required by USACE to both reexamine the assumptions made by the PBA team, and update the rates and capacities available for those options given current shipping (LPMS) data, rates, and methodological assumptions. The USACE team also developed modal capacity and rate estimations for the commodities that were not covered by the PBA. **Table 7-2** above provides an overview of the various modes, their rates, and the capacities. The rates per ton shown are incremental, meaning they are the transportation savings when comparing the current waterway routing at full operations to the alternative mode. For a description on how costs per ton are generated by Soo-REM for modes requiring capital investment (unmet demand), please see **Section 7.6.3** .

7.4.1 Past Analyses of Diversions

As part of the August 2005 Soo Locks Limited Reevaluation Study, Corps analysts relied upon a transportation rate study the Tennessee Valley Authority completed in 1998. This study consisted of a sample of 113 individual commodity movements that occurred in 1996. Rates were developed for the existing lake routing, and similarly for the least-costly overland route. The cost differential (i.e. rate savings) between the two routes (land and water) was utilized to determine the economic impact when traffic was forced to divert to an overland mode. In all cases, it was assumed that the alternative modes of transportation would have the physical capacity to accommodate the additional tonnage represented by each commodity movement.

For this Soo Lock study effort, alternative route choices (and the resulting transportation costs) are determined at the commodity-direction level, rather than at the individual movement level. Alternative modal decisions were aggregated more broadly so that Corps analysts could build upon work done during the 2014 Soo Locks Partial Benefits Analysis (PBA), which identified constraints to modal capacity for taconite and coal. At the individual movement (shipper decision) level, overland capacity might seem sufficient, but when individual movements and shippers compete for the same resources, logistical complications arise when there is insufficient capacity to transport all of the necessary tonnages. These capacity limitations are further elaborated in **Section 7.5** which discusses the costing procedure for unmet demand.

In cases where existing overland capacity is sufficient, Corps analysts relied upon two transportation rate studies. The first is an updated transportation rate study completed by TVA in 2005. This more comprehensive study included transportation rates for 857 individual commodity movements that occurred in 2002 for users of the Great Lakes and St. Lawrence Seaway Navigation System. This study included closure surveys, field interviews, and individual port write-ups. Similar to the 1998 effort, this study assumes that the alternative modes of transportation would have the physical capacity to accommodate the additional tonnage represented by each commodity movement. Therefore, these rates were only used by Corps analysts where sufficient overland capacity was identified. The second transportation rate study was completed by the University of Toledo in 2008, and used similar assumptions and methods as TVA. This study consisted of a smaller sample set of 51 individual commodity movements from 2006, although the movements selected were predominantly larger tonnage volumes.

Using both transportation rate studies, Corps analysts merged the movements together into a unified data set using SQL Server Management Studio. In cases where duplicates existed, information from the more recent 2008 study was used. From the combined data set, Corps analysts extracted 200 unique movements that (1) moved through Soo Locks complex and (2)

still existed in recent historical data. The rates were then updated to a common FY18 price level using indices developed by the U.S. Bureau of Labor Statistics (BLS) Producer Price Index (PPI). The individual legs of each movement were indexed according to the specific transportation mode used to deliver the commodity from ultimate origin to ultimate destination. The BLS indices used can be seen in **Table 7-3**.

Table 7-3—BLS PPI Indices by Corps Designated Mode and Haul Type

Series_ID	Mode_Type	Haul_Type	Industry	Product
PCU4832114832112	barge	long	Inland water freight transportation	Inland waterways towing transportation
PCU4841214841212	truck	long	General freight trucking, long-distance TL	General freight trucking, long-distance, truckload
PCU4841104841101	truck	short	General freight trucking, local	General freight trucking, local
PCU4831134831133	ocean barge	long	Coastal and Great Lakes freight transport	Coastal and intercoastal towing transportation
PCU4831134831132	ship	long	Coastal and Great Lakes freight transport	Great Lakes - St. Lawrence Seaway freight transportation
PCU4883204883209	other	NULL	Marine cargo handling	Other marine cargo handling
PCU482111482111	rail	long	Line-haul railroads	Line-haul railroads
PCU482---482---	rail	short	Rail transportation	Rail transportation
PCU3339223339228	conveyor	NULL	Conveyor and conveying equipment manufacturing	Bulk material handling conveyors & conveying systems
PCU4883204883209	load	NULL	Marine cargo handling	Other marine cargo handling
PCU4883204883209	unload	NULL	Marine cargo handling	Other marine cargo handling
PCU4883204883209	transfer	NULL	Marine cargo handling	Other marine cargo handling

Once indexed to a common price level, the 200 samples were then aggregated together by major commodity group using a ton-weighted average. The resulting rate savings can be seen in **Table 7-4**. Of note, only the rates for limestone, grain, and "others" are used to fully determine the impact costs for diverted traffic in those categories. The TVA and Toledo rates for coal are only partially used, and the rates for taconite were not utilized due to capacity constraints, as mentioned earlier and further explained **Sections 7.4.3** and **7.5**.

Table 7-4—TVA and Toledo Rates Summarized by Major Commodity Group, Q1 FY18 Dollars

Commodity Group	Water Rate	Land Rate	Savings
Coal	$ 36.97	$ 53.13	$ 16.16
Limestone	$ 7.65	$ 42.31	$ 34.67
Grains	$ 52.99	$ 81.95	$ 28.97
Iron Ore	$ 17.51	$ 28.83	$ 11.32
Others	$ 24.07	$ 86.62	$ 62.55

7.4.2 Vessel Diversions and Fleet Utilization

A major modeling assumption for the New Soo Lock Economic Validation Study is that the vessel fleet is fully utilized in any given year, and additional vessel trips to make up lost down-bound tonnage due to unscheduled closure events is not a feasible modal alternative. The assumption that vessel capacity (supply) exists in equilibrium given a projected annual commodity demand is a key driver when analyzing the Soo Locks complex. Construction of lake vessels requires significant upfront planning and costs, and the Jones Act does not allow the use

of foreign vessel charters. In a typical Corps navigation study, supply is primarily limited to the annual throughput of the lock. In the case of Soo Locks complex, annual lock throughput is fairly robust, but due to the unique vessel dimensions within the fleet, annual vessel capacity can become restricted when there is a main chamber closure. In the case of 1,000-foot vessels, there are 13 discrete vessels on the lakes dedicated to the delivery of taconite and coal. The shipping schedule for these vessels and other large vessels like it are planned at least a year in advance. When closures occur, the current modeling framework assumes that any down-bound trips lost during the outages could not be made up by extra vessel trips later in the year, due to the fleet being fully utilized in a shipping season. In the case of up-bound movements, some vessel capacity was identified for coal and limestone, which is limited to the backhaul opportunities for Mac-sized vessels that return empty. Analysts do not assume that Poe-sized vessels could be further employed for empty backhauls above and beyond their current shipping patterns (to make up lost deliveries due to a lock outage) since added backhaul would simply further delay any down-bound shipments.

As part of the PBA, vessel operators collectively indicated that that a typical sailing season ranges from 275 to 295 days per year. The larger vessels (i.e., 1,000-footers) average from 45 to 52 trips per season, are primarily engaged in long-haul trips with taconite and western coal from Lake Superior to lower lake destinations, and typically do not backhaul. The smaller ships (i.e., Class II) generally make twice as many trips (80-90) per season, including some lower lakes trips that don't go through the locks. Backhauling is more common on the smaller ships and generally entails taconite down-bound and stone up-bound. With regard to prospective closures of the Poe and/or MacArthur Locks, analysts noted that economic inefficiencies result when a ship sails for less than a full season.

Operators also indicated during PBA interviews that they did not anticipate purchasing or building any new vessels in the next ten years since the current fleet is in good condition and adequately supports the existing market. Two articulated tug-barges have been built and placed into service in the last decade, one Poe-sized and the other MacArthur-sized. These vessels have a significant crewing advantage (standard crew of 13) over typical Great Lakes vessels (standard crew of 21 to 25). As a result, they are significantly less costly to operate and, at present, are the likely vessels of choice should there be future demand for new vessels on the Great Lakes.

7.4.3 Taconite Diversions

There are very limited modal options that currently exist for taconite that circumvent the Soo. As part of a fully-integrated supply chain, captivity to the water transportation market creates not only an efficient, low transportation nexus for a significant amount of tonnage, but also places substantial risk on the Soo Locks complex. In the context of this study, this risk is

quantified in terms of transportation costs avoided, by comparing the current water routed deliveries to a next-best, least-cost alternative. In the case of taconite, the broader study team was unable to identify sufficient existing modal capacity to dispatch taconite tonnage that might be affected by lock service disruptions. To remain policy compliant, the USACE study team developed proxy transportation costs to dispatch and value all remaining tonnage.

The section below describes the current modal options available for taconite, and their limitations.

Current Port at Escanaba

Taconite has shipped from Escanaba since 1852, and the port has historically shipped the greatest amount of taconite of any port in the lower Great Lakes. It ships nearly 13 times the tonnage of the next largest port in the lower system. Historically, this facility has sourced taconite from the Empire (primary) and Tilden (secondary) mines, and the movement flows circumvent the Soo Locks complex completely. As part of the PBA, many interviewees and Expert Elicitation Workshop panelists recommended Escanaba as a viable solution to move displaced taconite during a lock outage. However, in 2016, Cliffs Natural Resources closed the Empire Mine; in early 2017, Canadian National announced it would be closing its dock at Escanaba. Further investigations revealed that ArcelorMittal will continue to receive its tonnages via mines in Minnesota, which would now be processed through the Soo Locks complex.

Conversations with Canadian National regarding the future of the facility at Escanaba indicated that the dock could become operational in the future, but long-term transport of taconite would require substantial investment. As shown in **Table 7-2**, capital costs were estimated at $47.5 million dollars, and the rate per ton increase over the existing route that utilizes the dock at Marquette totals $5.93 per ton. The primary driver for the increased rate per ton is a longer rail movement to reach the Escanaba ore dock, as opposed to a shorter rail movement to the Marquette dock.

With the closure of the Empire mine, capacity is a limiting factor at Escanaba. First, any taconite sourced to the port would need to be dispatched from the Tilden mine in Marquette, which has a maximum output capacity of approximately 8 million tons of pellets. Nearly 3 million of this tonnage is dedicated annually to Essar Steel's Algoma operation, which is situated above the Soo Locks complex. This restriction, along with the current equipment limitations at the port at Escanaba, restrict annual throughput to approximately 5 million tons per annum.

Second, due to fleet utilization restrictions, it is assumed that Escanaba would only have ships available to process taconite deliveries during a lock outage. Once the locks were to become fully operational, vessels would again become fully employed and begin operating under business-as-usual shipping patterns. The exception to this assumption is the winter season, when the Soo Locks complex is closed. Lake carriers state that Escanaba's shipping season typically spans from March 12 to January 25, or approximately 23 days longer than the typical shipping season. This restricts annual throughput in the winter season to approximately 360,000 tons per annum, and daily throughput during a lock outage of approximately 15,700 tons per day, or 5 million tons annually. According to lake carriers, no amount of icebreaking could make the Escanaba dock a year-round shipment facility, since the ice makes the taconite difficult to recover from the pile, and the dock becomes prone to mechanical failures during the harshest of winter months.

Canadian Sourcing

This alternative entails shipping Canadian taconite pellets produced from Labrador mines via the St Lawrence Seaway. It is assumed that the taconite will go through the Iron Ore Company of Canada (IOC) docks at the Port of Sept Isles. The production plant is located near Labrador City, 261 miles north of Sept Isles. The taconite is moved by united rail via the IOC-owned and -operated Quebec North Shore & Labrador (QNS&L) railway.

The study team identified very limited additional capacity via this mode; it totaled 50,000 tons per annum. Analysts assumed delivery to end users would be by Class VII vessel, at a seaway draft of 26 feet 6 inches. Class VII is used, because Welland-capable Canadian Salties are usually around 650 feet in length; they are bulk freighters, not self-unloaders. This is closer to a Class VII in operational needs than a Class VIII, since all of the Class VIIIs are self-unloaders. Analysts calculated an incremental delivery cost per ton increase to account for the difference in shipping costs between using a Class VII vessel and using the existing fleet mix and shipping pattern. This incremental increase in waterway shipping costs totaled $8.03 per ton. Per Corps planning guidance (ER 1105-2-100), shifts in origin must also account for the full change in delivered prices, rather than simply the difference in transportation costs. Therefore, an incremental increase in the taconite cost per ton was included, at $10.78 per ton. In total, any diverted traffic that was resourced through this Canadian source would incur an incremental impact cost of $18.81 per ton.

Unmet Taconite Demand

As stated previously, limitations in the existing alternative modal options for taconite led the study team to develop proxy unmet demand alternatives to evaluate the resource savings of

the current cargo movements. These modes, their rates, and their capacities are further explained in **Section 7.5**

7.4.4 Coal Diversions Summary

The modal options available for coal tonnages that would be displaced in case of a service disruption at the Soo Locks complex are distinctly different for up-bound and down-bound commodity flows. Two modal options were identified for down-bound coal, both which involve the use of rail capacity. For up-bound coal, three alternative modes were identified. These modes are explained in more detail in the following sections.

In the economic model, the study team did not identify any unmet coal tonnages due to service disruptions at the project. This is primarily driven by sufficient alternative modal capacity for the down-bound coal flows, which are projected to decrease significantly into the future given planned power plant closures. The projections for future waterway coal traffic moving through the Soo Locks complex is explained further in **Section 3.** Shippers also expressed concern regarding strict emission standards during the PBA interviews, and the impetus for reduced lock tonnage due to reductions in coal-fired electricity generation. These emission standards have the potential to prompt closure of coal-fired power plants, in combination with low cost natural gas which may eliminate the competitive advantage of coal-fired energy sources.

7.4.4.1 Coal Diversions (Down-Bound)

The bulk of coal tonnage moving through the Soo Locks complex has historically been down-bound coal. For the most part, these down-bound coal flows serve the coal-fired electric generating market, which has been on a steady decline at a national level. Fluctuations in coal tonnages for individual lock projects is primarily dictated by the specific decisions and operational changes at the individual power plant level. These decisions include switching individual boiler/generator units to different energy sources (e.g. natural gas), retiring generating units or entire facilities, and sourcing coal from more cost advantageous locations (e.g. Power River Basin, Illinois Basin). Since coal-fired power plants typically consume a significant amount of coal, these fluctuations can seem rather drastic in terms of total project tonnage.

Two alternative modal options were identified for dispatching down-bound coal that could be affected by a service disruption at the Soo Locks complex.

Direct Rail to Coal Plants

The direct rail alternative is exclusive to coal, and more specifically, coal-fired power plants with rail access. This route has historical precedence, since coal is frequently shipped via direct rail

to select power plants. This was validated as part of the PBA expert elicitation workshop and was a major point of consensus for the group.

To develop an estimate of the incremental cost differences between the waterway routed movement compared to the direct rail alternative (i.e. rate savings), the USACE study team utilized transportation rates developed by the Tennessee Valley Authority and the University of Toledo. A description of these studies, the respective study rates, and the method in which these studies were used in this Soo Lock study is further described in **Section 7.4.1** . From these rate samples, the team extracted the coal movements (origin-destination-commodity) to the active power plants. These specific sample rates were then tonnage-weighted together to develop a total rate savings of $11.00 per ton to directly rail coal to a power plant.

The PBA team estimated total rail capacity to these power plants at approximately 11,500 per day (ranging from 10,000 to 13,000), which is roughly one train per day. It is assumed this mode would only be available for 335 days out of the year, since it would take 30 days to begin operations in case of an unscheduled lock closure. In total, maximum annual throughput for direct rail is estimated at 3,900,000 tons each year.

Rail to Vessel via Toledo

The PBA team initially developed this rail alternative. It consists of diverting coal from Lake Superior ports to a terminal in Toledo, Ohio, and then trans-loading the coal onto vessels for delivery. Distances between Powder River Basin mines and Great Lakes ports were estimated using Burlington Northern and Santa Fe (BNSF) rail loading locations and Class I rail maps. During interviews and the expert elicitation workshop, participants identified Montana and sometimes Wyoming as the origin for Powder River Basin coal transiting the Soo Locks complex. Ultimately, the team chose Billings, Montana, as the rail origin point for rate estimation. Current rail movements for the historical shipping pattern average approximately 850 miles from Billings to Duluth. For a rail movement to Toledo, this mileage would increase approximately 815 miles, since the rail movement would need to be rerouted from Billings to Toledo by way of Chicago. Although vessel trips from Toledo to their ultimate destinations are significantly shorter vessel movements than from Duluth, the added rail mileage substantially increases this route's costs. Incrementally, railing to Toledo for vessel trans-loading compared to the current waterway routing would result in lost transportation savings of $22.58 per ton.

In terms of total capacity, this alternative is limited both physically and contractually. As noted in the PBA, major Class I railroads surrounding the Great Lakes have limited excess locomotive power, crews, and rail line capacity, particularly when transiting through Chicago. Additionally, it is unlikely that rail companies would be willing to obligate much of their limited resources to

coal transportation without long-term contracts. Due to the numerous constraints of short-term, long distance rail transportation, excess capacity is estimated to be only one to two trains per day, especially through Chicago. This alternative would require 30 days to implement due to contract negotiations and equipment repositioning. Assuming 1.5 trains per day, 100 cars per train, and 86 tons per car, approximately 12,900 tons per day (4.3 M tons per year, given the 30 day start- up period) of Powder River Basin coal could be railed to lower Great Lakes ports during an emergency closure of the Soo Locks complex.

7.4.4.2 Coal Diversions (Up-Bound)

Up-bound coal tonnage is less constrained than the down-bound coal flows, primarily due to the smaller tonnage volumes. These coal flows mostly consist of metallurgical grade coal utilized by Essar Steel's Algoma operation. Algoma Steel also receives a small amount of coke by vessel, but since the mill is a fully integrated facility that includes three coke batteries, Algoma Steel primarily receives metallurgical coal and produces their own coke on site. A smaller amount of steam coal also moves up-bound, which supplies power stations located off Lake Superior, such as the Presque Isle power plant.

Three modal options are identified for up-bound coal flows. The first is a vessel to truck movement that has occurred historically. The second are backhaul opportunities that exist for Mac-sized vessels, due to the empty return of the down-bound movements. Finally, the overland modes identified by TVA and the University of Toledo are used.

Vessel to Truck

This alternative consists of a vessel to truck movement from Thessalon, Ontario to Sault Ste. Marie to supply metallurgical coal to Essar Steel's Algoma operation in Sault Ste. Marie. Historically, this movement has occurred when the locks are not operational, to meet any production shortfalls that have occurred during the navigation season. As described in **Section 7.4.3** Algoma Steel has the ability to receive both direct rail shipments and vessel shipments of taconite from the Tilden mine in Marquette. However, its primary reliance on the Soo Locks complex is for metallurgical grade coal moving up-bound through the project.

Total available capacity to truck from Thessalon is estimated at approximately 1,100,000 tons per annum, which is the historically observed tonnage that has moved via vessel shipments. Total truck mileage from the vessel receiving location in Thessalon to Algoma Steel is approximately 114 miles round-trip. Using PC Miler, Corps analysts constructed a rate per ton for the truck movement. Incrementally comparing the current water inclusive routing to the vessel to truck routing yields a transportation savings of approximately $132.11 per ton. This significant cost increase is primarily driven by an assumed 100 percent empty backhaul for the

truck movement, which is a typical assumption when the travel distance is extremely short (i.e. trucks would not be able to capitalize on any potential return trip backhauls over such a small distance, and would simply return to their yards). Additionally, the short distance means that the capital costs for the equipment to truck the coal yields a truck cost per ton-mile that is substantially higher than the national average, at nearly $2.32 per ton-mile.

Empty Backhaul

Corps analysts identified a Mac-sized vessel backhaul as a potential alternate method of transporting up-bound commodities in case of a service disruption at the Soo Locks complex. Although an assumption for this analysis is that the vessel fleet is fully utilized in any given year, an exception exists for up-bound Mac-sized vessels, where empty backhaul is common. Since empty backhauls are driven by the frequency of the loaded down-bound vessel movements, total capacity of this modal alternative fluctuates from year to year depending on the amount of forecasted tonnage moving through the Soo. In a forecast year, it is estimated that total capacity of this mode is approximately 5 percent of the total annual projected tonnage. This percentage was derived by comparing the historical percentage of empty up-bound Mac-sized vessel transits to the loaded down-bound transits. This 5 percent metric assumes that only 50 percent of the total up-bound empty Mac-sized vessel capacity would be available on an annual basis, and that similar vessels (non-grain, self-unloaders) would be required. The 50 percent capacity reduction is meant to capture the uncertainty surrounding the seasonality and timing of an unscheduled closure event. In other words, only vessels returning empty after the closure event would be available to make up extra trips lost during the closure.

Only two commodities are projected to be available for transport via this mode; up-bound coal and limestone. It is assumed a similar vessel type would need to be available (self-unloading capability), and the origin and destination of these movements would remain the same. Since the vessel type and mileage of the replacement trip is identical to the scheduled trip that would be lost during a closure event, the primary transportation impacts are delay costs, rather than diversions costs. However, it is assumed additional hull cleaning costs would be incurred at an overtime rate in order to prepare a vessel (that was previously returning empty) to transport coal or limestone on an unscheduled basis, totaling $0.44 and $0.29 per ton for coal and limestone, respectively.

Overland Routing

Section 7.4.1 provides a full description of the overland routes identified by the rate experts at TVA and the University of Toledo, the rates that were developed by the contractors for each origin-destination-commodity movement, and the manner in which Corps analysts summarized the data. As shown in **Table 7-2**, the transportation rate savings of the current waterway

inclusive routings when compared to an all-overland routing for the coal group is approximately $16.16 per ton.

7.4.5 Grain Diversions

Most grain traversing the Soo Locks complex is wheat and oilseeds, and is dispatched via ship from Thunder Bay and Duluth. These grains are primarily destined for the export market for consumption overseas. Export tonnage volumes fluctuate primarily when local consumption exceeds local production. Otherwise, these field crops move by truck or rail directly to domestic use destinations over a distance of as much as 200 miles, but typically average less than 50. Export tonnages move by Salties, leaving Thunder Bay and Duluth, and topping off in Montreal or Seaway elevators.

The overland routings identified by TVA (primarily rail) are used when grain traffic moving by vessel diverts, and assumes there is sufficient overland capacity for the current and forecasted traffic volumes moving through the Soo Locks complex. Capacity to move export grain via rail was verified by Corps analysts in discussions with Canadian National.

Overland Routing

Section 7.4.1 provides a full description of the overland routes identified by the rate experts at TVA and the University of Toledo, the rates that were developed by the contractors for each origin-destination-commodity movement, and the manner in which Corps analysts summarized the data. As shown in **Table 7-2** the transportation rate savings of the current waterway inclusive routings when compared to an all-overland routing for the coal group is approximately $28.97 per ton.

7.4.6 Limestone Diversions

Limestone moving through the Soo Locks complex travels up-bound, and is primarily used at taconite production facilities where it is melded with the ore to create various blends of taconite pellets. Additionally, it is used at coal-fired power plants to desulfurize flue-gasses, and a smaller percentage of limestone is used by the sugar beets industry at processing plants to capture and remove impurities in the juice of sugar beets. Two modal options were identified for limestone movements: MacArthur vessel backhaul, and the overland routings identified by TVA and the University of Toledo.

Empty Backhaul

As discussed previously in **Section 7.4.4.2** the total capacity of Mac-sized vessels returning empty that would be available to replace trips lost due to an unscheduled closure event is estimated at approximately 5 percent of the total annual tonnage in a forecasted year, which is

shared between coal and limestone. Increased hull cleaning costs are estimated at $0.29 per ton for limestone.

Overland Routing

Section 7.4.1 provides a full description of the overland routes identified by the rate experts at TVA and the University of Toledo, the rates that were developed by the contractors for each origin-destination-commodity movement, and the manner in which Corps analysts summarized the data. As shown in **Table 7-2** the transportation rate savings of the current waterway inclusive routings when compared to an all-overland routing for limestone is approximately $34.67 per ton.

7.4.7 "Others" Diversions

The "Others" commodity group contains a mixture of commodities. These include animal feeds, salt, slag, cement and concrete, and more refined iron and steel products (e.g. plates and sheets). These commodities together represent a small percentage of total Soo Locks complex tonnage, and serve a variety of industries. For this analysis, sufficient overland capacity is assumed for these commodities, and the rates and individual routings determined by TVA and the University of Toledo are used to estimate alternative modal impacts.

Overland Routing

Section 7.4.1 provides a full description of the overland routes identified by the rate experts at TVA and the University of Toledo, the rates that were developed by the contractors for each origin-destination-commodity movement, and the manner in which Corps analysts summarized the data. As shown in **Table 7-2** the transportation rate savings of the current waterway inclusive routings when compared to an all-overland routing for the "others" commodity group is approximately $62.55 per ton.

7.5 Unmet Taconite Demand and Proxy Diversions

Previous economic analyses for the Soo Locks complex have focused on utilizing traditional modes of transportation (truck and rail) without regard to the existing capacity and capability. The New Soo Lock Economic Validation Study analysis builds upon work done by Baird/URS as part of the PBA Report. In the report, the detailed limitations of each modal option for coal and taconite are outlined. For this effort, the study team at USACE verified these modal capacity limitations for taconite movements, which are mostly captive to the current waterway shipping patterns. However, in the case of coal movements, the alternative modes identified by the PBA were sufficient to handle the expected tonnage diversions that could occur, given projected coal demand in the future and the likelihoods of lock service disruptions as estimated by the Soo-REM model. Therefore, the discussions below regarding alternative modal capacities will solely focus on the potential unmet demand as it pertains to taconite. Analysis of these modal

alternatives resulted in three proxy unmet demand modes to accommodate diverted traffic: 1) conveyance, 2) stockpiling, and 3) expanding Escanaba. Details regarding these proxy modes and the other options that were considered are summarized below, and further expanded upon in **attachments 2-4**.

Direct Truck and Rail

The PBA concluded that although trucking is an important part of short-haul transit for some commodities, truck delivery is not a viable line-haul alternative to accommodate taconite. This was due to the lack of requisite infrastructure, equipment, and labor requirements; pronounced shortages of both truck and truck drivers; and transport constraints (e.g. weight restrictions on roads, variability in weather conditions, and air pollutant emissions). By way of reference, approximately 2,800 trucks would be needed to carry the equivalent tonnage of one thousand-foot vessel.

In the case of rail movements, rail capacity is primarily commodity-specific, and access to this mode is dependent upon the origin-destination movement in question. The study found that rail infrastructure to move taconite is restrictive. This is primarily due to availability of rail cars required to ship taconite (e.g. ore jennies), lack of trained personnel (e.g. engineers), constraints on current locomotive and rail line capacity due to growing demand for freight rail services, and timeliness of delivery concerns because of an overly congested Chicago rail network. Furthermore, the industry is reluctant to make the requisite infrastructure improvements without a guarantee that rail would handle the long-term transport of taconite and coal that would otherwise transit the locks.

During the PBA interviews, shippers confirmed these assumptions. In general, the shippers indicated they do not have rail access to their facilities or to their customer's facilities. One shipper claimed that it has limited rail access but lacks rail unloading equipment. All shippers said that transportation via truck was not feasible due to the quantity of material and the lack of truck-specific infrastructure at their plants. Long hauls from mine to plant, as well as short hauls from intermediate rail receiving stations to plant, were considered infeasible.

Lightering

Vessel lightering entails loading Poe-restricted vessels trapped above the Soo Locks complex with Minnesota-produced taconite pellets at Lake Superior ports, and then transporting the pellets across Lake Superior to a safe location north of the Soo Locks complex. At this location, the pellets would be trans-loaded onto smaller vessels that would then transit the MacArthur Lock. South of the locks, a Poe-restricted vessel would receive the lightered cargo and complete the journey to lower Great Lakes ports and steel facilities.

Vessel lightering was initially explored by the PBA as a potential option for moving tonnage through the MacArthur Lock in case of a Poe Lock outage. However, further investigation by the USACE study team revealed that limitations in fleet availably make this transportation option an unlikely alternative. First, vessels acquired for the lightering operation would have to meet the technical, operational, and dimensional requirements to conduct a lightering operation. Second, the vessels used would have to not be employed in the shipping year that a service disruption occurs.

Upon further investigation, Corps analysts screened out lightering as a viable modal option. The two vessels that were previously identified as candidates for a vessel lightering operation did not meet current emission standards. The steamships identified burn heavy oil, and would need to be repowered with modern diesel engines, which would take at least a couple years and require millions of dollars in investment. Additionally, the vessels would need to be dry-docked for 5-year hull inspections before being place in service. These extensive requirements would have taken too long to make them operational for an unscheduled service disruption at the project. These limitations, combined with the limited lightering capacity estimated by the PBA, lead the USACE study team to screen out lightering as a viable, long-term solution for moving taconite displaced by an unscheduled lock service disruption.

Reserve Fleet

While the 1986 Feasibility Report had identified 15 vessels that could be activated for service is the Poe Lock was inoperable for a prolonged period of time, the 2005 LRR and the PBA concluded that excess self-unloading Mac-sized vessels were nonexistent (as discussed in the lightering section). In fact, the PBA determined that the fleet was essentially fully utilized with excess capacity in only up-bound empty backhauls.

As a proxy unmet demand mode a reserve fleet could supply relatively low cost transportation compared to some of the other unmet demand mode options. A self-unloading Mac-sized vessel costs approximately $85 million, would have an annual layup cost of approximately $3.5 million, and given a 30 million ton capacity and average taconite round trip times, approximately 1.2 million tons of taconite could be moved in a navigation season by a single vessel. The MacArthur Lock has approximately a 43 million ton annual capacity, and historically 21 percent of tonnage that moves through the Soo Locks could use the Mac chamber, which suggests there is substantial excess capacity.

Use of reserve Mac-sized vessels for unscheduled Poe Lock outages, however, is more complex. While a single reserve Mac-sized vessel could move 1.2 million tons annually, it would

only be called into service at the beginning of a Poe Lock closure. For unscheduled events, on average the vessel would only be utilized for half of the navigation season. In extreme events (e.g., Poe closed for the entire navigation season) Mac-sized vessel capacity is further limited by MacArthur Lock capacity. Currently the Soo project moves on average 236,486 tons per day and the MacArthur can only process 145,270 tons per day; a 91,316 tons per day shortfall. While there is this daily shortfall during Poe closure events, for shorter duration Poe Lock closures the reserve Mac-sized vessel fleet could continue shipping and makeup shipments after the Poe Lock is reopened. As noted, however, this shipment makeup is inhibited by the fact that on average the unscheduled Poe closures will occur in the middle of the navigation season, and depending upon the duration of the Poe closure the number of days available for additional shipments could be well less than half of the navigation season.

Given the limitations of a reserve fleet to move adequate tonnage during a Poe closure event, given limited time after a Poe closure event to makeup shipments utilizing the reserve Mac-sized vessel fleet, given the complexity of modeling a reserve fleet (e.g., modification of the PBA Baird ARENA® vessel-level simulation would be required), and given the capital investment linear scaling utilized for the new port at Escanaba (see **Section 7.6**) which attempts to estimate tonnage volumes requiring less capital investment than a new port at Escanaba, the reserve self-unloading Mac-sized vessel fleet was eliminated from consideration as a simplifying assumption.

New Port at Escanaba

A new port facility at Escanaba is a concept method for dispatching displaced taconite tonnages that were unable to process through the Soo Locks complex due to a service disruption at the project. As described in previous sections, this mode serves as a proxy for evaluating the economic benefits of the existing waterway shipments against a next-best, least-cost transportation alternative. This new port facility would source its taconite from mines in Minnesota via Duluth-Superior, compared to the existing port facility at Escanaba, which would utilize the taconite capacity of the local Tilden mine.

Seven candidate port locations (Port Inland, Escanaba, Menominee/Marinette, Green Bay, Manitowoc, Sheboygan, and Milwaukee) on the northern and western shore of Lake Michigan (below the Soo Locks complex) were considered as potential alternatives to the Port of Duluth-Superior. These candidate ports were compared by considering a range of criteria that would significantly affect transportation and port development costs. After careful review of these criteria, the Port of Escanaba was chosen as the most viable and likely least-cost alternative, because the Port of Escanaba has:

- Been used for the target commodities in the past.
- A recent history of docking Poe Lock-restricted ships.
- Three 1,000-foot docks.
- Direct service by rail, including rail rated for 286,000 lbs. gross weight per car.
- The second shortest rail distance from Duluth-Superior.
- The second highest estimated area of nearby land potentially available for development (of the seven candidate sites).

USACE hired LimnoTech to assess the capital and logistics necessary to use this route. The contractor evaluated a total taconite capacity of 18 million tons. Capital costs to construct an 18 million-ton port facility for taconite totaled $1.84 billion, and capital costs to build the requisite rail infrastructure to transport the taconite from Duluth-Superior to the new port facility totaled $2.9 billion. The combined capital expenditures total $4.7 billion to construct 18 million tons of annual modal capacity. Additional information on these capital investment costs can be found in **attachment 4.**

LimnoTech also estimated the operational costs for using the port facility and rail line. Port facility accessorial costs totaled $0.33 per ton, and rail operating costs totaled $13.05 per ton. LimnoTech's assessment of rail operating costs were derived from a 2009 report published by the Surface Transportation Board (STB), titled *Study of Railroad Rates: 1985–2007*. In the report, the STB publishes operating costs per ton-mile based on national averages, which vary by commodity and service characteristics. However, further investigation by Corps analysts revealed that the national averages published by the STB undervalued the costs of operating rail in the region under question, which can vary significantly based upon backhaul opportunities, geographic factors, and other major cost factors. Using more high resolution STB waybill data, Corps analysts adjusted the rail rate per ton to reflect the operating costs in the region. The resulting incremental operating costs per ton of using the new constructed port facility at Escanaba compared to using the existing waterway routing from Duluth-Superior totals $26.00 per ton.

For additional information regarding the new port facility at Escanaba and itemized cost tables, please see **attachment 4**.

Conveyance

The proxy scenario developed to estimate the cost of a potential conveyor solution was developed to address a portion of the unmet demand. This solution is referred to as a "proxy" as it represents a theoretical solution and cost estimate for continuing to move commodities

during a prolonged closure. Representatives from USACE worked with stakeholders and industry to better understand the effectiveness and limitations regarding this potential solution. Through this consultation, a few critical assumptions were refined to improve the accuracy of the theoretical cost.

First, the maximum number of tons that can be handled by the conveyor system is a function of the number of tons unloaded per day and the number of days in the navigation season. The normal navigation season at the Soo Locks complex is placed at 296 days. It has been assumed that the conveyor system would not operate any time there is ice present at the Soo Locks complex. The ice free season length has been placed at 228 days. Thus, the conveyors yearly throughput is tons conveyed per day (19,600) times the number of ice free days, (228), or 4,468,800.

Secondly, the maximum number of hours that can be worked in a shift, based on Coast Guard rules for crew members, is 14 hours. After a 14-hour shift, the crew needs to have ten hours of non-shift time in a 24-hour period. The loading and unloading operations engage the majority of the crew. Thus, after 14 hours, unless new crew members are brought on board, vessel loading/unloading operations stop. These unloading/loading operations cannot be restarted until ten hours of non-shift time has elapsed. Consequently, an additional ten hours of ship operating costs were added to the ships being unloaded and loaded.

Thirdly, vessel operating costs consider a number of vessel cost categories: wages, subsistence, stores, insurance, maintenance and repair, fuel, and other and new vessel construction costs. New vessel construction costs used to calculate vessel operating costs range from $75 million for a Class V vessel to $117 million for a Class X vessel. All of the above cost categories are considered when developing daily and hourly vessel operating costs.

Finally, the usage of conveyors at the Soo Locks complex includes removing 600,000 cubic yards in the upstream section of the channel adjacent to the upper lock wall. Total dredging costs for this upper section came to $20 million. The lower approach channel has already been deepened. Thus, there were no lower approach wall dredging costs.

For additional information regarding conveyance and itemized cost tables, see **attachment 2**.

Stockpiling

A stockpiling proxy scenario was developed to address a portion of the unmet demand. This solution is referred to as a “proxy” as it represents a theoretical solution and cost estimate for continuing to move commodities during a prolonged closure. USACE worked with stakeholders

and industry to better understand the effectiveness and limitations regarding this potential solution. Through this consultation, a few critical assumptions were refined to improve the accuracy of the theoretical cost.

See **attachment 3** for additional detail regarding the stockpiling alternative.

7.6 Unmet Taconite Demand and Proxy Diversions – General Methodology for Determining Least-Cost Alternate Transportation Costs

A methodological approach for this study is to dispatch all tonnages that could not be processed by the lock in case of a service disruption. In some cases, such as taconite, the study team was unable to identify sufficient existing alternative modal capacity to dispatch all tonnages that could be displaced by a long duration lock closure. To estimate the economic impact of these unmet tonnages (or, unmet demand), the study team developed proxy alternative transportation costs. These proxy methods of transportation are not actual proposed alternatives, but rather serve as a surrogate to value the existing methods of transportation against a next-best, least cost alternative.

The goal of the New Soo Lock Economic Validation Study is to update the NED evaluation of another Poe-sized lock in the footprint of the Sabin and Davis locks at the Soo Locks complex. Part of this economic update involves developing transportation charges for a market that does not currently exist. One of these markets would rail taconite directly to an expanded port at Escanaba for transload onto lake vessels for delivery to integrated steel mills on the lower Great Lakes. These potential transportation charges require evaluating the risk of alternate capital investment costs to accommodate different levels of unmet taconite demand. This risk of investment is driven by both probability and consequence to determine expected values based on need. In real markets, transportation infrastructure is constructed when a sufficient amount of traffic is projected to demand the use of that infrastructure over the investment's lifespan, to allow investors recover their investment. In other words, modal infrastructure investment would be optimized when expected marginal revenue from the investment equals or exceeds the marginal cost to mitigate any unmet demand, or the willingness-to-pay for reduced risk of unmet demand exceeds the cost to alternately transport. The costs come in the form of capital, operating, and maintenance costs. Each ton demanded shares some amount of this capital, operating, and maintenance cost burden over the investment's lifespan. If traffic demand is large enough, then there will be a sufficient amount of tonnage to spread those costs across, reducing average (expected) total costs to a more cost-effective and efficient level.

In the context of the Soo analysis, this means that a sufficient amount of unmet demand would have to occur so that the possibility of damages resulting from undelivered tonnages warrant

the cost of building infrastructure to accommodate them. In real markets, risk takers will seek to mitigate this risk using least-cost methods. As a practical example, the Soo Lock project has historically dealt with a shortened shipping season (approximately 296 days) due to ice, so that 365-day delivery of taconite to steel mills is not feasible. To mitigate this yearly closure, the steel industry has historically resolved the issue by stockpiling taconite at their facilities. This is a classic least-cost solution of expected damages exceeding the cost of the solution (stockpiling). It is also the only current market-proven solution to mitigating this extended closure risk.

Similar logic such as using least-cost mitigation methods must be applied to the Soo analysis, but with the recognition that capacity and capability restrictions exist for the different alternative methods of buying down risk. In other words, costs for each delivered ton will grow as more and more users vie to use the limited throughput restrictions of any existing or future infrastructure. Recognition must also be given to the problem that demanders of alternate delivery means would only use these mitigation methods during unscheduled closure events (vessel accidents and lock component failures). Alternative transportation options that do not currently exist could not expect a consistent and sustainable traffic demand level, since waterway deliveries are substantially more cost-effective when the Soo Locks complex is fully operational. Added transportation investments would serve as reserve capital and would only provide a transportation solution to increase modal capacity and relieve congestion in the years the market experiences disruption. When the transportation market in the Great Lakes region operates in equilibrium with a functional Soo Locks complex, these reserve capital investments would be largely underutilized, since they would not provide needed throughput capacity to solve traffic congestion.

7.6.1 Maximum Willingness to Pay

While it is known that stockpiling is a viable and market-proven risk mitigation measure for handling tonnages that are not deliverable during known closure events, what is not known is the maximum willingness-to-pay for such risk mitigation measures, much less what the willingness-to-pay for those risk mitigation measures would be for an unplanned or unknown risk. Or, in other words, the true price-elasticity of demand for these potential stranded tonnages is not known. It should be acknowledged that this willingness-to-pay threshold has been considered, but is not estimated or included in the current calculations due to the difficulty in its estimation.

Some considerations were given to using current profit for each ton of steel as the maximum wiliness-to-pay for risk mitigation measures of undeliverable tons of taconite, or perhaps using twice the profit of steel production under the assumption that the steel industry would temporarily be forced to operate at a loss in order to retain their customer base in the short-

run. Additionally, if prices did continuously rise due to unscheduled outages, quantities of total demanded steel might likely decrease and the impact to the national output of goods and services would need to be valued.

The idea of commodities being captive to a transportation mode is not a new concept in Corps planning, but the sheer level of captive tonnage utilizing the Soo Lock complex presents a unique circumstance. Regardless of the complexity, sufficient data was not available to determine these true willingness-to-pay values, and estimating the elasticity for the commodity was sufficiently outside the purview of Corps guidance, where elasticity is measured for the willingness-to-pay for waterway transit by comparing the difference between transportation options. In other words, the willingness-to-pay for the waterway delivery is a different value than the willingness-to-pay for the commodity. Therefore, the values calculated within this section of the analysis is an attempt to determine the willingness-to-pay for the waterway delivery using transportation costs as a proxy. The willingness-to-pay for the commodity requires consideration of product substitutes and extensive market research into the industry's (and the nation's) flexibility in handling undelivered taconite tonnages, and the temporary production shortfalls and value-chain impacts that could result from those undelivered tonnages. For estimations that consider the more broad-reaching effects of undelivered tonnages, please see **attachment 5** and **Section 9.2.3** which estimates potential GDP impacts if tonnages went undelivered.

As a policy-compliant method of approximating some type of elasticity or willingness-to-pay per ton of undeliverable taconite, the study team utilized costs for different transportation options with different cost structures. These include a stockpile alternative, a conveyor system to portage over the locks, and a multi-modal movement that would require rail investment from Duluth to Escanaba. To accurately determine an impact cost that matches what would be done in a real transportation market, each ton is assessed some portion of the capital investment cost burden, in addition to the operating and maintenance costs of delivering each ton. By assigning capital costs to each ton, the capital costs are specifically tailored to the level of unmet demand, as shown in **Figure 7-1**, which displays the expected capital costs for the expansion at Escanaba. A competing theory for the use of capital costs, which uses a minimum (floor) capital cost for the Escanaba investment, can be found in **Section 9.2.6 .**

Figure 7-1—Escanaba Capital Costs for Varying Throughput Levels

For this study, a cost assessment conducted by LimnoTech serves as the benchmark for the rail investment cost burden. Current Soo-REM model results show that even under the without-project condition, expected costs for the Escanaba investment (damages) total $853 million and do not exceed the minimum investment threshold cost of $2.8 billion for the rail and port expansion from Duluth to Escanaba. This suggests that even under the WOPC, a fully functional expanded Escanaba is not likely to be built. However, the goal of this analysis is not to determine whether these modal investments are worth constructing, or whether the traffic level diverting off the waterway system would be of sufficient magnitude to warrant construction of various types of infrastructure. Instead, the goal of the analysis is to value the risk that exists in the WOPC against least-cost transportation alternatives, and determine whether and how much of this risk can be bought down by implementing more cost-effective risk mitigation measures in the WPC, such as a new 1200' lock at the Soo Locks complex.

It should be noted that other potential unmet demand modes were considered throughout the study process, such as the utilization of a Class 7 "MacArthur-sized" vessel fleet, which was removed from consideration since the MacArthur Lock has an expected annual capacity of approximately 43 million tons. The MacArthur Lock would not be able to process 100% of the tonnage that transits the Soo Locks complex; unmet demand from the Poe Lock would

overwhelm MacArthur Lock throughput capacity, causing very high congestion delay and increases in transportation costs.

7.6.2 Assumptions on Capital Investment Timing

Another complicating factor in using these proxy alternate modes to value WOPC risk is that these proxy modes require significant implementation periods before they would be available to move stranded tonnage, and thus are not viable as alternatives in response to short term, unscheduled closure events. As previously stated, these proxy modes are not intended to represent alternatives to waterway transportation during emergency closure events, but rather to approximate the maximum willingness-to-pay to move stranded tonnage given short term unavailability waterway transportation. Given however that identified proxy modes would need to be invested in and maintained preemptively to mitigate uncertain future risk, the time value of money invested preemptively to hedge against this risk becomes a component of the least cost alternative, and thus estimated willingness-to-pay.

The current approach for estimating capital investment costs is to place the costs in the first year of the planning period. Regular maintenance cost streams are also assessed from that time period forward, and each time the mode is utilized, operational costs are incurred. These capital investment costs are assessed by using the largest closure duration experienced in each modeled simulation iteration of lock performance over the planning period. This method ensures all unmet tonnages are assessed an appropriate capital cost that is weighted by the probability and magnitude of each closure event that results in unmet demand. Placing these costs in the first year essentially means the investment is not discounted and would need to occur up front.

The study team considered multiple methodologies for implementing and assessing this cost. One such method was to place the investment cost in the year that the first closure event is experienced that requires use of the expanded modal costs, rather than the first analysis year. Alternatively, another method was explored of building the capital costs over the planning period in each modeled simulation, so as to accommodate the expected closure events over time since risk slowly accumulates at the project due to increasing lock unreliability.

Ultimately, the study team determined that capital investments costs used to assess risk due to closure events in the future would need to occur up front since the timing of unscheduled closure events are unpredictable. This same assumption is used for both the WOPC and WPC risk profiles to ensure a fair incremental comparison of risk. Placing the cost in the first year is also a necessary assumption to correctly assess an alternative transportation cost for tonnages throughout the entire planning period.

7.6.3 Unmet Demand Transportation Costs per Ton

Constructing rates to estimate a least-cost alternative mode in markets where a least-cost alternative to the waterway does not exist involves consideration of all capital necessary to accommodate the displaced waterway commodities. A determination must also be made as to the throughput use of the new mode must also be made. This is not a new concept in Corps planning and is consistent with ER 1105-2-100 (Planning Guidance). Historically, constructed rates have been developed for use in Corps feasibility studies through numerous Ohio River Navigation System (ORS) transportation rate analyses by Tennessee Valley Authority transportation rate specialists. The constructed rates are used to estimate the National economic development value of waterway navigation.

One example involves TVA's assessment of the Cumberland River steam plant's alternative modal options to receive coal and sorbent material. With a volume of over 6 million tons of barged coal per year, the least-cost alternative would likely be rail, but the nearest rail head is over two miles away. Trucking that volume of coal two miles to the plant was not found to be a least-cost option to barging, disregarding logistics. The least-cost option was determined to be constructing a rail head at the plant to deliver coal directly by rail.

In reality, TVA receives coal by barge at Cumberland steam plant on 20-year contracts. Direct rail does not compete with the existing barge delivery costs. To estimate the NED value of waterway transportation to the Cumberland steam plant, TVA rate specialists estimated the capital and operational costs associated with building a hypothetical rail spur to connect the power plant with the nearest rail head. Similarly, for the Soo Locks complex, analysis of the capital and operational costs associated with moving displaced commodities that do not have sufficient alternative modal capacity was used to determine the NED value of the current waterway system. In this way, Corps analysts are able to estimate the NED value of the waterway in a policy compliant manner relative to a least-cost alternative.

This underutilization of capital is reflected in the transportation costs identified in **Table 7-5**. This table displays the expected costs that would be incurred under the WOPC, and the expected tonnage level that would use the new mode over the 57 year planning period.

Table 7-5 – Constructed Costs per Ton for Diverted Taconite

	Canadian Sourcing	Existing Escanaba	Conveyor	Stockpile	Escanaba Expansion
Expected fixed costs (PV) [1/]	$ -	$ 104,132,188	$ 52,825,365	$ 251,490,951	$ 853,330,016
Expected fixed costs (AAE) [1/]	$ -	$ 3,857,152	$ 1,956,700	$ 9,315,456	$ 31,608,128
Expected annual tons	-	48,047	25,850	65,920	55,955
Expected fixed cost per ton	$ -	$ 80.28	$ 75.69	$ 141.31	$ 564.89
Variable cost per ton over water route [2/]	$ 18.82	$ 5.94	$ 1.38	$ 4.41	$ 26.00
Expected total cost per ton over water route	$ 18.82	$ 86.22	$ 77.07	$ 145.72	$ 590.89

[1/] Fixed costs are composed of the capital investment cost in 2020 and maintenance costs from 2021 to 2076. Displays the results of the WOPC using the medium traffic forecast.

[2/] Variable costs are incremental and net out the cost to move by the existing water route.

The primary basis for which a transportation rate is constructed is ultimately a function of the cost of the capital infrastructure, the cost of maintaining that capital, and the cost to operate the mode to transport commodities. Therefore, assessing NED benefits by itemizing the alternative transportation costs into the capital, maintenance, and operating components is simply a more granular accounting of traditional NED costs avoided where a transportation rate is used. Itemizing the transportation costs in this manner was necessary for the Soo study since the expansion of alternative modal capacity (the capital investment) is a significant contributor to the overall project benefits. Additionally, the total impact cost of these modal expansions is entirely predicated on the performance of the lock since the users of these alternative modal expansions are coming off the waterway system after a service disruption. Itemizing the transportation costs in this manner allows the study team to determine an appropriate estimate of costs that is specifically tailored to the total amount of unmet demands that occur under each planning scenario.

7.6.4 Transportation Costs per Ton for Scheduled Closure Events

Two scheduled closures were assumed in the analysis of sufficient duration to exhaust existing alternate transportation modes and require estimation of cost using proxy alternate modes. [redacted]. Because these closures are scheduled decades in advance, it would be inappropriate to use the same impact cost estimates used to characterize unscheduled closures. Therefore, long-run transportation costs per ton were developed using similar rate estimating methods that have been employed on other navigation studies for scheduled closure events. These estimates take a long-run perspective, and measure the cost per ton that could be incurred for using a mode if the mode were the full-time employer of moving tonnage, instead of the existing waterway movement that uses the locks. These long-run costs per ton are also used in value-to-the-nation estimates, as it

measures the rate savings for all tonnages against a least-costly alternative if that alternative were to replace the locks.

These costs per ton are only used for the diverted tonnages associated with the two scheduled closures events mentioned above. Additionally, the conveyor rate is not used, since the conveyor system was seen as an emergency mitigation method for solving unscheduled lock outages, and it not an appropriate long-run solution for moving taconite on an annual basis.

Table 7-6 below displays the corresponding long-run cost per ton for moving taconite using alternate methods, and **Table 7-7** displays the impact costs for the gate replacements.

Table 7-6—Long-Run Constructed Costs per Ton for Diverted Taconite

	Canadian Sourcing	Existing Escanaba	Conveyor	Stockpile	Escanaba Expansion
Fixed costs (PV) 1/	$ -	$ 89,897,305	$ 56,256,448	$ 324,617,425	$ 2,834,426,812
Fixed costs (AAE) 1/	$ -	$ 3,141,375	$ 1,965,828	$ 11,343,445	$ 99,046,328
Annual tons	-	5,000,000	4,468,800	2,565,000	8,700,000
Fixed cost per ton	$ -	$ 0.63	$ 0.44	$ 4.42	$ 11.38
Variable cost per ton over water route 2/	$ 18.82	$ 5.94	$ 1.38	$ 4.41	$ 26.00
Total cost per ton over water route	**$ 18.82**	**$ 6.57**	**$ 1.82**	**$ 8.83**	**$ 37.38**

1/ Fixed costs are composed of the capital investment cost in 2020 and maintenance costs from 2021 to 2076.
2/ Variable costs are incremental and net out the cost to move by the existing water route.

Table 7-7—Impact Costs for Diverted Taconite due to Scheduled Gate Replacements

		Forecast Scenario					
		Low		Medium		High	
	Year	2040	2043	2040	2043	2040	2043
	Days of Poe Closure	63	28	63	28	63	28
	Diverted Taconite	6,055,010	2,175,320	6,907,871	2,508,756	8,400,415	3,066,006
Canadian Sourcing	Capacity	50,000	50,000	50,000	50,000	50,000	50,000
	Tons Dispatched	50,000	50,000	50,000	50,000	50,000	50,000
	Cost per ton	$ 18.82	$ 18.82	$ 18.82	$ 18.82	$ 18.82	$ 18.82
	Cost	$ 941,000	$ 941,000	$ 941,000	$ 941,000	$ 941,000	$ 941,000
Existing Escanaba	Capacity	1,347,964	799,374	1,347,964	799,374	1,347,964	799,374
	Tons Dispatched	1,347,964	799,374	1,347,964	799,374	1,347,964	799,374
	Cost per ton	$ 6.57	$ 6.57	$ 6.57	$ 6.57	$ 6.57	$ 6.57
	Cost	$ 8,853,798	$ 5,250,508	$ 8,853,798	$ 5,250,508	$ 8,853,798	$ 5,250,508
Stockpile	Capacity	2,565,000	2,565,000	2,565,000	2,565,000	2,565,000	2,565,000
	Tons Dispatched	2,565,000	1,325,946	2,565,000	1,659,382	2,565,000	2,216,632
	Cost per ton	$ 8.83	$ 8.83	$ 8.83	$ 8.83	$ 8.83	$ 8.83
	Cost	$ 22,655,095	$ 11,711,276	$ 22,655,095	$ 14,656,322	$ 22,655,095	$ 19,578,173
Expand Escanaba	Capacity	8,700,000	8,700,000	8,700,000	8,700,000	8,700,000	8,700,000
	Tons Dispatched	2,092,046	-	2,944,907	-	4,437,451	-
	Cost per ton	$ 37.38	$ 37.38	$ 37.38	$ 37.38	$ 37.38	$ 37.38
	Cost	$ 78,210,377	$ -	$ 110,094,290	$ -	$ 165,892,499	$ -
All Modes	**Total Costs**	**$ 110,660,270**	**$ 17,902,784**	**$ 142,544,183**	**$ 20,847,830**	**$ 198,342,392**	**$ 25,769,681**

7.7 Other National Economic Development Benefits:

7.7.1 Vessel Delay and Layup Costs Avoided

With unscheduled service disruption events at the Soo Locks complex, project throughput is lessened. With closure or slowing of the MacArthur Lock, impacts are relatively minor. Vessels transiting the MacArthur Lock can simply shift over to the larger Poe Lock. Some queuing can occur, but given the capacity of the Poe Lock and current and anticipated future traffic levels, impacts are relatively minor. With closure or slowing of the Poe Lock, however, impacts can be significant. As discussed, a large portion of the fleet and a large portion of the tonnage transiting the project, are in Poe-restricted vessels. When the Poe Lock is closed, these vessels simply cannot transit the project.

Vessel costs from service disruption events manifest in queuing and increased transit time (delay costs) and in Poe-restricted vessels being laid up or idled during Poe Lock closure events. In the Soo-REM simulation model, given a service disruption, the resulting project throughput, average transit time, and hours of Poe-restricted vessel layup are estimated off the Baird ARENA® vessel-level simulation results (**attachment 7**).

7.7.2 Repair Costs Avoided

With simulated component unscheduled engineering reliability failure event, a repair cost is pulled along with the service disruption specification (type and duration) from the engineering reliability event-tree. As with the other metrics, SOO-ServiceDisruptionSim.xlsx summarizes the repair costs for transfer to the SOO-CostBenefit.xlsx workbook for amortization and use in the cost-benefit analyses.

7.7.3 Major Maintenance Costs Avoided

In addition to unscheduled repair costs, each analyzed alternative can have different maintenance cost needs. Maintenance costs are itemized into two categories: normal operations and maintenance (O&M) and major maintenance. Normal O&M is defined as a fixed annual expense for base operations, while major maintenance costs are periodic work packages which often increase in frequency and cost through time as the project (e.g., component) ages.

7.7.4 Decommissioning Costs Avoided

The age and condition of the existing Davis and Sabin locks, located in the North Canal, have resulted in discontinued use. In the without-project condition, expenditures will be necessary to close and decommission the locks. The USACE Detroit District Operations estimated that it would cost $21.55 million to decommission the Davis and Sabin locks, and it would occur from 2025-2028. In the with-project condition, the new Poe-sized lock will be constructed in the North Canal, utilizing features of the existing Davis and Sabin locks, thus decommissioning expenditures will not be necessary. **Table 7-8** and **Table 7-9** provide the results of this analysis at a 2.75 and 7.00 percent discount rates.

Table 7-8—Davis and Sabin Decommissioning Costs Avoided, 2.75 Percent Discount Rate

(FY2018 prices at 2.75 percent discount rate)		
	Total First Cost	
Year	WOPC	WPC
2020	$ -	$ -
2021	$ -	$ -
2022	$ -	$ -
2023	$ -	$ -
2024	$ -	$ -
2025	$ 1,000,000	$ -
2026	$ 7,650,500	$ -
2027	$ 7,650,500	$ -
2028	$ 5,250,000	$ -

Total First Cost:	**$ 21,551,000**	**$ -**
Average Annual Cost:	**$ 781,433**	**$ -**

Table 7-9 - Davis and Sabin Decommissioning Costs Avoided, 7.0 Percent Discount Rate

Davis/Sabin Decommissioning Costs Avoided		
(FY2018 prices at 7.00% discount rate)		
	Total First Cost	
Year	WOPC	WPC
2020	$ -	$ -
2021	$ -	$ -
2022	$ -	$ -
2023	$ -	$ -
2024	$ -	$ -
2025	$ 1,000,000	$ -
2026	$ 7,650,500	$ -
2027	$ 7,650,500	$ -
2028	$ 5,250,000	$ -

Total First Cost:	**$ 21,551,000**	**$ -**
Average Annual Cost:	**$ 1,482,200**	**$ -**

7.7.5 Recreation Benefits

Recreation benefits are based on the increase in the recreational experience due to construction of the new Poe-sized lock. The value of the recreation experience was calculated using the unit day value method for general recreation, as outlined in Economic Guidance Memorandum (EGM) 18-03.

Recreation was evaluated for three categories. The first is increased recreational experience for the users of the visitor center. The second is for increased recreational experience for the owners and passengers of small recreational craft that transit the locks. The third is increased recreational experience for the passengers of the tour boats that transit the locks.

Recreational experiences were rated according to the five criteria defined in EGM 18-03: recreational experience, availability of opportunity, carrying capacity, accessibility, and environmental quality. An assessment was performed for each of the three types of recreational users, for without-project, and with-project conditions. Each criterion was assigned a minimum, most likely, and maximum point value based on expert judgment, and a Unit Day Value (UDV) was identified for each total point value using the EGM 18-03 "conversion of points to dollar values" table for general recreation. This process was repeated for each of the three user categories to obtain the value of the recreational experience. A summary of the unit day values, by user type, for without-project and with-project conditions are summarized in **Table 7-10.**

Based upon PDT interpretation of "judgment factors" defined in table 1 of EGM 18-03, unit day point values are higher for three categories under the with-project condition. The recreation experience category is three points higher because a higher quality recreational experience is expected with the addition of a second Poe sized lock. The ability to view the new lock is considered to be an additional "general activity". The carrying capacity category is 3 points higher since the current facilities are considered "adequate", but the addition of a second Poe-sized lock make them "optimum". The environmental category is 4 points higher because the current facilities are considered to have "above average aesthetic quality", but the addition of a second Poe-sized lock would make them "highly aesthetic". Availability of opportunity and accessibility categories were assumed to be the same under the without-project, and with-project conditions.

Table 7-10—Summary of Unit Day Values

Scenario	Value	Visitor Center			Recreational Crafts			Tour Boat Passengers		
		Min	Most Likely	Max	Min	Most Likely	Max	Min	Most Likely	Max
Without-project	Point Values	49	58	67	53	63	73	53	63	73
	UDV	$8.51	$9.22	$9.72	$8.84	$9.52	$10.18	$8.84	$9.52	$10.18
With-project	Point Values	59	68	77	63	73	83	63	73	83
	UDV	$9.29	$9.77	$10.58	$9.52	$10.18	$11.12	$9.52	$10.18	$11.12

These unit day values were then multiplied by the number of visitors that would use the facilities under without-project and with-project conditions.

Historical data was provided by the Soo Area Office (SAO), including annual visitor's center attendance, and recreational passenger counts for private crafts and tour boats. Annual attendance at the visitor center averaged 342,600 (2012 to 2017), private recreational craft passengers averaged 1,300 (2008 to 2017), and tour boat passengers averaged 74,200 (2008 to 2017).

This historical data was used to develop estimates of recreation usage over the 50-year evaluation period under without-project and with-project conditions. For the without-project condition, visitation was expected to be the fixed averages referenced above for the 50-year planning horizon. For the with-project condition, projections were developed by applying the same 'percentage increase from the without-project condition' identified in the 2005 Soo Locks LRR, across the 2018 Soo Locks validation study planning horizon. 2005 LRR Projections are provided in **Table 7-11,** and with-project condition percentage increase in visitation is displayed in **Table 7-12.** Through 2005 interviews with industry experts, tour boat passengers were expected to increase 2.3 percent, recreational craft passengers were expected to remain constant, and visitor's center participation was expected to mirror the usage fluctuations experienced when the initial project was constructed.

Table 7-11 – 2005 Soo Locks LRR Recreation Projections

Recreational Activities by Usage Category Without-Project and With-Project Conditions			
Cond. / Year	**Visitors Center**	**Rec. Craft Passengers**	**Tour Boat Passengers**
Without-Project			
2014	515,217	4,200	222,574
2024	521,739	4,200	225,391
2034	506,522	4,200	218,817
2044	500,000	4,200	216,000
2054	484,783	4,200	209,426
2064	478,261	4,200	206,609
With-Project			
2014	932,985	4,200	227,726
2024	685,709	4,200	230,609
2034	704,194	4,200	223,883
2044	723,620	4,200	221,000
2054	743,582	4,200	214,274
2064	764,095	4,200	211,391

Table 7-12 – 2005 Soo Locks LRR – With Project Condition Percentage Increase in Visitation

Year	Visitors Center	Rec Craft Passengers	Tour Boat Passengers
2014	81%	0%	2.3%
2024	31%	0%	2.3%
2034	39%	0%	2.3%
2044	45%	0%	2.3%
2054	53%	0%	2.3%
2064	60%	**0%**	**2.3%**

A summary of 2018 validation study without-project and with-project condition recreational usage projections by decade is provided in **Table 7-13**.

Table 7-13—Recreational Activities by Usage Category Without-Project and With-Project Conditions

Cond. / Year	Visitors Center	Rec. Craft Passengers	Tour Boat Passengers
Without-Project			
2027	342,600	1,300	74,200
2036	342,600	1,300	74,200
2046	342,600	1,300	74,200
2056	342,600	1,300	74,200
2066	342,600	1,300	74,200
2076	342,600	1,300	74,200
With-Project			
2027	620,400	1,300	75,918
2036	450,271	1,300	75,918
2046	476,301	1,300	75,918
2056	495,824	1,300	75,918
2066	525,495	1,300	75,918
2076	547,356	1,300	75,918

Table 7-14 and **Table 7-15** summarize the results the 2018 Soo Locks validation study recreation analysis.

Table 7-14 - Average Annual Recreation Benefit Summary

Scenario	Benefit Category	Expected	
With-Project	Visitor Center	$	6,061,300
	Recreational Craft	$	13,200
	Tour Boats	$	772,800
	Total:	***$***	***6,847,300***
Without-Project	Visitor Center	$	3,158,800
	Recreational Craft	$	12,400
	Tour Boats	$	706,400
	Total:	***$***	***3,877,600***
Incremental Benefits	Visitor Center	$	2,902,500
	Recreational Craft	$	800
	Tour Boats	$	66,400
	Total:	***$***	***2,969,700***

Table 7-15 - Soo Locks Complex Expected Annual Benefit Summary

Category	Expected Annual Benefit (2.75%)	Expected Annual Benefit (7.00%)
Visitor Center:	**$2,902,500**	**$2,902,500**
Recreational Craft:	**$800**	**$800**
Tour Boats:	**$66,400**	**$66,400**
Total Recreation Benefits:	**$2,969,700**	**$2,969,700**

7.7.6 Labor Resource Benefits

Appendix D, Page D-31 of ER 1105-2-100, (dated 30 June 2004), provides guidance on the NED benefit evaluation procedure for unemployed or underemployed labor resources, which is defined as …"the economic effects of the direct use of otherwise unemployed or underemployed labor resources during project construction or installation."

This guidance further defines the criteria required for benefit inclusion:

> Benefits from use of otherwise unemployed or underemployed labor resources may be recognized as a project benefit if the area has substantial and persistent unemployment at the time the plan is submitted for authorization and for appropriations to begin construction. Substantial and persistent unemployment exists in an area when:

(a) The current rate of unemployment, as determined by appropriate annual statistics for the most recent 12 consecutive months, is 6 percent or more and has averaged at least 6 percent for the qualifying time periods specified in subparagraph (b) below and:

(b) The annual average rate of unemployment has been at least: (a) 50 percent above the national average for three of the preceding four calendar years, or (b) 75 percent above the national average for two of the preceding three calendar years, or (c) 100 percent above the national average for one of the preceding two calendar years.

Given the criteria above and recent unemployment trends in Chippewa County, Michigan, determined by the U.S. Bureau of Labor Statistics, construction of a new Poe-sized lock qualifies for labor resource benefits. **Table 7-16** shows that Chippewa County, Michigan, experienced an unemployment rate greater than 6 percent over the most recent 12 months of published data. **Table 7-17** displays that Chippewa County, Michigan, experienced an annual average rate of unemployment that was 50 percent above the National average for three of the preceding four calendar years (2017, 2016, and 2014)

Table 7-16—Chippewa County, Michigan—Monthly Unemployment Rates

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	12%	12%	11%	10%	11%	11%	11%	10%	9%	9%	10%	10%
2014	12%	12%	12%	10%	10%	10%	10%	9%	7%	7%	8%	8%
2015	10%	10%	10%	8%	8%	8%	8%	7%	5%	6%	6%	7%
2016	9%	9%	9%	8%	7%	7%	8%	7%	6%	6%	6%	8%
2017	10%	11%	9%	7%	6%	7%	7%	7%	6%	6%	6%	9%
Source: U.S. Bureau of Labor Statistics												

Table 7-17—Annual Unemployment Rates—National vs. Chippewa County, Michigan

Year	Chippewa County, Michigan - Annual Unemployment Rate	National - Annual Unemployment Rate	Chippewa, County Michigan - (Percent Higher than National)
2013	10.53%	7.40%	42.23%
2014	9.56%	6.20%	54.17%
2015	7.72%	5.30%	45.60%
2016	7.37%	4.90%	50.34%
2017	7.41%	4.40%	68.37%
Source: U.S. Bureau of Labor Statistics			

The study team expects that unemployed labor from this county would be utilized to construct a second Poe sized lock.

Given the total man hours required for construction and the expected construction duration, LRH cost engineering estimates that 60 Full-Time Equivalent (FTE) construction employees would be required on an annual basis. Although the annual average is 60 FTEs, the labor need is expected to fluctuate based on peak construction activities. To gauge the magnitude of this peak fluctuation, cost engineering interviewed the resident engineer for Marmet Lock and Dam, who estimated that a maximum of 250-400 workers may be required. Based on this assessment, it is assumed that a range of 60-400 FTEs would be required to construct a second Poe sized lock.

Since Chippewa County, MI is a relatively small county (2017 population of 38,520 and 2017 labor force of 16,451), the Bureau of Labor Statistics (BLS) does not provide detailed estimates on occupational employment. To estimate the number unemployed construction workers in Chippewa County, MI, state level labor force and construction estimates were analyzed and extrapolated to the County. As displayed in **Table 7-18**, in 2017 the state of Michigan had a labor force of 4,882,583, and 162,792 of these employees were classified as “construction workers”, representing 3.33 percent of the total workforce. This percentage was applied to the 2017 Chippewa County, MI unemployed labor force projection (1,287) to obtain an estimated number of unemployed construction workers in the county.

Table 7-18 – Labor Resource Benefit Employment Analysis

Statistic	Value	Data Reference
FTEs Required to Construct New Lock	60-400	USACE Huntington District Cost Engineering
Michigan - Labor Force	4,882,583	U.S. Bureau of Labor Statistics (2017)
Michigan - Construction Employment	162,792	U.S. Bureau of Labor Statistics (2017)
Michigan - Percentage of Construction Employment of Total Labor Force	3.33%	U.S. Bureau of Labor Statistics (2017)
Chippewa County, MI - Population	38,520	U.S. Census Bureau (2010)
Chippewa County, MI - Labor Force	16,451	Michigan Dept. of Technology, Management and Budget (2017)
Chippewa County, MI - Unemployment	7.41%	U.S. Bureau of Labor Statistics (2017)
Chippewa County, MI - Unemployed Labor Force	1,287	Michigan Dept. of Technology, Management and Budget (2017)

Assumed Unemployed Workers in Chippewa County:	**43**

Chippewa County, MI is expected to have 43 unemployed construction workers within the county. Given the construction FTE projections provided by cost engineering (60 average annual and 400 peak), county labor would be available to fill 72 percent of average annual need, and 11 percent of peak need. This estimate could be conservative since current workers in "non-construction" sectors may have the required skills to enter the construction field if these high paying jobs became available.

Based upon these estimates, assuming that 25 percent of construction workers would be hired locally seems reasonable. The initial investment would create new jobs, thereby directly reducing unemployment. There would be demands for both labor and construction materials required for the project, and incomes of individuals in associated industries would be increased indirectly due to the interrelationship and interdependence of these industries. These conditions would stimulate the economy and raise the general level of income.

Applying the same labor metrics identified in the 2005 LRR, direct labor costs account for 40.8 percent of the total construction cost and are allocated among three categories of workers: skilled (40 percent), semi-skilled (50 percent), and administrative/supervisory (10 percent). It is also assumed that 25 percent of this direct labor would be hired locally.

Since O&M major maintenance activities would occur to rehabilitate the Poe and MacArthur Locks in the without-project condition, an incremental analysis of labor resource benefits was performed.

Table 7-19 and **Table 7-20** display labor resource benefits at 2.75 percent and 7.0 percent, respectively.

Table 7-19—Labor Resource Benefit—New Poe-Sized Lock, 2.75 Percent Discount Rate

UNEMPLOYED OR UNDEREMPLOYED LABOR RESOURCES BENEFIT

(FY 2018 dollars at 2.75%)

1. Estimate On-Site Labor Cost			
Total Project Cost (remaining)*:			$793,648,170
Percent Allocated to Labor:			40.8%
On Site Labor Cost:			$323,810,000
2. Allocation of On-Site Labor Cost			
Labor Classification	On Site Labor Cost	Percent Allocation	Wages
Skilled	$323,810,000	40%	$129,524,000
Semiskilled and Unskilled	$323,810,000	50%	$161,905,000
Administrative and Supervisory	$323,810,000	10%	$32,381,000
		TOTAL:	$323,810,000
3. Allocation of Wages to Locally Unemployed or Underemployed Labor			
Labor Classification	Wages	Percent of Locally Hired Labor	Wages Paid to Local Hired Unemployed or Underemployed Labor
Skilled	$129,524,000	25%	$32,381,000
Semiskilled and Unskilled	$161,905,000	25%	$40,476,250
Administrative and Supervisory	$32,381,000	25%	$8,095,250
		TOTAL:	$80,952,500
4. Average Annual Labor Resource Benefits			
		Average Annual Labor Resource Benefits:	$2,998,555
		Less WOPC O&M Major Maintenance Labor Resource Benefits Foregone:	$1,390,701
		TOTAL:	$1,607,854

** Only remaining costs are applicable. Does not include E&D, S&A, or land costs.*

Table 7-20—Labor Resource Benefit—New Poe-Sized Lock, 7.0 Percent Discount Rate

UNEMPLOYED OR UNDEREMPLOYED LABOR RESOURCES BENEFIT

(FY 2018 dollars at 7%)

1. Estimate On-Site Labor Cost			
Total Project Cost (remaining)*:			$793,648,170
Percent Allocated to Labor:			40.8%
On Site Labor Cost:			$323,810,000
2. Allocation of On-Site labor Cost			
Labor Classification	On Site Labor Cost	Percent Allocation	Wages
Skilled	$323,810,000	40%	$129,524,000
Semiskilled and Unskilled	$323,810,000	50%	$161,905,000
Administrative and Supervisory	$323,810,000	10%	$32,381,000
TOTAL:			$323,810,000
3. Allocation of Wages to Locally Unemployed or Underemployed Labor			
Labor Classification	Wages	Percent of Locally Hired Labor	Wages Paid to Local Hired Unemployed or Underemployed Labor
Skilled	$129,524,000	25%	$32,381,000
Semiskilled and Unskilled	$161,905,000	25%	$40,476,250
Administrative and Supervisory	$32,381,000	25%	$8,095,250
		TOTAL:	$80,952,500
4. Average Annual Labor Resource Benefits			
Average Annual Labor Resource Benefits:			$5,865,806
Less WOPC O&M Major Maintenance Labor Resource Benefits Foregone:			$2,720,505
TOTAL:			$3,145,301

** Only remaining costs are applicable. Does not include E&D, S&A, or land costs.*

Section 8. Project Costs

In the cost-benefit analysis of this project, costs are considered under the without-project and with-project conditions. The costs include not only the implementation (construction) costs of the recommended plan, but also the without-project and with-project condition operations, maintenance, repair, rehabilitation, and replacement (OMRR&R) costs. The recommended plan construction cost used is the FY 2018 Cost Engineering Mandatory Center of Expertise (MCX) project first cost (Constant Dollar Cost at current price level) of $903,158,151 ($871,005,000

remaining and $32,153,000 sunk through FY2017). The OMRR&R costs received from CELRE were indexed to FY 2018.

As with the benefit (impacts avoided) cash flows, costs are discounted/indexed to a base year and amortized for comparison against the average annual benefits. The recommended plan cost used for the benefit-cost ratio (BCR) includes: 1) the project first cost; 2) interest during construction; and 3) any OMRR&R costs greater than the without-project condition. Headquarters U.S. Army Corps of Engineers guidance is that any OMRR&R cost reductions are to be handled as a benefit to the with-project condition. The amortized project costs discounted at 2.75 percent is $32.8 million.

8.1 Operations, Maintenance, Repair, Rehabilitation, and Replacement Costs

The study team itemized future OMRR&R costs were itemized (**attachment 6**) for four future maintenance policy scenarios:

- Without-project condition fix-as-fail (FAF) maintenance policy—reactive maintenance where minimal repairs are performed as needed to maintain the current level of service. Long-run cost effectiveness of maintenance and repairs is not considered.
- Without-project condition most likely maintenance policy—expected replacements and rehabilitation scheduled according to operations/engineering judgment based on previous experience, age of components, LRD gate replacement policy, etc.
- With-project condition with FAF maintenance of old lock chambers—while the new Poe Lock is anticipated to be reliable and experience no unscheduled service disruptions, normal O&M and scheduled maintenance are assumed, the original chambers (existing Poe Lock) are operated under reactive maintenance where minimal repairs are performed as needed to maintain the current level of service. The MacArthur lock would only be operated and maintained as necessary to facilitate new lock construction and major rehabilitation of the existing Poe Lock in order to minimize navigation impacts. Otherwise it can be considered to be in a "caretaker" status. Long-run cost effectiveness of maintenance and repairs is not considered.
- With-project condition with most likely existing Poe Lock chamber maintenance—while the new Poe Lock is anticipated to be reliable and experience no unscheduled service disruptions, normal O&M and scheduled maintenance are assumed, the original Poe Lock is operated under expected replacements and rehabilitation scheduled according to operations/engineering judgment based on previous experience, age of components, LRD gate replacement policy, etc. The MacArthur

lock would only be operated and maintained as necessary to facilitate new lock construction and major rehabilitation of the existing Poe Lock in order to minimize navigation impacts. Otherwise it can be considered to be in a "caretaker" status.

As discussed in the main report, unlike inland navigation projects, Soo receives funding beyond status quo FAF. For this economic update, CELRE recommended the use of the most likely without-project and with-project condition scenarios. The OMRR&R cash flow streams over the planning period are shown in **Figure 8-1**. For the cost-benefit analysis, these cash flows are amortized at the various discount/amortization rates. The planning period (2020-2076) average annual values at 2.75 percent are shown in **Table 8-1**.

Figure 8-1—Operations, Maintenance, Repair, Rehabilitation, and Replacement Costs by Year, Q1 FY18 Dollars

Table 8-1—Average Annual Project OMRR&R Costs, 2020-2076, Q1 FY18 Dollars, 2.75% Discount Rate

OMRR&R Cost Category	Average Annual Project Costs by Maintenance Scenario			
	WOPC by Maint. Scenario		WPC by Maint. Scenario	
	FAF	Most Likely	FAF old Chmbs.	Most Likely old Chmbs.
Normal O&M *	$17,943,596	$17,943,596	$17,943,596	$17,943,596
Replacements				
Project Level	$0	$4,962,663	$0	$4,283,890
New Poe	$0	$0	$0	$0
Old Poe	$0	$3,939,239	$0	$2,373,038
MacArthur	$0	$1,890,659	$0	$0
Major Maintenance				
Project Level	$2,253,264	$564,715	$2,203,507	$504,675
New Poe	$0	$0	$90,397	$270,535
Old Poe	$2,170,914	$1,857,029	$2,170,914	$768,363
MacArthur	$2,112,220	$1,913,442	$28,173	$28,173
TOTAL	$24,479,993	$33,071,343	$22,436,587	$26,172,269

** Normal O&M costs are $14M annually, however, 2.75 percent amortization over 50 years of the 57-year planning period results in an average annual normal O&M of $17.9M.*

During the feasibility analysis, the only major maintenance needs were identified for the MacArthur Lock. The feasibility analysis assumed a $29.0 million rehabilitation of the MacArthur Lock with operations and maintenance expenditures ranging from $2.3 to $3.9 million over the analysis period.

In 1994, a structural reliability analysis was performed in accordance with ETL 1110-2-532, Reliability Assessment of Navigation Structures. The reliability review consisted of a two-step approach. The initial step entailed a detailed inspection of the lock structure and mechanical components, including a review of all past periodic inspections. This analysis concluded that the Poe Lock was in satisfactory condition with no deteriorated conditions contributing to an overall probability of extended lock closure. For the 2005 LRR, given use of the MacArthur chamber only during old Poe or new Poe closures, the MacArthur Lock rehabilitation and major maintenance costs were removed. As a result the 2005 LRR contained no excessive major maintenance costs.

8.2 Sabin and Davis Locks Decommissioning Costs

Under the most likely future without-project condition, lock operations would consist of two locks: the Poe and MacArthur. The Sabin and Davis locks would be decommissioned. The Sabin Lock has essentially been out of active service since 1984, and the Davis Lock has not been staffed on a full-time basis since 1996 (only used on an as needed basis). A concept plan for permanent closure of the Davis and Sabin locks was completed in 1997 and called for steel sheet pile closure cells at each end of each lock, demolition/removal of gates/operating machinery/operating buildings, filling of the lock culverts and chambers, and overall site restoration.

Under the most likely with-project condition, lock operations would consist of three locks: the original Poe, the new Poe, and the MacArthur if and when one of the Poe-sized locks is closed. The Sabin and Davis locks will be removed as part of the new Poe construction.

The estimated cost without-project condition Sabin and Davis decommissioning cost in the 2005 LRR was $9,476,000 (1-OCT-2003 price level). In this economic update the Sabin-Davis locks decommissioning costs are estimated as $21,551,000 (FY 2018 price level) over four years from 2025 through 2028.

8.3 First Costs

The project first cost is defined as the "constant dollar cost at current price level" cost[9]. The project was authorized in Section 1149 of the Water Resources Development Act of 1986 at a project first cost of $227,428,000. In the Section 902, cost limit calculation, the authorized cost at the current price level, is $415,821,315. In the 2005 LRR, the project cost was $341,713,802 (1-OCT-2003 price level)[10]. Currently, the Cost Engineering Mandatory Center of Expertise (MCX) FY 2018 project first cost is $903,158,151 ($871,005,000 remaining and $32,153,000 sunk through FY2017). The MCX FY 2019 project first cost is $922,432,000 ($890,279,000 remaining and $32,153,000 sunk through FY2017). These cost and schedule risk analysis construction costs contain contingencies for an 80 percent confidence (P80) of successful execution and completion.

For the cost-benefit analysis, analysts convert the project first cost (construction cost) to an average annual equivalent value at the various discount/amortization rates. According to ER 1105-2-100 D-3.e. (11)(a) "…expended PED costs will be considered sunk and not included in the benefit-cost ratio." In addition, according to CWPM 21-001, IDC is not to be calculated on

[9] CECW-P Memorandum dated 25-AUG-2011, Subject: Corps of Engineers Civil Works Cost Definitions and Applicability.
[10] Soo LRR dated August 2005 Table 6 (page 19).

sunk expenditures, which excludes PED costs as noted. Amortization of the sunk and remaining construction cost laydown used in this economic update are shown in **Table 8-2**.

Table 8-2—With-project Condition Construction Cost Amortization, Q1 FY18 Dollars, 2.75 Percent Discount Rate, 2027 Base Year

[redacted]

** CWPM 12-001 specifies that IDC should not be calculated on sunk expenditures, sunk year factors set = 1.0.*

*** CELRH-EC-TC and Cost Engineering Mandatory Center of Expertise (MCX) P80 certified cost.*

8.4 Analysis Costs

Cost occur under both the without-project and with-project conditions. In a cost-benefit analysis a with-project condition reduction in costs is a cost-avoided or benefit. For the development of benefit-to-cost ratios, the ratio is sensitive as to whether a reduction in cost is subtracted from the denominator of the ratio or added to the numerator as a cost-avoided benefit. As such, the definition of the with-project condition cost is the project's construction cost and any OMRR&R costs greater than the without-project condition. Any OMRR&R cost reduction will be considered as a benefit to the project, and not as a cost reduction to the project.

As can be seen in **Table 8-3**, whether the OMRR&R costs increases or decreases from the without-project to with-project condition is a function of the maintenance scenarios assumed and the granularity of the OMRR&R cost category. This determination can also be sensitive to the cash flow distribution through time and the discount/amortization rate assumed.

For the base cost-benefit analysis, the most likely without-project condition and most likely with-project condition will be used as directed by CELRE. As shown in **Table 8-3,** the overall at a 2.75 percent discount/amortization rate, OMRR&R costs are reduced by $7.2 million annually. Looking at a chamber level OMRR&R cost category, however, costs are $0.3 million greater for the new Poe chamber. For this economic updated cost-benefit analysis, the OMRR&R costs will be handled as a single cost category, and the total of $6.9 million ($7.2 million minus $0.3 million) will be considered a benefit to the with-project condition.

Table 8-3— With-project Condition OMRR&R Costs and Benefits, *2020-2076, Q1 FY18 Dollars, 2.75% Discount Rate*

Cost Category	Most likely WOPC to Most likely With-project Condition	
	Cost	**Benefit**
Normal O&M	$0	$0
Replacements	$0	$4,135,633
Major Maintenance	$270,535	$3,033,975
TOTAL	$270,535	$7,169,608

Section 9. Economic Evaluation

9.1 Benefit-Cost Analysis of Recommended Plan

Benefits of the chosen alternative include a reduction, relative to the baseline, in the impacts of unscheduled service disruptions and in the costs of scheduled disruptions such as maintenance events. Additionally, the project increases Also, the alternative adds recreation benefits and labor resource benefits.

Unscheduled service disruptions at the project [redacted] result in service disruption impact costs. These include costs of tonnage diverted over existing alternate modes, vessel costs, unscheduled repair costs, and unmet demand costs.

Scheduled project costs are costs generally associated with scheduled events. They include project investment costs, maintenance costs, and both the investment and maintenance costs for alternative transportation modes. They also include unmet demand proxy modes. [redacted] costs.

Benefits resulting from these net costs (service disruption and scheduled project costs) were evaluated by comparing annualized costs in the baseline and with-project conditions for the respective subcategories of each. In cases in which the with-project condition results in a net reduction in costs of one these subcategories, this reduction is a benefit of the with-project condition. Likewise, in cases in which the with-project condition results in a net increase in a cost category, that increase is a cost of the project. **Table 9-1** itemizes the scheduled project cost categories, with costs for both the without-project and with-project conditions shown, as well as net reductions (benefits) and net increases (costs).

Table 9-1—Average Annual Scenario Costs, 2020–2076, Q1 FY18 Dollars, 2.75 percent Discount Rate

Cost Category	WOPC	WPC	Benefit	Cost
Project Investment				
Construction (new Poe Lock)	$421,776	$32,860,129	$0	$32,438,353
Davis / Sabin decommissioning	$781,433	$0	$781,433	$0
Asset Renewal Plan				
Project Level Components	$4,962,663	$4,283,890	$678,772	$0
Poe Lock Components	$3,939,239	$2,373,038	$1,566,202	$0
Mac Lock Components	$1,890,659	$0	$1,890,659	$0
Sub-Total Investment Costs	**$11,995,770**	**$39,517,057**	**$4,917,066**	**$32,438,353**
Project Maintenance				
Normal O&M				
Pre-2027 (pre-online)	$3,943,596	$3,943,596	$0	$0
Post-2027 (post-online)	$14,000,000	$14,000,000	$0	$0
Scheduled Maintenance				
Project Level Components	$564,715	$504,675	$60,039	$0
Old Poe Lock Components	$1,857,029	$768,363	$1,088,667	$0
New Poe Lock Components	$0	$270,535	$0	$270,535
Mac Lock Components	$1,913,442	$28,173	$1,885,269	$0
Sub-Total Maintenance Costs	**$22,278,782**	**$19,515,341**	**$3,033,975**	**$270,535**
TOTALS	**$34,274,552**	**$59,032,398**	**$7,951,041**	**$32,708,888**

The service disruption impact costs are itemized in **Table 9-2** and **Table 9-3**. Diverted tonnage costs both those using existing alternate modes as well as unmet demand proxy modes are itemized by commodity type.

Table 9-2—Average Annual Service Disruption Impacts, 2020–2076, Q1 FY18 Dollars, 2.75 percent Discount Rate

Impact Cost Category	WOPC	WPC	Benefit	Cost
Service Disruption Diverted Tonnage Costs				
Taconite				
Escanaba (existing)	$632,452	$102,842	$529,610	$0
Canadian ore	$137,472	$52,745	$84,726	$0
Coal				
empty upbound mac vessels	$2,658	$849	$1,809	$0
vessel to truck	$0	$0	$0	$0
all overland route	$403	$107	$296	$0
direct rail to coal plants	$336,020	$180,398	$155,622	$0
rail to Toledo	$11,557	$8,285	$3,272	$0
Aggregates				
empty upbound mac vessels	$3,526	$1,164	$2,362	$0
all overland route	$920	$298	$622	$0
Grains (all overland route)	$729,997	$206,200	$523,797	$0
Others (all overland route)	$429,645	$138,918	$290,727	$0
Sub-Total Diverted Tons Costs	**$2,284,650**	**$691,807**	**$1,592,843**	**$0**
Service Disruption Vessel Costs				
Vessel Transit Time Costs	$19,567,206	$17,617,904	$1,949,303	$0
Poe-restricted Vessel Layup (wait at port)	$2,003,976	$672,392	$1,331,584	$0
Sub-Total Vessel Costs	**$21,571,182**	**$18,290,296**	**$3,280,887**	**$0**
Service Disruption Repair Costs				
Engineering Reliability Components	$60,719	$55,210	$5,508	$0
Accidents	$0	$0	$0	$0
Sub-Total Repair Costs	**$60,719**	**$55,210**	**$5,508**	**$0**
TOTALS	**$23,916,551**	**$19,037,313**	**$4,879,238**	**$0**

Table 9-3—Average Annual Unmet Demand Impacts, 2020–2076, Q1 FY18 Dollars, 2.75 percent Discount Rate

Impact Cost Category	WOPC	WPC	Benefit	Cost
Unmet Demand Proxy Impact Costs				
Service Disruption Tonnage Cost (Taconite)				
Conveyor	$35,673	$12,204	$23,470	$0
Stockpile	$1,206,879	$101,512	$1,105,367	$0
Escanaba (expansion)	$4,244,304	$331,135	$3,913,169	$0
Alt. Route Investments *				
Escanaba (existing)				
Investment	$1,983,498	$1,460,915	$522,584	$0
Maintenance	$1,873,654	$1,380,010	$493,643	$0
Conveyor System				
Investment	$1,804,813	$790,390	$1,014,423	$0
Maintenance	$151,887	$66,517	$85,371	$0
Stockpile Expansion				
Investment	$3,475,607	$1,113,265	$2,362,342	$0
Maintenance	$5,839,849	$1,870,551	$3,969,297	$0
Escanaba (expansion)				
Investment	$30,724,042	$4,212,713	$26,511,329	$0
Maintenance	$884,086	$119,497	$764,589	$0
TOTALS	**$52,224,293**	**$11,458,710**	**$40,765,584**	**$0**

** Proxy costs for Unmet Demands were estimated through costing of alternative routing or stockpiling capital investment. Values shown are expected values. Investments made were specific to individual simulation iteration need. Investment was then timed in year 2020 regardless of the year or years needed.*

These total scenario costs (essentially the WOPC and WPC columns in the tables above) are shown as future cost streams over the planning period in **Figure 9-1**, excluding WPC investment costs. For readability, the y-axis is shown in log scale, as first year unmet demand investment costs are significantly higher than any other single year cost.

Figure 9-1—Mean Total Impact Costs & OMRR&R by Planning Period Year, Q1 FY18 Dollars, Present Value, 2.75 percent Discount Rate

The cost streams in the figure above include mean service disruption impact costs. They include unmet demand impacts; and OMRR&R costs, including normal O&M, major maintenance and component replacement investments, and decommissioning of the Davis and Sabin locks. The difference between the without-project and with-project cost streams shown in the figure broadly speaking represent the majority of project benefits, although for the benefit-cost analysis these deltas are computed by benefit category as shown in **Table 9-1** and **Table 9-2** above, rather than as a lump sum. Total benefits by category are shown in **Table 9-4** and **Table 9-5**, for both the 2.75 percent and 7.0 percent discount rate, respectively.

Table 9-4—Average Annual Benefits by Category, 2020–2076, Q1 FY18 Dollars, 2.75 percent Discount Rate

Benefit Category	
Service Disruption Impact Costs Avoided	
Diverted Traffic Costs	$1,592,843
Vessel Transit Time Costs	$1,949,303
Poe-restricted Vessel Layup (wait at port)	$1,331,584
Sub-Total Service Disruption Costs Avoided	**$4,873,730**
Unmet Demand Proxy Transportation Impacts Avoided	
Taconite - via conveyor system	$1,123,263
Taconite - via expanded stockpile	$7,437,006
Taconite - via expanded Escanaba	$31,189,087
Sub-Total Unmet Demand Impacts Avoided	**$39,749,357**
Without-project Costs (WOPC) Costs Avoided (benefits)	
Normal Operations & Maintenance	$0
Scheduled Maintenance	$3,033,975
Escanaba (existing)	$1,016,227
Davis / Sabin decommissioning	$781,433
Service Disruption Repair Costs	
Engineering Reliability Components	$5,508
Accidents	$0
Major Maintenance/Component Replacement	
Project Level Components	$678,772
Poe Lock Components	$1,566,202
MacArthur Lock Components	$1,890,659
Sub-Total WOPC Costs Avoided	**$8,972,776**
Recreation Benefits	
Visitor Center	$2,902,500
Recreational Craft	$800
Tour Boats	$66,400
Sub-Total Recreation Benefits	**$2,969,700**
Labor Resource Benefits	
Labor Resource Benefits	$1,607,854
TOTAL PROJECT BENEFITS without Labor Resource Benefits:	**$56,565,563**
TOTAL PROJECT BENEFITS with Labor Resource Benefits:	**$58,173,417**

Table 9-5—Average Annual Benefits by Category, 2020–2076, Q1 FY18 Dollars, 7.0 percent Discount Rate

Benefit Category	
Service Disruption Impact Costs Avoided	
Diverted Traffic Costs	$1,705,679
Vessel Transit Time Costs	$1,610,559
Poe-restricted Vessel Layup (wait at port)	$1,402,366
Sub-Total Service Disruption Costs Avoided	**$4,718,604**
Unmet Demand Proxy Transportation Impacts Avoided	
Taconite - via conveyor system	$2,644,211
Taconite - via expanded stockpile	$11,935,342
Taconite - via expanded Escanaba	$71,132,880
Sub-Total Unmet Demand Impacts Avoided	**$85,712,433**
Without-project Costs (WOPC) Costs Avoided (benefits)	
Normal Operations & Maintenance	$0
Scheduled Maintenance	$1,685,338
Escanaba (existing)	$1,815,010
Davis / Sabin decommissioning	$1,482,243
Service Disruption Repair Costs	
Engineering Reliability Components	$0
Accidents	$0
Major Maintenance/Component Replacement	
Project Level Components	$1,345,568
Poe Lock Components	$1,297,073
MacArthur Lock Components	$2,769,883
Sub-Total WOPC Costs Avoided	**$10,395,114**
Recreation Benefits	
Visitor Center	$2,902,500
Recreational Craft	$800
Tour Boats	$66,400
Sub-Total Recreation Benefits	**$2,969,700**
Labor Resource Benefits	
Labor Resource Benefits	$3,145,301
TOTAL PROJECT BENEFITS without Labor Resource Benefits:	**$103,795,851**
TOTAL PROJECT BENEFITS with Labor Resource Benefits:	**$106,941,152**

In addition to the above benefits, estimated gross benefits including annualized recreation and labor resource benefits attributable to the with-project condition are included. These are summarized in **Table 9-6.**

Table 9-6—Average Annual Other Benefit Categories, 2020–2076, Q1 FY18 Dollars

Benefit Category	2.75% Discount Rate	7.0% Discount Rate
Recreation Benefits		
Visitor Center	$2,902,500	$2,902,500
Recreational Craft	$800	$800
Tour boats	$66,400	$66,400
Sub-Total Recreation Benefits	**$2,969,700**	**$2,969,700**
Labor Resource Benefits		
Labor Resource Benefits	$1,607,854	$3,145,301
TOTALS	**$4,577,554**	**$6,115,001**

Figure 9-2 shows a comparison of annualized benefits by category to annualized costs, illustrating the relative contribution to total project benefits of each category. The green-shaded segments of the annualized benefits are the combined unmet demand benefits. They include the alternate mode investment and maintenance costs, as well incremental transportation costs of tonnage diverted over these proxy unmet demand modes. The orange-shaded segments include the costs associated with tonnage diverted to existing alternate modes. They also cover the existing facility at Escanaba, as well as vessel delay and layup costs. Yellow-shaded segments include scheduled maintenance and investment costs avoided. These include the reductions in scheduled component replacement costs afforded by the presence of the new lock chamber. Finally, unscheduled repair costs, Davis/Sabin decommissioning costs avoided, and recreation and labor resource benefits are combined into the “other” category. As illustrated in this figure, unmet demand costs represent the majority of benefits.

Figure 9-2—Average Annual Benefits by Benefit Category, 2020–2076, Q1 FY18 Dollars, 2.75 percent Discount Rate

Total service disruption impacts (the total green- and red-shaded areas in **Figure 9-2** above, along with unscheduled repair costs) are shown in **Figure 9-3** subdivided by project risk category; that is risk of accident related closures (blue shaded area), risk of closures due to Poe lock component failures (purple-shaded area), risk of closures due to project level component failures (gray-shaded area), and finally risk of closures due to MacArthur lock component failures (orange-shaded area). As shown in the figure, the majority of impact costs result from [redacted]

Figure 9-3- Average Annual Service Disruption Impacts by Risk Category, 2020–2076, Q1 FY18 Dollars, 2.75 percent Discount Rate

When the investment alternative costs are matched against benefits, the net benefits and benefit-cost ratios can be summarized, as shown in **Table 9-7**. These net benefit and benefit-cost ratio calculations are shown at both the current FY18 discount rate of 2.75 percent, as well as a 7.0 percent rate.

Table 9-7—Benefit-to-Cost Evaluation, 2020–2076, Q1 FY18 Dollars

Cash Flow Category	New Poe-Size Lock	
	2.75% Discount Rate	7.0% Discount Rate
Total Average Annual Project Costs	$32,708,888	$69,480,408
Total Average Annual Project Benefits	$56,565,563	$103,795,851
BASE NET BENEFITS	$23,856,675	$34,315,443
BENEFIT-TO-COST RATIO (BCR)	**1.73**	**1.49**
Base Net Benefits	$23,856,675	$34,315,443
Allowable Labor Resource Benefits	$1,607,854	$3,145,301
NET BENEFITS	$25,464,528	$37,460,744
BENEFIT-TO-COST RATIO (BCR)	**1.78**	**1.54**

9.2 Sensitivity Analyses

Elements of uncertainty should always be identified or acknowledged in estimates of benefits. Where practicable, uncertain input parameters were captured in the analysis stochastically. The following sections seek to illustrate the degree to which identified critical or controversial input parameters drive model results as well as the results of sensitivity analyses required by policy.[11] It is important to note that the scenarios described below are intended to illustrate the sensitivities of model outputs to changes in critical input assumptions, but these changes in assumptions are not interchangeable or equally probable to those assumed in the base analysis as detailed in preceding sections, nor was the level of rigor used in development of sensitivity assumptions comparable with that used to inform the base analysis. In some cases a range of possible assumptions are provided, such as for traffic forecasts or accident closure durations, however these ranges do not necessarily represent a distribution of possible inputs or have any probabilistic weighting attached. Additionally, not all sensitivity scenarios presented below represent policy compliant analyses. For these reasons, these sensitivity analyses are intended to demonstrate the relative significance of key input assumptions as well as to provide additional information to decision makers, and should not be viewed as representing a distribution of possible outputs.

9.2.1 Alternate Forecast Scenarios

The preceding economic analyses were largely based on the results of the mid-level (or reference) traffic forecast scenario, which represents the most probable future. In light of

[11] See ER 1105-2-100 Section E-9 subsection (e) subsection 4 for required sensitivity analyses.

uncertainty surrounding this traffic level and the future of key industrial markets, alternate traffic forecast scenarios were developed to help gauge the sensitivity of the project benefits against different levels of tonnage. These include a high traffic scenario, and a low traffic scenario. Two additional sensitivities were also run: a traffic forecast scenario that assumes no traffic growth occurs and traffic remains at historically observed levels, and one that assumes the most probable traffic growth occurs, but growth is held flat after 20 years from the first forecasted year. Holding growth flat after 20 years has the effect of weighting the initial years of the project's economic life and deemphasizing the latter years, which, by their nature involve greater uncertainty.

Table 9-8 displays the derivation of these results from the reference case at the prevailing federal discount rate. These results show that under either traffic scenario, the project remains economically justified with positive net benefits and a benefit-cost ratio ranging from approximately 1.27 to 2.79. Even when growth is limited to the low scenario, which assumes a decline in traffic due to decreased reliance on integrated steel and substantial declines in coal consumption, the project remains economically justified. This however does not remain true for the 7.0 percent rate, where the low forecast scenario results in a benefit-cost ratio of 0.98.

Table 9-8—Benefit-to-Cost Evaluation, Traffic Forecast Sensitivity, 2020–2076, Q1 FY18 Dollars, 2.75 percent Discount Rate

	Traffic Forecast Scenario				
Cash Flow Category	**Base**	**Low**	**High**	**No Growth**	**No Growth After 20 Yrs**
Total Average Annual Project Costs	$32,708,888	$32,708,888	$32,708,888	$32,708,888	$32,708,888
Total Average Annual Project Benefits	$56,565,563	$39,790,021	$89,742,299	$54,450,202	$54,600,800
BASE NET BENEFITS	$23,856,675	$7,081,133	$57,033,411	$21,741,314	$21,891,912
BENEFIT-TO-COST RATIO (BCR)	**1.73**	**1.22**	**2.74**	**1.66**	**1.67**
Base Net Benefits	$23,856,675	$7,081,133	$57,033,411	$21,741,314	$21,891,912
Allowable Labor Resource Benefits	$1,607,854	$1,607,854	$1,607,854	$1,607,854	$1,607,854
NET BENEFITS	$25,464,528	$8,688,986	$58,641,265	$23,349,168	$23,499,766
BENEFIT-TO-COST RATIO (BCR)	**1.78**	**1.27**	**2.79**	**1.71**	**1.72**

Table 9-9—Benefit-to-Cost Evaluation, Traffic Forecast Sensitivity, 2020–2076, Q1 FY18 Dollars, 7.0% Discount Rate

Cash Flow Category	Traffic Forecast Scenario				
	Base	**Low**	**High**	**No Growth**	**No Growth After 20 Yrs**
Total Average Annual Project Costs	$69,480,408	$69,480,408	$69,480,408	$69,480,408	$69,480,408
Total Average Annual Project Benefits	$103,795,851	$67,849,633	$172,692,849	$97,913,388	$99,469,633
BASE NET BENEFITS	$34,315,443	-$1,630,775	$103,212,441	$28,432,980	$29,989,225
BENEFIT-TO-COST RATIO (BCR)	**1.49**	**0.98**	**2.49**	**1.41**	**1.43**
Base Net Benefits	$34,315,443	($1,630,775)	$103,212,441	$28,432,980	$29,989,225
Allowable Labor Resource Benefits	$3,145,301	$0	$3,145,301	$3,145,301	$3,145,301
NET BENEFITS	$37,460,744	($1,630,775)	$106,357,742	$31,578,281	$33,134,526
BENEFIT-TO-COST RATIO (BCR)	**1.54**	**0.98**	**2.53**	**1.45**	**1.48**

A more granular itemization of these benefits and the individual benefit categories' sensitivity to changes in traffic levels (at different interest rates) can be found in the following tables.

Table 9-10—Average Annual Benefits by Category, Traffic Forecast Sensitivity, 2020–2076, Q1 FY18

Dollars, 2.75 percent Discount Rate

Benefit Category	Traffic Forecast Scenario				
	Base	Low	High	No Growth	No Growth After 20 Yrs
Service Disruption Impact Costs Avoided					
Diverted Traffic Costs	$1,592,843	$1,151,613	$2,737,872	$1,801,709	$1,543,087
Vessel Transit Time Costs	$1,949,303	$1,181,907	$4,363,781	$2,129,370	$1,864,671
Poe-restricted Vessel Layup (wait at port)	$1,331,584	$883,270	$2,384,739	$1,479,598	$1,302,127
Sub-Total Service Disruption Costs Avoided	**$4,873,730**	**$3,216,790**	**$9,486,391**	**$5,410,678**	**$4,709,885**
Unmet Demand Proxy Transportation Impacts Avoided					
Taconite - via conveyor system	$1,123,263	$1,049,191	$1,241,001	$1,146,824	$1,108,912
Taconite - via expanded stockpile	$7,437,006	$6,299,550	$8,564,024	$7,456,942	$7,351,184
Taconite - via expanded Escanaba	$31,189,087	$16,814,026	$58,599,743	$28,404,610	$29,485,758
Sub-Total Unmet Demand Impacts Avoided	**$39,749,357**	**$24,162,767**	**$68,404,768**	**$37,008,376**	**$37,945,854**
Without-project Costs (WOPC) Costs Avoided (benefits)					
Normal Operations & Maintenance	$0	$0	$0	$0	$0
Scheduled Maintenance	$3,033,975	$3,033,975	$3,033,975	$3,033,975	$3,033,975
Escanaba (existing)	$1,016,227	$1,483,272	$922,818	$1,105,207	$1,017,837
Davis / Sabin decommissioning	$781,433	$781,433	$781,433	$781,433	$781,433
Service Disruption Repair Costs					
Engineering Reliability Components	$5,508	$6,450	$7,581	$5,200	$6,483
Accidents	$0	$0	$0	$0	$0
Major Maintenance/Component Replacement					
Project Level Components	$678,772	$678,772	$678,772	$678,772	$678,772
Poe Lock Components	$1,566,202	$1,566,202	$1,566,202	$1,566,202	$1,566,202
MacArthur Lock Components	$1,890,659	$1,890,659	$1,890,659	$1,890,659	$1,890,659
Sub-Total WOPC Costs Avoided	**$8,972,776**	**$9,440,764**	**$8,881,440**	**$9,061,448**	**$8,975,361**
Recreation Benefits					
Visitor Center	$2,902,500	$2,902,500	$2,902,500	$2,902,500	$2,902,500
Recreational Craft	$800	$800	$800	$800	$800
Tour Boats	$66,400	$66,400	$66,400	$66,400	$66,400
Sub-Total Recreation Benefits	**$2,969,700**	**$2,969,700**	**$2,969,700**	**$2,969,700**	**$2,969,700**
Labor Resource Benefits					
Labor Resource Benefits	$1,607,854	$1,607,854	$1,607,854	$1,607,854	$1,607,854
TOTAL PROJECT BENEFITS without Labor Resource Benefits:	**$56,565,563**	**$39,790,021**	**$89,742,299**	**$54,450,202**	**$54,600,800**
TOTAL PROJECT BENEFITS with Labor Resource Benefits:	**$58,173,417**	**$41,397,875**	**$91,350,153**	**$56,058,056**	**$56,208,654**

Table 9-11—Average Annual Benefits by Category, Traffic Forecast Sensitivity, 2020–2076, Q1 FY18

Dollars, 7.0 percent Discount Rate

Benefit Category	Traffic Forecast Scenario				
	Base	Low	High	No Growth	No Growth After 20 Yrs
Service Disruption Impact Costs Avoided					
Diverted Traffic Costs	$1,705,679	$1,260,975	$2,730,064	$1,923,161	$1,687,646
Vessel Transit Time Costs	$1,610,559	$1,061,529	$3,263,154	$1,745,597	$1,552,151
Poe-restricted Vessel Layup (wait at port)	$1,402,366	$981,679	$2,425,789	$1,559,180	$1,404,488
Sub-Total Service Disruption Costs Avoided	**$4,718,604**	**$3,304,183**	**$8,419,006**	**$5,227,938**	**$4,644,286**
Unmet Demand Proxy Transportation Impacts Avoided					
Taconite - via conveyor system	$2,644,211	$2,474,295	$2,914,043	$2,699,269	$2,610,892
Taconite - via expanded stockpile	$11,935,342	$10,085,189	$13,716,716	$11,972,442	$11,793,269
Taconite - via expanded Escanaba	$71,132,880	$37,786,995	$134,445,101	$64,490,004	$67,053,496
Sub-Total Unmet Demand Impacts Avoided	**$85,712,433**	**$50,346,478**	**$151,075,860**	**$79,161,715**	**$81,457,657**
Without-project Costs (WOPC) Costs Avoided (benefits)					
Normal Operations & Maintenance	$0	$0	$0	$0	$0
Scheduled Maintenance	$1,685,338	$1,685,338	$1,685,338	$1,685,338	$1,685,338
Escanaba (existing)	$1,815,010	$2,649,167	$1,648,179	$1,973,932	$1,817,887
Davis / Sabin decommissioning	$1,482,243	$1,482,243	$1,482,243	$1,482,243	$1,482,243
Service Disruption Repair Costs					
Engineering Reliability Components	$0	$0	$0	$0	$0
Accidents	$0	$0	$0	$0	$0
Major Maintenance/Component Replacement					
Project Level Components	$1,345,568	$1,345,568	$1,345,568	$1,345,568	$1,345,568
Poe Lock Components	$1,297,073	$1,297,073	$1,297,073	$1,297,073	$1,297,073
MacArthur Lock Components	$2,769,883	$2,769,883	$2,769,883	$2,769,883	$2,769,883
Sub-Total WOPC Costs Avoided	**$10,395,114**	**$11,229,271**	**$10,228,283**	**$10,554,036**	**$10,397,991**
Recreation Benefits					
Visitor Center	$2,902,500	$2,902,500	$2,902,500	$2,902,500	$2,902,500
Recreational Craft	$800	$800	$800	$800	$800
Tour Boats	$66,400	$66,400	$66,400	$66,400	$66,400
Sub-Total Recreation Benefits	**$2,969,700**	**$2,969,700**	**$2,969,700**	**$2,969,700**	**$2,969,700**
Labor Resource Benefits					
Labor Resource Benefits	$3,145,301	$3,145,301	$3,145,301	$3,145,301	$3,145,301
TOTAL PROJECT BENEFITS without Labor Resource Benefits:	**$103,795,851**	**$67,849,633**	**$172,692,849**	**$97,913,388**	**$99,469,633**
TOTAL PROJECT BENEFITS with Labor Resource Benefits:	**$106,941,152**	**$70,994,934**	**$175,838,150**	**$101,058,689**	**$102,614,934**

9.2.2 No Failures during Construction

A key requirement in Corps of Engineers planning is to analyze and account for benefits over the 50-year analysis period for the project under consideration. The relationship of this analysis period to the overall planning horizon (and the planning period) can be seen in **Figure 9-4**.

Figure 9-4—Planning Period

A significant and highly influential factor to the benefit streams that occur over this 50-year analysis period is the activity that occurs in the planning period before the Base Year, also known as the construction (or implementation) period. As an example, consider a hypothetical lock with significant risk that its components might fail in the near term. When analyzing prospective solutions (alternatives) to mitigate this near-term risk, one must consider the timing of the different solutions to solving this risk. Solutions that can be brought online sooner or that can mobilize faster may show more positive benefits than more robust solutions that take longer to implement. If lock components fail, get fixed, and become reliable before the proposed solution comes online, benefits over the 50-year analysis period can be significantly reduced, since there is less risk to buy down in the future. If the condition of those lock components were held constant, this would allow the with-project condition to solve the full level of risk, yielding greater net benefits.

Essentially, this means analyzing the entirety of the planning period and accounting for the likelihood that significant failures can occur before the project is online not only determines the economic viability of the project, but also determines how efficient the timing of the investment is relative to the risk that exists today, and up until the project is able to come online. Another way of phrasing the concept is that most likely analysis answers two questions:
1) is the project economically viable?
2) Is the solution too late?

In the context of this study, risk is primarily driven by the likelihood that an accident could occur that closes one or both of the existing chambers at the Soo Locks complex, which would temporarily disrupt the connection between Lake Superior and the Lower Great Lakes. Were this to occur in either the without-project condition or the with-project condition during the construction timeframe, it is likely that there may not be sufficient overland capacity to handle all diverted tonnages, leading to unmet demand and unmet demand transportation costs. Therefore, in the most likely results, unmet demand costs can also exist in the with-project condition. However, the expected size of unmet demand and the magnitude of the capital investment costs required to handle those tonnages in the with-project condition is significantly smaller than the without-project condition, since the exposure period and likelihood that this accident risk (and lock component failure risk) could occur is limited to a period of 7 years compared to 57 years. However, although the accident risk is a constant value, weighing in the 7-year risk during construction produces a different result than an analysis that only evaluates that risk during the 50-year analysis period.

The broader stakeholder community has asked the Corps whether or not the risk in the construction period should be discounted and considered an acceptable level of risk. This assumes that no alternative capital investment costs should be considered in the time period before the new Poe-sized chamber is able to come online. In other words, this sensitivity test isolates the question “Is the project economically viable?” To account for this, a sensitivity test was run that eliminates all failures (both accident and lock component) before project implementation. Since the intent of this update is not to compare the timing of possible solutions to mitigating the risk at the project, but to estimate the economic viability of the recommended plan, this sensitivity test is an important result to decision-makers.

This sensitivity analysis is for information purposes only. The 1983 Principles and Guidelines (P&G) explicitly requires that the implementation period be included in the period of analysis. Paragraph 1.4.12 defines the Period of Analysis: "The period of analysis is to be the same for each alternative plan. The period of analysis is to be the time required for implementation plus the lesser of—(1) The period of time over which any alternative plan would have significant beneficial or adverse effects; or (2) A period not to exceed 100 years." Because this sensitivity does not include the implementation period, it is not compatible with the P&G and cannot be supported by USACE in an official capacity.

As shown in **Table 9-12**, the results of this sensitivity test shows a more robust benefit-cost ratio over the reference case, which is 1.90 at the prevailing federal discount rate, compared to the reference case at 1.78.

As mentioned previously, weighing in the accident risk that exists before the project is online produces a different result, since each of the 7-years' worth of risk in the WPC incrementally adds more risk than adding an additional 7 years to the 50-years that already exist in the analysis period of the WOPC.

Another driver to the increased benefits in this sensitivity case is lock component risk. [redacted] If the new lock were in place at the time of this component's failure, the navigation impacts could be substantially mitigated compared to the without-project condition, where the new lock is not available. In other words, the results of this sensitivity case help highlight the benefits that could be had if aging components survive the construction duration. Another interpretation of these results might be that it helps account for the likelihood that repair and replacement actions are different in the with-project condition. In the WPC, it is more likely that repair and replacement actions would be tailored to temporarily extend the service life of each component, rather than replace them in a more long-term-oriented, costly, and disruptive manner, such as what would be required in a WOPC. If a new lock were in the process of being constructed, this is a likely reaction to these aging components, so the method utilized in this sensitivity test that holds their reliability constant is a reasonable substitute to having repair and replacement actions that are specific to each planning scenario. The repair and replacement actions at Locks and Dams 52 and 53, in lieu of an upcoming operational Olmsted Lock and Dam, serve as a perfect real-world example of this reality. An additional consideration is that if construction operations were available and mobilized on-site in the with-project condition at the time of a service disruption in the older chambers, the duration of the outage and resulting navigation impact might be significantly mitigated compared to the without-project condition in that same time period. This sensitivity case helps to establish the upper bound of benefits that could potentially be had if these types of inputs were available and were specifically tailored to each planning scenario.

Table 9-12—Benefit-to-Cost Evaluation, Period of Analyzed Risk Sensitivity, Q1 FY18 Dollars, 2.75 percent Discount Rate

Cash Flow Category	Period of Analyzed Risk	
	2020-2076	2027-2078
Total Average Annual Project Costs	$32,708,888	$32,708,888
Total Average Annual Project Benefits	$56,565,563	$60,677,043
BASE NET BENEFITS	$23,856,675	$27,968,155
BENEFIT-TO-COST RATIO (BCR)	**1.73**	**1.86**
Base Net Benefits	$23,856,675	$27,968,155
Allowable Labor Resource Benefits	$1,607,854	$1,607,854
NET BENEFITS	$25,464,528	$29,576,009
BENEFIT-TO-COST RATIO (BCR)	**1.78**	**1.90**

Table 9-13—Benefit-to-Cost Evaluation, Period of Analyzed Risk Sensitivity, Q1 FY18 Dollars, 7.0 percent Discount Rate

Cash Flow Category	Period of Analyzed Risk	
	2020-2076	2027-2078
Total Average Annual Project Costs	$69,480,408	$69,480,408
Total Average Annual Project Benefits	$103,795,851	$111,870,838
BASE NET BENEFITS	$34,315,443	$42,390,430
BENEFIT-TO-COST RATIO (BCR)	**1.49**	**1.61**
Base Net Benefits	$34,315,443	$42,390,430
Allowable Labor Resource Benefits	$3,145,301	$3,145,301
NET BENEFITS	$37,460,744	$45,535,731
BENEFIT-TO-COST RATIO (BCR)	**1.54**	**1.66**

Table 9-14—Average Annual Benefits by Category, Period of Analyzed Risk Sensitivity, Q1 FY18 Dollars, 2.75 percent Discount Rate

Benefit Category	Period of Analyzed Risk	
	2020-2076	2027-2076
Service Disruption Impact Costs Avoided		
Diverted Traffic Costs	$1,592,843	$1,547,180
Vessel Transit Time Costs	$1,949,303	$1,914,140
Poe-restricted Vessel Layup (wait at port)	$1,331,584	$1,288,253
Sub-Total Service Disruption Costs Avoided	**$4,873,730**	**$4,749,573**
Unmet Demand Proxy Transportation Impacts Avoided		
Taconite - via conveyor system	$1,123,263	$1,655,229
Taconite - via expanded stockpile	$7,437,006	$9,138,807
Taconite - via expanded Escanaba	$31,189,087	$31,973,235
Sub-Total Unmet Demand Impacts Avoided	**$39,749,357**	**$42,767,272**
Without-project Costs (WOPC) Costs Avoided (benefits)		
Normal Operations & Maintenance	$0	$0
Scheduled Maintenance	$3,033,975	$3,033,975
Escanaba (existing)	$1,016,227	$2,232,558
Davis / Sabin decommissioning	$781,433	$781,433
Service Disruption Repair Costs		
Engineering Reliability Components	$5,508	$6,899
Accidents	$0	$0
Major Maintenance/Component Replacement		
Project Level Components	$678,772	$678,772
Poe Lock Components	$1,566,202	$1,566,202
MacArthur Lock Components	$1,890,659	$1,890,659
Sub-Total WOPC Costs Avoided	**$8,972,776**	**$10,190,498**
Recreation Benefits		
Visitor Center	$2,902,500	$2,902,500
Recreational Craft	$800	$800
Tour Boats	$66,400	$66,400
Sub-Total Recreation Benefits	**$2,969,700**	**$2,969,700**
Labor Resource Benefits		
Labor Resource Benefits	$1,607,854	$1,607,854
TOTAL PROJECT BENEFITS without Labor Resource Benefits:	**$56,565,563**	**$60,677,043**
TOTAL PROJECT BENEFITS with Labor Resource Benefits:	**$58,173,417**	**$62,284,897**

Table 9-15—Average Annual Benefits by Category, Period of Analyzed Risk Sensitivity, 2020–2076, Q1 FY18 Dollars, 7.0 percent Discount Rate

Benefit Category	Period of Analyzed Risk	
	2020-2076	2027-2076
Service Disruption Impact Costs Avoided		
Diverted Traffic Costs	$1,705,679	$1,629,758
Vessel Transit Time Costs	$1,610,559	$1,550,379
Poe-restricted Vessel Layup (wait at port)	$1,402,366	$1,332,757
Sub-Total Service Disruption Costs Avoided	**$4,718,604**	**$4,512,894**
Unmet Demand Proxy Transportation Impacts Avoided		
Taconite - via conveyor system	$2,644,211	$3,912,061
Taconite - via expanded stockpile	$11,935,342	$14,826,912
Taconite - via expanded Escanaba	$71,132,880	$73,081,753
Sub-Total Unmet Demand Impacts Avoided	**$85,712,433**	**$91,820,726**
Without-project Costs (WOPC) Costs Avoided (benefits)		
Normal Operations & Maintenance	$0	$0
Scheduled Maintenance	$1,685,338	$1,685,338
Escanaba (existing)	$1,815,010	$3,987,414
Davis / Sabin decommissioning	$1,482,243	$1,482,243
Service Disruption Repair Costs		
Engineering Reliability Components	$0	$0
Accidents	$0	$0
Major Maintenance/Component Replacement		
Project Level Components	$1,345,568	$1,345,568
Poe Lock Components	$1,297,073	$1,297,073
MacArthur Lock Components	$2,769,883	$2,769,883
Sub-Total WOPC Costs Avoided	**$10,395,114**	**$12,567,518**
Recreation Benefits		
Visitor Center	$2,902,500	$2,902,500
Recreational Craft	$800	$800
Tour Boats	$66,400	$66,400
Sub-Total Recreation Benefits	**$2,969,700**	**$2,969,700**
Labor Resource Benefits		
Labor Resource Benefits	$3,145,301	$3,145,301
TOTAL PROJECT BENEFITS without Labor Resource Benefits:	**$103,795,851**	**$111,870,838**
TOTAL PROJECT BENEFITS with Labor Resource Benefits:	**$106,941,152**	**$115,016,139**

9.2.3 Applying Gross Domestic Product Impact per Ton for Taconite Unmet Demand

In the period following an unscheduled closure at the Soo Locks complex, affected tonnage is diverted from the waterway to existing alternate modes with available transportation capacity. Where multiple alternate modes are available, they are used in the order of least cost, given the quantity of affected tonnage. Once the existing alternate modes have been exhausted and no longer have the capacity to accommodate affected tonnage, the remaining tonnage becomes unmet demand.

This sensitivity analysis is for information purposes only as it may group National Economic Development (NED) and Regional Economic Development (RED) benefit accounts which are not additive. Because of this, there is a potential of double counting benefits and cannot be supported within USACE policy. This GDP analysis begins with the assumption that labor and capital associated with the taconite and steel industry would be not be used to produce other goods and services in the short-run during an unscheduled closure. The vehicle and vehicle parts manufacturing sectors (end-users of steel) are assumed to remain fully employed and productive for the initial 2 weeks of closure, and after the lock closure has exceeded 6 months of duration. From 2 weeks to 6 months labor and capital production is lost from the vehicle and vehicle parts manufacturing sectors as substitution is enacted. The analysis also assumes that if a closure of 6 months or greater occurs, the end-users of steel would return to full employment and production within 3 months for any future closures, since the global market would have made adjustments to supply products to those industries. These assumptions would require vetting and approval with USACE Headquarters per ER 1105-2-100 Paragraph E-3a (4) (c), as it was not the focus of the study which uses transportation rate proxies to measure economic impacts. Further investigation would be necessary to determine if the GDP method netted out all potential RED transfers, and is compliant within USACE policy to be used as an NED impact.

Several complications exist when determining a GDP impact for each ton of undelivered taconite. Primarily, the first ton of any amount of undelivered taconite is likely to have a less severe impact on the value chain (or downstream users) of that taconite than the final ton. This value chain includes the steel mills and the products they make, and also the producers of final goods and services such as the automotive sector. The economic flexibility of the National account to withstand this short-run supply shock will be entirely dependent on the availability of product substitutes throughout this value chain, and the quantity of unmet demand. Additionally, if final goods, such as automobiles, are not produced due to a short-run supply disruption of taconite, determining how consumers will react to that unavailability and where they will instead choose to consume (or save their disposable income) is a much entangled calculation. For example, if automobiles are not produced and consumers instead choose to

consume in other sectors of the U.S. economy, the impact to the National account due to undelivered taconite would be somewhat (but partially) mitigated by the consumption that occurs in other market sectors. If consumption were to occur outside the National account (such as purchasing foreign automobiles), the reduction in U.S. net exports (and thus GDP) might be fairly substantial. Finally, a key concept in the use of the GDP calculations herein is that these impacts represent a short-run supply disruption, which is driven by unanticipated lock closures. This is a substantially different impact that the long-run impact that would result if lock closures are known in advance, or if steel markets outside the U.S. were expecting an increase in steel demand.

Despite these complications, significant research by both the Department of Homeland Security (DHS) and Michigan State University (MSU) has shown that there is fairly limited flexibility in the U.S. market to adapt to a short-run disruption of taconite. To gauge the flexibility of the National account to adapt to short-run lock closures and undelivered taconite, data from both reports were utilized. Michigan State University determined three calculations of value-chain impacts. The first assumes the value-chain impacts (downstream users of integrated steel) stop at the steel mill. In other words, 100 percent product substitution is assumed to occur after the steel mill is forced to decrease output, and the impacts are limited to the lost production of taconite and the lost production at the respective steel plants. Essentially, this calculation measures only the intermediate consumption that occurs up until the steel product is made. The second calculation assumes that 50 percent product substitution occurs for the downstream users of steel. Finally, a third calculation assumes that 0 percent product substitution occurs, or each ton of undelivered taconite causes a full impact to all firms involved in the use of taconite.

While the Michigan State University measurements help define the full level of economic contribution that taconite provides to various market sectors, this is a different measurement than determining an economic impact for any given amount of unmet demand. The duration of the closure event is important since these per-ton impacts are expected to vary throughout a given closure event. This variation reflects the availability or short-term substitution (or elasticity), the gradual exhaustion of this ability to substitute, leading to higher impact costs and eventually for closures of sufficient duration that industry adaptations become necessary to allow long-term substitution.

To capture this variation in cost, a curve describing per-ton impact costs as a function of time in days within a closure event is needed. To estimate this curve, four inflection points were identified with associated per-ton impact costs. These inflection points were determined using information from the Homeland Security study, and discussions with Michigan State. According

to the Homeland Security report, automobile and other downstream impacts would begin at approximately two weeks of Poe lock closure, and complete cessation of automobile production is likely to occur at approximately six weeks. In discussions with Michigan State, it was estimated that long-term substitutes such as foreign steels would take approximately six months to position themselves to provide a comparable, long-run substitute. At each of these inflection points, a different level of substitutability is assumed by using the impact costs calculated by Michigan State University. These inflection points and the respective percent of substitution that are assumed to occur can be seen in **Figure 9-5**.

Figure 9-5—GDP Substitutability Timeline

Using these inflections points, a curve was then approximated by interpolating linearly between them. This curve is intended to capture how impacts can accrue as substitutions such as inventories-on-hand are exhausted. In other words, product substitution does not instantly change at the inflection points identified but instead is expected to gradually increase and decrease between these points, reflecting markets adjusting and recovering from the closure event. Given this curve, the total impact cost of undelivered taconite for a given closure event of duration (N) would be the sum of tonnage undelivered each day (n) of the closure valued at that day's corresponding per-ton impact cost. This can be calculated as the total area under this curve between the start of the closure (n_0) and the end of the closure (n_X). This is illustrated in **Figure 9-6**. Note that the durations, days, and some other values present in the figure are adjusted for simplicity and scale of presentation, and do not account for the length of the shipping season and other factors.

Figure 9-6—GDP Impact Cost per Ton Example

As described above, the inflection points are defined as closure days relative to n_0. This is done to reflect the fact that as soon as the closure begins, actors within the automotive and related industries can begin to take action to effect long-term substitution given closures of sufficient length. This, somewhat conservatively, assumes perfect information on the part of the USACE and thus the shipping industry and all other affected industries within the modeled value chain as to the duration of the service disruption event.

In the example in **Figure 9-6** above, 10 days into the year/shipping season the project is closed. From this point on the cost in terms of economic impact for each ton undelivered depends on when in the closure each volume of taconite does not get delivered. For the first 14 days of the closure following n_0 existing inventories or other substitutions can be made, and impact costs are relatively low. From day n_{14} the available substitutions are exhausted and impact costs gradually increase, reaching a peak at n_{180}. After this point, long-term substitutions can be made, and impact costs per ton are gradually lessened through to the end of the closure, after which point taconite resumes delivery via water routing.

This calculation was performed within the model simulation using iteration level outputs from Soo-REM. Outputs include the year, closure duration, affected taconite tonnage, and undelivered taconite tonnage. From this, the average affected taconite tonnage per day is estimated. The shape of the curve is defined primarily by results from the GDP model and adjusted based on these Soo-REM outputs. The total area under the curve through the end of the closure (n_x) is then calculated, and returned as the impact cost. This was done for eight categories of impact cost: GDP impacts, employment impacts, labor income impacts, and total sales impacts, all both direct and indirect.

Two additional adjustments were made in the computation of these GDP impact costs. First, it was assumed that in a given simulation iteration, following the first (if any) closure event of sufficient duration for affected industries to effect long-term substitutions, the duration required in future closures before these long-term substitutions can be made would be cut in half. To do this, a separate curve was computed for each year of a given iteration, and given a prior year closure of 180 days or longer, the second curve using the shortened long-term substitution was used for all subsequent closures.

Secondly, if a closure of more than a navigation season in length occurs or where duration and timing of the closure lead to overlap into a subsequent navigation season, impacts assessed for the period of closure in the second navigation season were adjusted to assume the availability of long-term substitutions. This was done to reflect the ability of related industries, following the first season closure and throughout the winter closure, to continue working to effect long term substitutions, rather than treating the consecutive season closures as two independent events.

Benefits by category are shown at the 2.75 percent and 7.0 percent discount rates given this alternate unmet demand valuation method in **Table 9-16** and **Table 9-17**. These tables do not present the base condition results for comparison since benefit categories are not consistent between the base condition and the sensitivity. Computed benefit-cost ratios at both discount rates are presented in **Table 9-18** and **Table 9-19**.

Table 9-16—Average Annual Benefits by Category, Unmet Demand Valuation Sensitivity, 2020–2076, Q1 FY18 Dollars, 2.75 percent Discount Rate

Benefit Categories	
Service Disruption Impact Costs Avoided	
Diverted Traffic Costs	$1,592,063
Vessel Transit Time Costs	$1,947,828
Poe-restricted Vessel Layup (wait at port)	$1,326,423
Sub-Total Service Disruption Costs Avoided	**$4,866,314**
Unmet Demand Economic Impacts Avoided	
GDP Impacts	$206,944,012
WOPC Costs Avoided (benefits)	
Normal O&M	$0
Scheduled Maintenance	$3,033,975
Escanaba (existing)	$979,990
Davis / Sabin decommissioning	$781,433
Service Disruption Repair Costs	
Engineering Reliability Components	$8,038
Accidents	$0
Asset Renewal Plan	
Project Level Components	$678,772
Poe Lock Components	$1,566,202
Mac Lock Components	$1,890,659
Sub-Total WOPC Costs Avoided	**$8,939,069**
Recreation Benefits	
Visitor Center	$2,902,500
Recreational Craft	$800
Tour boats	$66,400
Sub-Total Recreation Benefits	**$2,969,700**
Labor Resource Benefits	
Labor Resource Benefits	$1,607,854
TOTAL PROJECT BENEFITS without LRB	**$223,719,095**
TOTAL PROJECT BENEFITS with LRB	**$225,326,948**

Table 9-17—Average Annual Benefits by Category, Unmet Demand Valuation Sensitivity, 2020–2076, Q1 FY18 Dollars, 7.0 percent Discount Rate

Benefit Categories	
Service Disruption Impact Costs Avoided	
Diverted Traffic Costs	$4,516,254
Vessel Transit Time Costs	$2,615,640
Poe-restricted Vessel Layup (wait at port)	$5,673,954
Sub-Total Service Disruption Costs Avoided	**$12,805,849**
Unmet Demand Economic Impacts Avoided	
GDP Impacts	$611,238,906
WOPC Costs Avoided (benefits)	
Normal O&M	$0
Scheduled Maintenance	$1,685,338
Escanaba (existing)	$872,269
Davis / Sabin decommissioning	$1,482,243
Service Disruption Repair Costs	
Engineering Reliability Components	$0
Accidents	$0
Asset Renewal Plan	
Project Level Components	$1,345,568
Poe Lock Components	$1,297,073
Mac Lock Components	$2,769,883
Sub-Total WOPC Costs Avoided	**$9,452,373**
Recreation Benefits	
Visitor Center	$2,822,457
Recreational Craft	$2,755
Tour boats	$197,443
Sub-Total Recreation Benefits	**$3,022,655**
Labor Resource Benefits	
Labor Resource Benefits	$3,145,301
TOTAL PROJECT BENEFITS without LRB	**$636,519,783**
TOTAL PROJECT BENEFITS with LRB	**$639,665,084**

Table 9-18—Benefit-to-Cost Evaluation, Unmet Demand Valuation Sensitivity, 2020–2076, Q1 FY18 Dollars, 2.75 percent Discount Rate

Cash Flow Category	Unmet Demand Valuation	
	Proxy Modes	GDP Impacts
Total Average Annual Project Costs	$32,708,888	$32,708,888
Total Average Annual Project Benefits	$56,565,563	$223,719,095
BASE NET BENEFITS	$23,856,675	$191,010,207
BENEFIT-TO-COST RATIO (BCR)	**1.73**	**6.84**
Base Net Benefits	$23,856,675	$191,010,207
Allowable Labor Resource Benefits	$1,607,854	$1,607,854
NET BENEFITS	$25,464,528	$192,618,060
BENEFIT-TO-COST RATIO (BCR)	**1.78**	**6.89**

Table 9-19—Benefit-to-Cost Evaluation, Unmet Demand Valuation Sensitivity, 2020–2076, Q1 FY18 Dollars, 7.0 percent Discount Rate

Cash Flow Category	Unmet Demand Valuation	
	Proxy Modes	GDP Impacts
Total Average Annual Project Costs	$69,480,408	$69,480,408
Total Average Annual Project Benefits	$103,795,851	$230,864,698
BASE NET BENEFITS	$34,315,443	$161,384,290
BENEFIT-TO-COST RATIO (BCR)	**1.49**	**3.32**
Base Net Benefits	$34,315,443	$161,384,290
Allowable Labor Resource Benefits	$3,145,301	$3,145,301
NET BENEFITS	$37,460,744	$164,529,591
BENEFIT-TO-COST RATIO (BCR)	**1.54**	**3.37**

9.2.4 Future With-Project Condition – Old Poe Fix-As-Fails

Traditionally the future without-project condition is defined as economically justified OMRR&R within budget constraints. This used to include rehabilitations and even replacement-in-kind strategies in the future without-project condition. However, austere funding over the years has

shifted the accepted definition to more of a status quo OMRR&R, meaning for the most part fix-as-fails (FAF), with no enactment of advanced maintenance even if economically justified.

For the New Soo Locks Economic Validation Study however the assumed most likely future WOPC includes significant rehabilitation work, totaling $160.2M of investment in Poe Lock components, $68.5M in MacArthur Lock components, and $139.4M in project level components. This projected future work includes replacement of every component with identified reliability issues at some point over the planning period, as well as replacement of non-reliability components (i.e., components for which no risk of service disruption was identified or captured in modeling).

Acquisition of additional funding above status quo/FAF is common, and the project has historically received sufficient OMRR&R funding to cover the expected rehabilitation work included in the most likely future WOPC. Additionally, this projected work is consistent with historical operation of the project.

Due to the significance of these most likely rehabilitation and replacement actions, [redacted] a sensitivity analysis was performed in which the new lock was evaluated against the FAF baseline.

Table 9-20 and **Table 9-21** show a comparison between computed benefits of the new lock given both assumptions regarding future OMRR&R investment; fix-as-fails, and the most likely scenario involving scheduled component replacements, for both the current 2.75 percent discount rate and the 7.0 percent rate.

Table 9-20—Average Annual Benefits by Category, Baseline Condition OMRR&R Sensitivity, 2020–2076, Q1 FY18 Dollars, 2.75 percent Discount Rate

Benefit Category	OMRR&R Assumption	
	Most Likely	Fix-as-Fails
Service Disruption Impact Costs Avoided		
Diverted Traffic Costs	$1,592,843	$2,396,197
Vessel Transit Time Costs	$1,949,303	$3,673,185
Poe-restricted Vessel Layup (wait at port)	$1,331,584	$2,155,403
Sub-Total Service Disruption Costs Avoided	**$4,873,730**	**$8,224,785**
Unmet Demand Proxy Transportation Impacts Avoided		
Taconite - via conveyor system	$1,123,263	$1,685,014
Taconite - via expanded stockpile	$7,437,006	$9,875,937
Taconite - via expanded Escanaba	$31,189,087	$36,305,726
Sub-Total Unmet Demand Impacts Avoided	**$39,749,357**	**$47,866,677**
Without-project Costs (WOPC) Costs Avoided (benefits)		
Normal Operations & Maintenance	$0	$0
Scheduled Maintenance	$3,033,975	$3,033,975
Escanaba (existing)	$1,016,227	$637,759
Davis / Sabin decommissioning	$781,433	$781,433
Service Disruption Repair Costs		
Engineering Reliability Components	$5,508	$244,490
Accidents	$0	$0
Major Maintenance/Component Replacement		
Project Level Components	$678,772	$678,772
Poe Lock Components	$1,566,202	$1,566,202
MacArthur Lock Components	$1,890,659	$1,890,659
Sub-Total WOPC Costs Avoided	**$8,972,776**	**$8,833,290**
Recreation Benefits		
Visitor Center	$2,902,500	$2,902,500
Recreational Craft	$800	$800
Tour Boats	$66,400	$66,400
Sub-Total Recreation Benefits	**$2,969,700**	**$2,969,700**
Labor Resource Benefits		
Labor Resource Benefits	$1,607,854	$1,607,854
TOTAL PROJECT BENEFITS without Labor Resource Benefits:	**$56,565,563**	**$67,894,451**
TOTAL PROJECT BENEFITS with Labor Resource Benefits:	**$58,173,417**	**$69,502,305**

Table 9-21- Average Annual Benefits by Category, Baseline Condition OMRR&R Sensitivity, 2020–2076, Q1 FY18 Dollars, 7.0 percent Discount Rate

Benefit Category	OMRR&R Assumption	
	Most Likely	Fix-as-Fails
Service Disruption Impact Costs Avoided		
Diverted Traffic Costs	$1,705,679	$2,478,058
Vessel Transit Time Costs	$1,610,559	$3,668,252
Poe-restricted Vessel Layup (wait at port)	$1,402,366	$2,230,049
Sub-Total Service Disruption Costs Avoided	**$4,718,604**	**$8,376,359**
Unmet Demand Proxy Transportation Impacts Avoided		
Taconite - via conveyor system	$2,644,211	$3,954,150
Taconite - via expanded stockpile	$11,935,342	$15,976,000
Taconite - via expanded Escanaba	$71,132,880	$83,295,107
Sub-Total Unmet Demand Impacts Avoided	**$85,712,433**	**$103,225,257**
Without-project Costs (WOPC) Costs Avoided (benefits)		
Normal Operations & Maintenance	$0	$0
Scheduled Maintenance	$1,685,338	$1,685,338
Escanaba (existing)	$1,815,010	$1,139,056
Davis / Sabin decommissioning	$1,482,243	$1,482,243
Service Disruption Repair Costs		
Engineering Reliability Components	$0	$212,282
Accidents	$0	$0
Major Maintenance/Component Replacement		
Project Level Components	$1,345,568	$1,345,568
Poe Lock Components	$1,297,073	$1,297,073
MacArthur Lock Components	$2,769,883	$2,769,883
Sub-Total WOPC Costs Avoided	**$10,395,114**	**$9,931,442**
Recreation Benefits		
Visitor Center	$2,902,500	$2,902,500
Recreational Craft	$800	$800
Tour Boats	$66,400	$66,400
Sub-Total Recreation Benefits	**$2,969,700**	**$2,969,700**
Labor Resource Benefits		
Labor Resource Benefits	$3,145,301	$3,145,301
TOTAL PROJECT BENEFITS without Labor Resource Benefits:	**$103,795,851**	**$124,502,758**
TOTAL PROJECT BENEFITS with Labor Resource Benefits:	**$106,941,152**	**$127,648,059**

As shown in the table, average annual benefits are around $11.3M higher at the 2.75 percent interest rate for the analysis using the FAF investment future. This increase in average annual benefits relative to the most likely analysis is attributable in part to the reduction in baseline condition risk achieved by most likely future without-project and with-project condition OMRR&R actions, which reduce project risk that would otherwise be mitigated by the presence of a redundant Poe sized lock. Essentially proposed future OMRR&R actions address to some extent the same risk as the new lock, and this overlap leads to a net reduction in benefits realized by construction of the new lock. The most likely OMRR&R assumption results in cost savings between the without and with-project conditions in avoidance of all MacArthur Lock component replacements (which are not performed under the most likely with-project condition), as well as avoidance of scheduled Poe lock closure impacts during miter gate replacements, as well as avoidance of maintenance costs. These however are offset by the reduction in baseline, without-project condition risk realized by proposed future OMRR&R actions which would otherwise have been captured by availability of the new lock. The final benefit-to-cost ratios for both the most likely OMRR&R future and the fix-as-fails sensitivity case are shown in **Table 9-22** and **Table 9-23**.

Table 9-22—Benefit-to-Cost Evaluation, Baseline Condition OMRR&R Sensitivity, 2020–2076, Q1 FY18 Dollars, 2.75 percent Discount Rate

Cash Flow Category	OMRR&R Assumption	
	Most Likely	**Fix-as-Fails**
Total Average Annual Project Costs	$32,708,888	$32,708,888
Total Average Annual Project Benefits	$56,565,563	$67,894,451
BASE NET BENEFITS	$23,856,675	$35,185,563
BENEFIT-TO-COST RATIO (BCR)	**1.73**	**2.08**
Base Net Benefits	$23,856,675	$35,185,563
Allowable Labor Resource Benefits	$1,607,854	$1,607,854
NET BENEFITS	$25,464,528	$36,793,417
BENEFIT-TO-COST RATIO (BCR)	**1.78**	**2.12**

Table 9-23—Benefit-to-Cost Evaluation, Baseline Condition OMRR&R Sensitivity, 2020–2076, Q1 FY18 Dollars, 7.0 percent Discount Rate

Cash Flow Category	OMRR&R Assumption	
	Most Likely	Fix-as-Fails
Total Average Annual Project Costs	$69,480,408	$69,480,408
Total Average Annual Project Benefits	$103,795,851	$124,502,758
BASE NET BENEFITS	$34,315,443	$55,022,350
BENEFIT-TO-COST RATIO (BCR)	**1.49**	**1.79**
Base Net Benefits	$34,315,443	$55,022,350
Allowable Labor Resource Benefits	$3,145,301	$3,145,301
NET BENEFITS	$37,460,744	$58,167,651
BENEFIT-TO-COST RATIO (BCR)	**1.54**	**1.84**

9.2.5 Accident Closure Duration

[redacted]. This risk comprises the probability of each identified accident category, the probability given this occurrence that the accident is a severe accident resulting in an extended closure event, and the duration (and thus impact cost) of this extended closure. These latter were taken without adjustment from a 1994 analysis performed by Planning Management Consultants under contract with the Institute for Water Resources.

Given the significance of these parameters, however, in the characterization of total baseline project risk, analysts performed a sensitivity analysis focused on these assumed durations of severe accidents. This component of accident risk was chosen as the focus of this sensitivity analysis because it directly drives service disruption impact cost, as well as drives total service disruption risk in a nonlinear fashion. This is because it is the largest contributor to extended service disruptions that result is higher volumes of affected tonnage than can be accommodated by existing alternate modes.

In the 1994 report and in this analysis all accident service disruption durations were characterized as beta distributions, fit to parameters elicited from an expert panel. Elicited parameters were the mean, maximum, 5th, and 95th percentile durations. The averages from elicited values were used to define beta distributions to represent possible accident durations.

To test the sensitivity of the analysis to changes in assumed accident closure durations, beta distributions defined by the minimum and maximum elicited parameters, rather than the average, were used to characterize possible closure durations for a "Low" and "High" case, respectively. These are shown in **Table 9-24**.

Table 9-24—Range of Elicited Accident Closure Duration Parameters

Case	[redacted]	Closure Duration (Days)			
		5th	Mean	95th	Max
Base	[redacted]	6	23	54	82
	[redacted]	17	42	80	114
	[redacted]	25	108	203	330
	[redacted]	11	62	190	327
	[redacted]	4	12	22	35
Low	[redacted]	0.04	3	7	14
	[redacted]	2	7	14	25
	[redacted]	5	10	90	150
	[redacted]	5	18	45	120
	[redacted]	1	3	7	20
High	[redacted]	30	120	300	360
	[redacted]	55	180	360	450
	[redacted]	60	240	360	450
	[redacted]	30	180	360	540
	[redacted]	15	30	60	90

[redacted]

As expected, given the significant variation in elicited ranges of closure durations, the impact on modeled impact costs, benefits, and thus benefit-cost analysis is fairly significant, and given the "Low" case closure durations the project is no longer justified at either discount rate, with a BCR of 0.97 at the 2.75 rate, and 0.68 at the 7 percent rate. The tables below break down the benefits by category for both the 2.75 percent and 7.0 percent discount rates (**Table 9-25** and

Table 9-26), and the benefit-cost-ratios (**Table 9-27** and **Table 9-28**), with the “Base” case used in the analysis provided for reference.

Table 9-25—Average Annual Benefits by Category, Accident Duration Sensitivity, 2020–2076, Q1 FY18

Dollars, 2.75 percent Discount Rate

Benefit Category	Accident Durations		
	Base	Low	High
Service Disruption Impact Costs Avoided			
Diverted Traffic Costs	$1,592,843	$1,086,162	$2,753,405
Vessel Transit Time Costs	$1,949,303	$1,881,526	$2,017,931
Poe-restricted Vessel Layup (wait at port)	$1,331,584	$595,916	$2,997,643
Sub-Total Service Disruption Costs Avoided	**$4,873,730**	**$3,563,605**	**$7,768,979**
Unmet Demand Proxy Transportation Impacts Avoided			
Taconite - via conveyor system	$1,123,263	$951,308	$1,208,166
Taconite - via expanded stockpile	$7,437,006	$5,567,109	$8,221,471
Taconite - via expanded Escanaba	$31,189,087	$9,379,718	$70,816,268
Sub-Total Unmet Demand Impacts Avoided	**$39,749,357**	**$15,898,135**	**$80,245,904**
Without-project Costs (WOPC) Costs Avoided (benefits)			
Normal Operations & Maintenance	$0	$0	$0
Scheduled Maintenance	$3,033,975	$3,033,975	$3,033,975
Escanaba (existing)	$1,016,227	$1,353,224	$846,319
Davis / Sabin decommissioning	$781,433	$781,433	$781,433
Service Disruption Repair Costs			
Engineering Reliability Components	$5,508	$6,515	$6,431
Accidents	$0	$0	$0
Major Maintenance/Component Replacement			
Project Level Components	$678,772	$678,772	$678,772
Poe Lock Components	$1,566,202	$1,566,202	$1,566,202
MacArthur Lock Components	$1,890,659	$1,890,659	$1,890,659
Sub-Total WOPC Costs Avoided	**$8,972,776**	**$9,310,780**	**$8,803,791**
Recreation Benefits			
Visitor Center	$2,902,500	$2,902,500	$2,902,500
Recreational Craft	$800	$800	$800
Tour Boats	$66,400	$66,400	$66,400
Sub-Total Recreation Benefits	**$2,969,700**	**$2,969,700**	**$2,969,700**
Labor Resource Benefits			
Labor Resource Benefits	$1,607,854	$1,607,854	$1,607,854
TOTAL PROJECT BENEFITS without Labor Resource Benefits:	**$56,565,563**	**$31,742,220**	**$99,788,375**
TOTAL PROJECT BENEFITS with Labor Resource Benefits:	**$58,173,417**	**$33,350,074**	**$101,396,229**

Table 9-26—Average Annual Benefits by Category, Accident Duration Sensitivity, 2020–2076, Q1 FY18

Dollars, 7.0 percent Discount Rate

Benefit Category	Accident Durations		
	Base	Low	High
Service Disruption Impact Costs Avoided			
Diverted Traffic Costs	$1,705,679	$1,204,140	$2,888,039
Vessel Transit Time Costs	$1,610,559	$1,531,782	$1,669,499
Poe-restricted Vessel Layup (wait at port)	$1,402,366	$682,497	$3,086,630
Sub-Total Service Disruption Costs Avoided	**$4,718,604**	**$3,418,420**	**$7,644,169**
Unmet Demand Proxy Transportation Impacts Avoided			
Taconite - via conveyor system	$2,644,211	$2,252,506	$2,810,656
Taconite - via expanded stockpile	$11,935,342	$8,805,563	$13,217,655
Taconite - via expanded Escanaba	$71,132,880	$18,924,442	$164,505,104
Sub-Total Unmet Demand Impacts Avoided	**$85,712,433**	**$29,982,511**	**$180,533,415**
Without-project Costs (WOPC) Costs Avoided (benefits)			
Normal Operations & Maintenance	$0	$0	$0
Scheduled Maintenance	$1,685,338	$1,685,338	$1,685,338
Escanaba (existing)	$1,815,010	$2,416,898	$1,511,550
Davis / Sabin decommissioning	$1,482,243	$1,482,243	$1,482,243
Service Disruption Repair Costs			
Engineering Reliability Components	$0	$0	$0
Accidents	$0	$0	$0
Major Maintenance/Component Replacement			
Project Level Components	$1,345,568	$1,345,568	$1,345,568
Poe Lock Components	$1,297,073	$1,297,073	$1,297,073
MacArthur Lock Components	$2,769,883	$2,769,883	$2,769,883
Sub-Total WOPC Costs Avoided	**$10,395,114**	**$10,997,002**	**$10,091,654**
Recreation Benefits			
Visitor Center	$2,902,500	$2,902,500	$2,902,500
Recreational Craft	$800	$800	$800
Tour Boats	$66,400	$66,400	$66,400
Sub-Total Recreation Benefits	**$2,969,700**	**$2,969,700**	**$2,969,700**
Labor Resource Benefits			
Labor Resource Benefits	$3,145,301	$3,145,301	$3,145,301
TOTAL PROJECT BENEFITS without Labor Resource Benefits:	**$103,795,851**	**$47,367,632**	**$201,238,938**
TOTAL PROJECT BENEFITS with Labor Resource Benefits:	**$106,941,152**	**$50,512,933**	**$204,384,239**

Table 9-27—Benefit-to-Cost Evaluation, Accident Duration Sensitivity, 2020–2076, Q1 FY18 Dollars, 2.75 percent Discount Rate

Cash Flow Category	Accident Duration		
	Medium	Low	High
Total Average Annual Project Costs	$32,708,888	$32,708,888	$32,708,888
Total Average Annual Project Benefits	$56,565,563	$31,742,220	$99,788,375
BASE NET BENEFITS	$23,856,675	-$966,668	$67,079,487
BENEFIT-TO-COST RATIO (BCR)	**1.73**	**0.97**	**3.05**
Base Net Benefits	$23,856,675	($966,668)	$67,079,487
Allowable Labor Resource Benefits	$1,607,854	$0	$1,607,854
NET BENEFITS	$25,464,528	($966,668)	$68,687,340
BENEFIT-TO-COST RATIO (BCR)	**1.78**	**0.97**	**3.10**

Table 9-28—Benefit-to-Cost Evaluation, Accident Duration Sensitivity, 2020–2076, Q1 FY18 Dollars, 7.0 percent Discount Rate

Cash Flow Category	Accident Duration		
	Medium	Low	High
Total Average Annual Project Costs	$69,480,408	$69,480,408	$69,480,408
Total Average Annual Project Benefits	$103,795,851	$47,367,632	$201,238,938
BASE NET BENEFITS	$34,315,443	-$22,112,776	$131,758,530
BENEFIT-TO-COST RATIO (BCR)	**1.49**	**0.68**	**2.90**
Base Net Benefits	$34,315,443	($22,112,776)	$131,758,530
Allowable Labor Resource Benefits	$3,145,301	$0	$3,145,301
NET BENEFITS	$37,460,744	($22,112,776)	$134,903,831
BENEFIT-TO-COST RATIO (BCR)	**1.54**	**0.68**	**2.94**

9.2.6 Escanaba Capital Investment Floor

As part of the Soo Locks Economic Validation Study, the Economics team was tasked with calculating the transportation cost savings (benefits) provided by construction of a new lock that would be equal in size to the existing "Poe" Lock. The Poe Lock connects Duluth, Minnesota, on Lake Superior, which produces the majority of the taconite that feeds America's major steel mills on the Lower Great Lakes in Illinois, Indiana, Ohio, and Pennsylvania. There is not existing road or rail infrastructure available to move the amount of taconite required by the

mills should Soo Locks experience a long-term closure. To estimate impacts during lock closure, proxy transportation modes and their associated costs were developed to determine an impact cost for delivering taconite using hypothetical alternatives means and methods. One of these proxy modes would transport ore from Duluth to steel mills on the lower lakes by rerouting through a hypothetical port expansion at Escanaba.

This sensitivity analysis compares the base analysis which scales the Escanaba capital costs to the throughput needed to a floor method which assumes there is a minimum (floor) cost incurred for transporting any amount of tonnage through such a facility.

9.2.6.1 Base Analysis

Corps policy directs teams to use "risk-based analysis" in determining the feasibility of constructing projects, with risk being defined as the probability of an event occurring multiplied by the consequences of that event. For instance, if an event would cause $10 worth of damage but only has a 10 percent chance of occurring, then the risk, or expected value of consequence, is ($10 x .10), or $1.

Generally inland navigation studies estimate benefits based on the probability of a project (generally, a lock) failing and on the resulting consequences such as the increase in transportation costs that would occur when cargo that would have moved through the lock shifts to another mode of transportation, such as rail. However, Soo Locks is unique in that it is the only feasible existing way to transport the taconite to the mills. As identified by the URS/Baird *Partial Benefits Evaluation—Soo Locks, Michigan (2014)*, there are not sufficient rail or road resources to consistently transport the taconite in the amounts needed to keep the mills running. Furthermore, constructing additional transportation capacity to move the ore in the event of a long-term closure of Soo Locks would likely require billions of dollars in investment as well as a construction period that would exceed the duration of any closure at Soo Locks.

To account for the uniqueness of Soo Locks, the team made reasonable assumptions about the alternative modes of transporting the taconite. This was done to find a policy-compliant way of comparing transportation cost savings between moving the ore through Soo Locks and moving it any other way. These alternative theoretical modes are referred to as "proxy" modes so as not to give the impression that they are formulated alternative plans to a new lock, but merely tools for comparison. These proxy modes include: (1) a conveyor that would move the ore over the lock, (2) stockpiling at the mills in advance of a closure, and (3) building additional rail and port infrastructure to reach Escanaba on Lake Michigan. These proxy options were identified since they would mitigate the need for vessels to go through Soo Locks to reach the steel mills. It is assumed that if all three of these were constructed, they would collectively be able to

replace the capacity of the Soo Locks. Or in other words, the hypothetic modes are suitable proxies for estimating alternate transportation impacts for a 296-day closure of the Soo Locks complex.

The baseline analysis assumed "unmet tonnage" would first be moved by the least cost options, conveyor and stockpiling proxy modes. Since the port expansion would require a minimum of $2.8 billion in capital investment, it was employed last. However, if the amount of unmet tonnage was only slightly greater than the capacity of the conveyor and stockpiling proxy modes, the team felt it inappropriate to approximate the impacts based on construction of a $2.8 billion 8.7 million ton capacity facility. Therefore, the team made the decision to scale the port expansion proxy cost below the 8.7 million ton capacity facility based on the amount of unmet tonnage that would occur as a result of various lock closure durations, resulting in a cost-per-ton that could provide a reasonable estimate of the costs of transporting various amounts of unmet tonnages, and more appropriately reflect shipper willingness-to-pay. Additional technical information regarding this methodology and the corresponding assumptions can be found in **Section 7.6**.

It is also important to note that the team understands that there are alternatives beyond a conveyor, stockpiling, and Escanaba expansion (e.g. truck) and the first unmet tons may find other modes of transportation in a real-world situation. However, accounting for all the possible means and methods to move the unmet tonnage would be a time consuming and costly analysis.

Utilizing this base methodology, the project is estimated to have approximately $25 million in net annual benefits and a benefit-to-cost-ratio of 1.78 at a 2.75 percent discount rate. **Table 9-7** displays the assumed relationship between the facility size and cost, and also the distribution of needed throughput of Escanaba (amount of unmet tonnage demanding use of Escanaba) across all modeled simulations of lock performance. The various facility sizes used to create this relationship of facility size-to-cost can be seen in **Table 9-29**[12]. Using this method, Escanaba capital costs average approximately $853 million as seen in **Figure 9-8** and **Table 9-30.** Note, that in some simulation iterations unmet demand is met by conveyor and stockpiling and no Escanaba expansion is required (lowering the overall average). The corresponding cost-per-ton for using the expanded Escanaba mode given its expected usage is approximately $590 per ton as shown in **Table 9-30.**

[12] See Attachment 4 for additional information on these cost estimates.

Table 9-29— Expanded Escanaba Capital Costs

Facility Capacity	**8,700,000**	**18,000,000**	**25,000,000**	**29,000,000**
Rail Capital Costs	$ 1,814,996,570	$ 1,815,205,473	$ 4,333,940,682	$ 4,334,150,458
Rolling Stock Costs	$ 257,665,080	$ 528,002,214	$ 733,336,408	$ 844,803,542
Port Capital Costs	$ 761,639,000	$ 1,843,968,000	$ 2,561,066,550	$ 3,026,513,000
Total Capital Costs	**$ 2,834,300,650**	**$ 4,187,175,687**	**$ 7,628,343,640**	**$ 8,205,467,000**

Figure 9-7—Base Analysis — Escanaba Capital Costs for Varying Throughput Levels

Figure 9-8— Base Analysis – Escanaba Capital Cost Distribution – Q1 FY18 Dollars, 2.75 percent Discount Rate

Table 9-30—Base Analysis – Taconite Transportation Costs per Ton – Q1 FY18 Dollars, 2.75 percent Discount Rate

	Canadian Sourcing	Existing Escanaba	Conveyor	Stockpile	Escanaba Expansion
Expected fixed costs (PV) [1/]	$ -	$ 104,132,188	$ 52,825,365	$ 251,490,951	$ 853,330,016
Expected fixed costs (AAE) [1/]	$ -	$ 3,857,152	$ 1,956,700	$ 9,315,456	$ 31,608,128
Expected annual tons	-	48,047	25,850	65,920	55,955
Expected fixed cost per ton	$ -	$ 80.28	$ 75.69	$ 141.31	$ 564.89
Variable cost per ton over water route [2/]	$ 18.82	$ 5.94	$ 1.38	$ 4.41	$ 26.00
Expected total cost per ton over water route	**$ 18.82**	**$ 86.22**	**$ 77.07**	**$ 145.72**	**$ 590.89**

[1/] Fixed costs are composed of the capital investment cost in 2020 and maintenance costs from 2021 to 2076. Displays the results of the WOPC using the medium traffic forecast.

[2/] Variable costs are incremental and net out the cost to move by the existing water route.

9.2.6.2 Floor Analysis

A competing assumption in analyzing the port expansion proxy mode is that implementing a portion of the Escanaba expansion is not a reasonable real-world outcome and that an additional analysis should be performed to determine the benefits based on an "all-or-nothing"

Escanaba investment decision. In other words, the analysis assumes that once one ton of unmet tonnage exceeds the capacity of the stockpile and conveyor, the port expansion is implemented at a minimum cost necessary to build out a fully functioning transportation mode is incurred. The team completed this analysis at the request of the vertical team.

To accomplish this analysis, the team needed to identify the minimum costs of a functional port facility and associated assets such as track and rolling stock (rail cars) that could handle at least 1 ton of taconite. To produce this estimate, the team used values from a contractor report, which totaled $2.8 billion ($1.8 billion for track and $1 billion for rolling stock and port equipment capable of moving 8.7 million tons per year)[13]. Three other facility sizes were also estimated using the LimnoTech report, as shown in **Figure 9-9.** As one would expect, including a large capital investment to move small amounts of unmet demand into the analysis leads to an increase in benefits over the base analysis described above, with net annual benefits of $46 million and a benefit-to-cost ratio of 2.42 at a 2.75 percent discount rate. The expected Escanaba capital cost is approximately $1.7 billion when using a capital investment cost floor of $2.8 billion when the mode is needed for any amount of tonnage (compared to $853 million in the base analysis). Using this method, stockpile and conveyor are used significantly less frequently as alternate transportation modes, since all tonnages default to the Escanaba mode when conveyor and stockpiling do not have sufficient combined transportation capacity to meet all unmet demand and the floor facility is assumed available. This can be seen in **Figure 9-9** and is reflected in the costs-per-ton in **Table ES-1-1** which shows increased use of the Escanaba mode.

[13] $1 billion for 8.7 million tons of rolling stock and port throughput was chosen since it was a cost estimate that can be validated in the CELRE LimnoTech report. These costs are foreseeably lower if only a single ton needed to move.

Figure 9-9- Floor Analysis — Escanaba Capital Costs for Varying Throughput Levels

Figure 9-10— Floor Analysis – Escanaba Capital Cost Distribution – Q1 FY18 Dollars, 2.75 percent Discount Rate

Table 9-31—Floor Analysis – Taconite Transportation Costs per Ton – Q1 FY18 Dollars, 2.75 percent Discount Rate

	Canadian Sourcing	Existing Escanaba	Conveyor	Stockpile	Escanaba Expansion
Expected fixed costs (PV) [1/]	$ -	$ 104,056,100	$ 33,459,692	$ 70,072,683	$ 1,693,714,291
Expected fixed costs (AAE) [1/]	$ -	$ 3,854,334	$ 1,239,378	$ 2,595,557	$ 62,736,735
Expected annual tons	-	47,854	12,944	17,229	116,429
Expected fixed cost per ton	$ -	$ 80.54	$ 95.75	$ 150.65	$ 538.84
Variable cost per ton over water route [2/]	$ 18.82	$ 5.94	$ 1.38	$ 4.41	$ 26.00
Expected total cost per ton over water route	**$ 18.82**	**$ 86.48**	**$ 97.13**	**$ 155.06**	**$ 564.84**

[1/] Fixed costs are composed of the capital investment cost in 2020 and maintenance costs from 2021 to 2076. Displays the results of the WOPC using the medium traffic forecast.

[2/] Variable costs are incremental and net out the cost to move by the existing water route.

9.2.6.3 Results Comparison

The analysis of the benefits provided by Soo Locks is incredibly complicated due to its unique nature as the singular method of moving an important resource. It is reasonable to incorporate risk-informed simplifying assumptions to complete the analysis, regardless of the methodology utilized. There can also be reasonable disagreement about the validity or relative merit of each of these assumptions, which is the intent of a sensitivity test on the assumption.

Table 9-32 and **Table 9-33** present a benefit comparison of the base method to the floor method, and **Table 9-34** and **Table 9-35** display the benefit-to-cost evaluations for the sensitivity analysis.

Table 9-32- Average Annual Benefits by Category, Escanaba Scaling Sensitivity, 2020–2076, Q1 FY18 Dollars, 2.75 percent Discount Rate

Benefit Category	Escanaba Cost Scaling	
	Scaled Capital Cost	Fixed Floor
Service Disruption Impact Costs Avoided		
Diverted Traffic Costs	$1,592,843	$1,604,514
Vessel Transit Time Costs	$1,949,303	$1,961,740
Poe-restricted Vessel Layup (wait at port)	$1,331,584	$1,338,524
Sub-Total Service Disruption Costs Avoided	**$4,873,730**	**$4,904,778**
Unmet Demand Proxy Transportation Impacts Avoided		
Taconite - via conveyor system	$1,123,263	$536,533
Taconite - via expanded stockpile	$7,437,006	$1,626,766
Taconite - via expanded Escanaba	$31,189,087	$58,439,173
Sub-Total Unmet Demand Impacts Avoided	**$39,749,357**	**$60,602,471**
Without-project Costs (WOPC) Costs Avoided (benefits)		
Normal Operations & Maintenance	$0	$0
Scheduled Maintenance	$3,033,975	$3,033,975
Escanaba (existing)	$1,016,227	$1,002,940
Davis / Sabin decommissioning	$781,433	$781,433
Service Disruption Repair Costs		
Engineering Reliability Components	$5,508	$6,933
Accidents	$0	$0
Major Maintenance/Component Replacement		
Project Level Components	$678,772	$678,772
Poe Lock Components	$1,566,202	$1,566,202
MacArthur Lock Components	$1,890,659	$1,890,659
Sub-Total WOPC Costs Avoided	**$8,972,776**	**$8,960,914**
Recreation Benefits		
Visitor Center	$2,902,500	$2,902,500
Recreational Craft	$800	$800
Tour Boats	$66,400	$66,400
Sub-Total Recreation Benefits	**$2,969,700**	**$2,969,700**
Labor Resource Benefits		
Labor Resource Benefits	$1,607,854	$1,607,854
TOTAL PROJECT BENEFITS without Labor Resource Benefits:	**$56,565,563**	**$77,437,864**
TOTAL PROJECT BENEFITS with Labor Resource Benefits:	**$58,173,417**	**$79,045,717**

Table 9-33- Average Annual Benefits by Category, Escanaba Scaling Sensitivity, 2020–2076, Q1 FY18 Dollars, 7.0 percent Discount Rate

Benefit Category	Escanaba Cost Scaling	
	Scaled Capital Cost	Fixed Floor
Service Disruption Impact Costs Avoided		
Diverted Traffic Costs	$1,705,679	$1,737,329
Vessel Transit Time Costs	$1,610,559	$1,624,878
Poe-restricted Vessel Layup (wait at port)	$1,402,366	$1,438,183
Sub-Total Service Disruption Costs Avoided	**$4,718,604**	**$4,800,389**
Unmet Demand Proxy Transportation Impacts Avoided		
Taconite - via conveyor system	$2,644,211	$1,263,005
Taconite - via expanded stockpile	$11,935,342	$2,146,831
Taconite - via expanded Escanaba	$71,132,880	$136,410,728
Sub-Total Unmet Demand Impacts Avoided	**$85,712,433**	**$139,820,564**
Without-project Costs (WOPC) Costs Avoided (benefits)		
Normal Operations & Maintenance	$0	$0
Scheduled Maintenance	$1,685,338	$1,685,338
Escanaba (existing)	$1,815,010	$1,791,280
Davis / Sabin decommissioning	$1,482,243	$1,482,243
Service Disruption Repair Costs		
Engineering Reliability Components	$0	$0
Accidents	$0	$0
Major Maintenance/Component Replacement		
Project Level Components	$1,345,568	$1,345,568
Poe Lock Components	$1,297,073	$1,297,073
MacArthur Lock Components	$2,769,883	$2,769,883
Sub-Total WOPC Costs Avoided	**$10,395,114**	**$10,371,384**
Recreation Benefits		
Visitor Center	$2,902,500	$2,902,500
Recreational Craft	$800	$800
Tour Boats	$66,400	$66,400
Sub-Total Recreation Benefits	**$2,969,700**	**$2,969,700**
Labor Resource Benefits		
Labor Resource Benefits	$3,145,301	$3,145,301
TOTAL PROJECT BENEFITS without Labor Resource Benefits:	**$103,795,851**	**$157,962,038**
TOTAL PROJECT BENEFITS with Labor Resource Benefits:	**$106,941,152**	**$161,107,339**

Table 9-34 – Benefit-to-Cost Evaluation, Escanaba Scaling Sensitivity, 2020-2076, Q1 FY18 Dollars, 2.75 percent Discount Rate

Cash Flow Category	Escanaba Cost Scaling	
	Scaled Capital Cost	Fixed Floor
Total Average Annual Project Costs	$32,708,888	$32,708,888
Total Average Annual Project Benefits	$56,565,563	$77,437,864
BASE NET BENEFITS	$23,856,675	$44,728,975
BENEFIT-TO-COST RATIO (BCR)	**1.73**	**2.37**
Base Net Benefits	$23,856,675	$44,728,975
Allowable Labor Resource Benefits	$1,607,854	$1,607,854
NET BENEFITS	$25,464,528	$46,336,829
BENEFIT-TO-COST RATIO (BCR)	**1.78**	**2.42**

Table 9-35 - Benefit-to-Cost Evaluation, Escanaba Scaling Sensitivity, 2020-2076, Q1 FY18 Dollars, 7.00 percent Discount Rate

Cash Flow Category	Escanaba Cost Scaling	
	Scaled Capital Cost	Fixed Floor
Total Average Annual Project Costs	$69,480,408	$69,480,408
Total Average Annual Project Benefits	$103,795,851	$157,962,038
BASE NET BENEFITS	$34,315,443	$88,481,630
BENEFIT-TO-COST RATIO (BCR)	**1.49**	**2.27**
Base Net Benefits	$34,315,443	$88,481,630
Allowable Labor Resource Benefits	$3,145,301	$3,145,301
NET BENEFITS	$37,460,744	$91,626,931
BENEFIT-TO-COST RATIO (BCR)	**1.54**	**2.32**

9.2.7 Sensitivity Scenario Comparison

The results of all of the above described sensitivity scenarios are summarized in **Figure 9-11** and **Table 9-36**. The red line in the figure indicates the average annual equivalent cost, which remains constant across all sensitivity scenarios, and to which the average annual benefit values depicted are compared.

Figure 9-11—Sensitivity Scenario Average Annual Benefit Comparison, 2.75 percent Discount Rate

Table 9-36 – Comparison of Sensitivity Analyses

Cash Flow Category	Base	Traffic Forecast Scenario				OMRR&R	Risk Period	Unmet Demand	Accident Duration		Escanaba Cost Scaling
		Low	High	No Growth	No Growth After 20 Yrs	Fix-as-Fails	2027-2078	GDP Impacts	Low	High	Fixed Floor
Total Average Annual Project Costs	$32,708,888	$32,708,888	$32,708,888	$32,708,888	$32,708,888	$32,708,888	$32,708,888	$32,708,888	$32,708,888	$32,708,888	$32,708,888
Total Average Annual Project Benefits	$56,565,563	$39,790,021	$89,742,299	$54,450,202	$54,600,800	$67,894,451	$60,677,043	$223,719,095	$31,742,220	$99,788,375	$77,437,864
BASE NET BENEFITS	$23,856,675	$7,081,133	$57,033,411	$21,741,314	$21,891,912	$35,185,563	$27,968,155	$191,010,207	($966,668)	$67,079,487	$44,728,975
BENEFIT-TO-COST RATIO (BCR)	**1.73**	**1.22**	**2.74**	**1.66**	**1.67**	**2.08**	**1.86**	**6.84**	**0.97**	**3.05**	**2.37**
Base Net Benefits	$23,856,675	$7,081,133	$57,033,411	$21,741,314	$21,891,912	$35,185,563	$27,968,155	$191,010,207	($966,668)	$67,079,487	$44,728,975
Allowable Labor Resource Benefits	$1,607,854	$1,607,854	$1,607,854	$1,607,854	$1,607,854	$1,607,854	$1,607,854	$1,607,854	$0	$1,607,854	$1,607,854
NET BENEFITS	$25,464,528	$8,688,986	$58,641,265	$23,349,168	$23,499,766	$36,793,417	$29,576,009	$192,618,060	($966,668)	$68,687,340	$46,336,829
BENEFIT-TO-COST RATIO (BCR)	**1.78**	**1.27**	**2.79**	**1.71**	**1.72**	**2.12**	**1.90**	**6.89**	**0.97**	**3.10**	**2.42**

9.1 Uncertainty Analysis

The Soo-REM model was designed around a Monte Carlo style analysis, which seeks to define the distribution of possible outcomes by repeated random sampling from distributions of uncertain inputs. These uncertainties result from a combination of parameterized uncertainty (for example ranges of possible lock closure durations) and probabilistic inputs (component failure or accident occurrence probabilities).

As more model iterations are performed, the correspondingly increasing sample of results will more closely mirror the true distribution of all possible outcomes. Convergence testing is performed to test the degree to which the cumulative sample of outputs for a given number of performed iterations represents the true distribution of possible outcomes. Convergence is reached when the cumulative mean model output on which convergence is tested remains consistent across subsequent iterations, within specified tolerances.

Convergence testing analyzes the cumulative mean of the tested model output sequentially after each model iteration. The model converges when the computed estimated error at that model iteration is within a specified tolerance at a specified confidence level.

Typically convergence testing is performed during simulations after each iteration is complete, and the simulation is ended when the computed error of the cumulative mean output falls within the specified tolerances and convergence is reached. For this analysis to reduce model run times and ensure that a consistent number of model iterations were performed across all analyzed scenarios, convergence testing was performed on a completed 20,000 iteration simulation, and an appropriate number of iterations for the full array of final model runs determined to achieve desired confidence levels.

The model output upon which convergence was tested was the total present value, at the FY18 federal discount rate of 2.75 percent, of all service disruption impact costs in baseline condition scenario, using the high sensitivity case traffic forecast. This scenario was selected for convergence testing as it represent the scenario with the highest degree of expected variability in outputs. The high traffic forecast scenario results in greater risk of vessel accidents, which are computed on a per-vessel-passage basis, and greater costs of service disruptions due to higher volumes of affected tonnage for each outage duration.

Figure 9-12 illustrates the cumulative mean average annual service disruption cost for the baseline condition. The orange lines indicate the range of approximated error. As more iterations are performed the cumulative mean stabilizes or "converges." For this analysis,

convergence was assumed when 99 percent confidence was reached of the cumulative mean value falling with 2 percent (convergence tolerance) of the true mean of all possible outcomes. This is reached after 8,777 iterations as depicted in **Figure 9-12.**

Figure 9-12—Cumulative Mean Average Annual Impacts, Baseline Condition, 2.75 percent Discount Rate

Based on this convergence testing analysis, 10,000 iterations were performed for the baseline without-project and in the with-project condition. The Soo-REM model returns distributions of total impacts by analysis year, with the mean or expected values from these distributions used to compute baseline average annual equivalent impacts and MRR alternative benefits (delta vs the baseline).

The primary present value and amortization calculations are performed external to Soo-REM. This is done for the ease and simplicity of future project benefit update calculations, so a fixed expected value cost stream can be discounted and amortized for a given discount rate without requiring time consuming and costly reruns of the Soo-REM model. This stream of mean or expected value annual impact costs can be used to compute a mean total impact cost over the analysis period, and likewise total present value of impact costs as well as average annual equivalent impact costs, that is identical to the mean of these metrics as calculated for iteration.

However given that the distribution of mean annual model outputs does not reflect an actual possible single-iteration outcome, other descriptive statistics such as standard deviation, 25th and 75th percentiles, etc., cannot be computed from the annual stream of mean impact costs. To compute these descriptive statistics and allow for greater analysis of results, a separate sensitivity module within Soo-REM calculates cumulative metrics such total present value and average annual equivalent value for a specified analysis period at a specified discount rate.

Iteration level results from the Soo-REM model can be used to provide a more detailed picture of the shape of output distributions. **Figure 9-13** shows a histogram of average annual total service disruption costs for the baseline condition.

Figure 9-13—Average Annual Service Disruption Impacts, Histogram, Baseline Condition, 2.75 percent Discount Rate

Figure 9-14 shows a similar histogram for the present value of unmet demand capital investment and maintenance costs.

Figure 9-14—Average Annual Unmet Demand Mode Capital Investment and Maintenance Costs, Histogram, Baseline Condition, 2.75 percent Discount Rate

Figure 9-15 below displays the maximum observed unscheduled Poe closure duration in each iteration. In the figure the scheduled 63 day and 28 day Poe closures do not appear as they are not unscheduled events.

Figure 9-15 - Maximum Poe Lock Closure Duration, Histogram, Baseline Condition

Figure 9-16 below shows the longest observed MacArthur lock closure duration in each iteration. These are generally very short in duration, with some rare longer duration closure events. Given the shorter durations and lower frequency of MacArthur lock closures, these contribute far less to total impact costs.

Figure 9-16 - Maximum MacArthur Lock Closure Duration, Histogram, Baseline Condition

Figure 9-17 shows the longest observed closures of both the Poe and MacArthur locks concurrently in each iteration. These are much more rare events, and in over 60 percent of iterations did not occur at all. A significant number of those that did occur, are very short in duration, primarily due to small periods of overlap between independent Poe and MacArthur lock closures. [redacted]

Figure 9-17 —Maximum Total Project Closure Duration, Histogram, Baseline Condition

9.1.1 Comparison of a Distribution of Benefits to a Distribution of Cost

The impact distributions described above as well as distributions of project implementation cost can, with some necessary simplifications, be combined to produce distributions of decision metrics such as net annual benefits and benefit-cost ratio. These distributions can approximate the range of project feasibility based on cost and benefit uncertainty, and can be used to estimate probabilities that various thresholds such as a BCR of 1.0 or 2.5 are met or exceeded. This section will discuss the calculation performed to combine uncertain cost estimates with uncertain benefits to produce these distributions.

Cost uncertainty is accounted for in a similar manner to uncertainties on the benefit side. Cost and schedule risk factors are identified and their likelihood of impacting the baseline cost estimate and the severity of that impact are estimated. A 10,000 iteration Monte Carlo style analysis is then performed in which values for each parameter are sampled from assigned distributions. As described in the section above, this results in a distribution of costs. The difference in each computed cost and the baseline cost is contingency. The distribution of cost and contingency is illustrated in **Table 9-37**.

Table 9-37—Cost Estimate and Contingency Distribution

Base Cost Est.	$637,658,085		
Confidence	**Construction Cost**	**Contingency**	**% Contingency**
0%	$686,957,161	$49,299,076	7.73%
10%	$797,888,348	$160,230,263	25.13%
20%	$812,366,537	$174,708,452	27.40%
30%	$822,788,767	$185,130,682	29.03%
40%	$831,825,107	$194,167,022	30.45%
50%	$841,006,050	$203,347,965	31.89%
60%	$849,777,087	$212,119,002	33.27%
70%	$859,846,100	$222,188,015	34.84%
80%	$871,005,154	$233,347,069	36.59%
90%	$888,046,719	$250,388,634	39.27%
100%	$965,889,988	$328,231,903	51.47%

A Weibull distribution is fit to the distribution of percent contingencies shown above using the @Risk software. From this distribution, costs can be sampled for comparison to similarly randomly sampled benefits to produce distributions of possible project benefit-cost ratios and net annual benefits. Before this can be done however, these cost estimates and contingencies must first be converted into average annual equivalent costs, as described in **Section 8.3**. To do this, the base cost without contingency is first apportioned to each year of construction by percentage weighting. Percent contingency is then sampled from the uncertainty distribution and applied to each year's base cost. PED cost, which according to ER 1105-2-100 are considered sunk and excluded from the benefit-cost ratio calculation, estimated as a percentage of the 80 percent confidence cost estimate are then subtracted from the yearly costs with contingency. The resulting annual expenditures are then indexed to present value and amortized over the 50 year analysis period.

Benefits then must be calculated for comparison against these randomly sampled AAE costs. Benefits are a composite of both uncertain values (differences between uncertain with and without-project service disruption impact costs) and values for which no uncertainty was modeled (OMRR&R cost savings, recreation benefits). To create a distribution of possible service disruption impact cost savings, the difference between with and without-project service disruption impact costs must be compared. These result from separate model simulations (with and without-project conditions), and though each simulation was run using the same seed value, each iteration in a given simulation models 57 years where each year's risk is informed by randomly sampled performance in all previous years. As such differing risk characteristics between the with and without-project condition will cause divergence within a single iteration potentially as early as the second year.

Because of this comparing for example the third iteration in both simulations does not ensure that both simulations are describing a system response to the same closure events or risk factors. On the contrary the without-project condition in that iteration may include no significant service disruptions for the full analysis period while the with-project condition in the corresponding iteration may include a significant disruption, resulting in potentially negative savings or benefits.

Because of this pairing iterations from one simulation with that of the other to compute deltas is not a straightforward process. To do this, it is assumed that for the most part when significant closures occur in the without-project condition they should be paired with a with-project condition in which significant closures also occurred, to best represent how the with-project condition deals with comparable conditions. In other words these two distributions, with and without-project impact costs, should be fairly well correlated. To account for this, both distributions were ranked, and the ranked delta impact costs used as the distribution of possible service disruption impact cost reductions.

The only other benefit category for which uncertainty must be computed is the labor resource benefits, which were recomputed from the randomly sampled project first cost estimate. Other benefit categories for which no uncertainty was modeled were simply added to the randomly sampled sum of service disruption impact cost savings and Labor Resource Benefits.

Average annual equivalent benefits and costs computed as described above were randomly sampled and compared in a 10,000 iteration @Risk simulation, resulting in distributions of 10,000 possible benefit-cost ratios and net annual benefit estimates. Distributions of benefit-cost ratios at both the 2.75 percent and 7.0 percent discount rates are presented below as **Figure 9-18** and **Figure 9-19**. Dotted lines indicate the 1.0 BCR threshold for project viability. Net annual benefit distributions at both discount rates are presented in **Figure 9-20** and **Figure 9-21.**

Figure 9-18—Benefit-Cost Ratio Distribution, 2.75 percent Discount Rate

Figure 9-19—Benefit-Cost Ratio Distribution, 7.0 percent Discount Rate

The figures above illustrate that the distribution of benefit-cost ratios is fairly left-skewed. The mean BCRs at both evaluated discount rates are notably higher than the median, which is 1.2 at the 2.75 percent federal discount rate, and 0.79 at the 7 percent rate. While the BCR is likely to be above 1, in particular at the 2.75 percent rate, a BCR less than one is also reasonably probable. This is consistent with the intent of a redundant Poe-sized lock to address risk of low probability, yet high consequence events such as catastrophic component failures or unprecedented accidents leading to prolonged closures. Put another way, while it is possible, even probable, that no or insufficient significant closure events could occur in the next 57 years to justify investment in a new lock, the severe consequences of possible prolonged closures make this investment prudent as mitigation of this risk. Note that these mean BCRs differs from those shown in the remainder of this analysis. This is for two reasons; first the reported BCRs are computed with the 80 percent confidence contingency estimate rather than the mean, and second these mean ratios are the mean of cost/benefit comparisons, rather than comparison of mean costs and benefits.

Figure 9-20—Net Annual Benefits Distribution, 2.75 percent Discount Rate

Figure 9-21—Net Annual Benefits Distribution, 7.0 percent Discount Rate

It is important to note that these distributions reflect uncertainties modeled in the Soo-REM evaluation of with and without-project condition service disruption impacts, and cost and schedule uncertainties, but do not reflect the sensitivity scenarios described in the sensitivity analysis sections above, or the effects of any other unidentified/unquantified factors which could influence project cost or benefits. The sensitivity sections are intended to demonstrate the sensitivity of model outputs to changes in identified critical input assumptions, but analyzed sensitivity cases do not have quantified probability estimates assigned to them, nor do they or modeled uncertainty parameters represent the comprehensive extent of all possible factors on which cost or benefit depend. This distinction is important to note as it illustrates that the above benefit-cost ratio and net annual benefit distributions are limited in that they show only the range of possible decision metric calculations based on identified and modeled uncertainties.

Table 9-38 illustrates the probabilities of identified key benefit-cost ratio thresholds being met or exceeded for both the 2.75 percent and 7.0 percent discount rates. The key thresholds include the project justification BCR threshold of 1 or greater, the OMB budget threshold of 2.5 (at the 7.0 percent discount rate), the reported project benefit-cost ratios (using the 80 percent confidence cost estimate), and a BCR of 4, which was the highest integer BCR resulting from the 10,000 iteration analysis.

Table 9-38—Benefit-Cost Ratio Threshold Exceedance Probabilities

	Benefit-Cost Ratio	Chance of Exceeding
2.75% Rate	1.0	71%
	1.78	40%
	2.5	28%
	4	10%
7.0% Rate	1.0	45%
	1.54	38%
	2.5	25%
	4	9%

Section 10. New Soo Locks Economic Validation Study - 902 Analysis

Section 902 of the Water Resources Development Act 1986 (as amended) established a maximum cost for water resources development and conservation projects. Pursuant to ER 1105-2-100, Appendix G, Amendment 1, dated June 30, 2004, "The maximum project cost allowed by Section 902 includes the authorized cost (adjusted for inflation), the current cost of

any studies, modifications, and action authorized by WRDA ’86 or any other law, and 20 percent of the authorized cost (without adjustment for inflation).”

Adjustments for inflation are allowed for changes in construction costs applied to unconstructed features. The construction component of the authorized cost is updated using the Civil Works Construction Cost Index System (EM 1110-2-1304), and the real estate component of the authorized cost is be updated using the Consumer Price Index, specifically, the unadjusted percentage changes reflected under the "Rent, residential" expenditure category.

The ER 1105-2-100 is the primary policy USACE follows to determine and calculate project Section 902 cost limits. To mitigate inconsistencies across USACE and lessen the possibility for miscalculations, the HQUSACE Planning Division developed a Section 902 cost limit calculation tool. This tool went through the certification process described in EC 1105-2-412, and was certified as a “Corps of Engineers Corporate Model” by the Headquarters USACE Chief of Planning and Policy in a memorandum on November 15, 2010. Headquarters USACE then provided the “Section 902 Limit Tool” to USACE commands for their use in calculating project Section 902 cost limits. Use of the tool was not mandatory upon initial release. That changed on March 7, 2012, when the USACE Deputy Commanding General for Civil and Emergency Operations (DCG-CEO) issued a policy memorandum that required USACE commands to use the Section 902 Limit Tool:

> For ALL authorized projects seeking Preconstruction Engineering and Design (PED) and/or Construction funds, it will be determined:
> a. Whether or not a Section 902 Cost Limit is applicable;
> b. What the appropriate Section 902 Cost Limit is using the most current cost estimate, in accordance with references 1.b. and ref 1.g.

The “ref 1.g.” cited above listed the “Certified Section 902 Limit Tool.” Headquarters USACE further reinforced these requirements in an additional policy memorandum issued on April 6, 2012.

The Certified Section 902 Limit Tool was used to assess the New Soo Locks Economic Validation Study 902 Analysis. Results of this analysis are presented in **attachment 11**, and summarized below.

Given the WRDA 2007 authorized cost of $341.71 million, the maximum project cost limited by section 902 is $532.96 million. The Walla-Walla Cost Engineering Mandatory Center of Expertise completed a cost agency technical review in February 2018, which identified a $922.4 million project first cost. Since the Mandatory Center of Expertise certified FY19 project first cost ($922.4m)

exceeds the FY19 902 limit maximum cost ($532.96m), reauthorization of this project is required through a Post Authorization Change Report.