US Army Corps
of Engineers®
Walla Walla District

United States
Environmental Protection Agency
Region 10

DREDGED MATERIAL MANAGEMENT PLAN AND ENVIRONMENTAL IMPACT STATEMENT

McNary Reservoir and Lower Snake River Reservoirs

APPENDIX C
Economic Analysis

DRAFT
October 2001

FINAL
July 2002

FINAL DREDGED MATERIAL MANAGEMENT PLAN AND ENVIRONMENTAL IMPACT STATEMENT
McNary Reservoir and Lower Snake River Reservoirs

JULY 2002

ERRATA SHEET FOR APPENDIX C - ECONOMICS

This appendix has not been substantially changed from the draft and will not be reprinted. Please make the following changes to the draft appendix and consider the draft appendix with corrections as the final appendix.

Front cover:
Apply the attached label (FINAL, July 2002) on the front cover to the right of the draft date.

Footnotes throughout the appendix:
Change all footnote references from "Draft DMMP/EIS, October 2001" to "Final DMMP/EIS, July 2002."

Page C-3, Plate 2, Page C-52 and C-53, Tables 16, 17, 18
References to damage reaches of "SNRIVRD" (Snake River Road), referring to the road running near the Snake River in Lewiston, should be changed to Snake River Avenue.

Page C-E-4, E6.0 Water Quality
The following sentence is added to the last paragraph:
For water quality plans, issues and costs associated with these projects, see the Feasibility Study for further information.

Page C-G-2
2nd paragraph, last sentence should read:
Depending on the contamination level of the sediment disposed, this will likely affect water quality in the area of disposal. The actual act of dredging may also affect water quality through increased turbidity.

Page C-G-2
Last paragraph should read:
The states also review permit applications for discharges in fresh water, estuaries, and the territorial sea (along with Federal resource agencies). Under Section 401 of CWA, these disposal operations must be certified by the affected state.

*** * * END OF CHANGES * * ***

DREDGED MATERIAL MANAGEMENT PLAN
AND ENVIRONMENTAL IMPACT STATEMENT

McNARY AND LOWER SNAKE RIVER RESERVOIRS

APPENDIX C

ECONOMIC ANALYSIS

prepared for:

U.S. Army Corps of Engineers
Walla Walla District
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Vancouver, WA 98682-2434

October 2001

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EXECUTIVE SUMMARY

Located at the confluence of the Snake and Clearwater Rivers, the town of Lewiston, Idaho, is protected from flooding by a system of levee embankments that were built as part of the Lower Granite Lock and Dam (Lower Granite) project. Also, several roads and railroads in the Lewiston, Idaho, and Clarkston and Asotin, Washington, areas were relocated as part of the project. Sediment deposition in the Lower Granite pool is reducing channel capacity, which limits the discharge the levee system can contain during flood events. Measures were evaluated to reduce the likelihood of flooding and to reduce the extent of damage. These measures range from dredging additional material to provide adequate channel capacity for flood events to increasing levee heights sufficiently to contain flooding.

The benefit from reduced flood damages may vary depending on the quantity of dredging, the height of modified levees, and the method of dredged material disposal. The purpose of this study is to evaluate the benefits and costs associated with each of the proposed alternatives. Each alternative is a combination of a dredging program (DP), levee modification (L), and disposal method (D). The dredging programs, levee modifications, and disposal methods of the various alternatives are described below.

Dredging Programs:

- Dredging for maintenance of the navigation (Nav) channel only. This dredging program is the basis for the existing conditions.
- Dredging 300,000 (300k) cubic yards (229 366.5 cubic meters) annually.
- Dredging 1,000,000 (1M) cubic yards (764 555 cubic meters) annually during project years 1-10, and subsequently dredging 325,000 cubic yards (248 480.3 cubic meters) annually for years 11-74.
- Dredging 2,000,000 (2M) cubic yards (1 529 110 cubic meters) annually during project years 1-20, and 725,000 cubic yards (554 302.3 cubic meters) annually thereafter for project years 21-74.

Levee Height Modifications:

- No change in the levee height (xst.).
- A nominal 3-foot (ft) (0.9-meter) raise in the existing levee.
- A nominal 4-ft (1.2-meter) raise in the existing levee.
- A nominal 8-ft (2.4-meter) raise in the existing levee.
- A nominal 12-ft (3.7-meter) raise in the existing levee.

Disposal Methods:

- In-water disposal (IW).
- Upland disposal (UL).

The economic feasibility of the various alternatives is evaluated using benefit-cost analysis (BCA). The baseline scenario for the BCA ("without project") is navigation dredging only with the existing levee height and in-water disposal (denoted Nav/xst./IW). The benefits and costs of each alternative are calculated by comparing them to the baseline scenario. Alternative scenario costs or project costs represent the total cost of an alternative minus the cost of the without-project scenario. Project benefits represent the expected flood damages that are eliminated or reduced by the alternative. These are calculated by subtracting the expected flood damages under the alternative scenario from the expected damages in the baseline scenario.[1]

Two project time frames are examined, the 21-year period from 2001 to 2021, and the 74-year period from 2001 to 2074. The results are analyzed in present values, using two different discount rates 6.875 percent and 3.5 percent for comparative purposes. In general, the U.S. Army Corps of Engineers (Corps) uses the discount rate established by section 80 of the Water Resources Development Act of 1974, which at the time of the analysis was set to 6.875 percent [1998 Federal Register (FR) Volume 63]. The other rate used in this report is 3.5 percent, representing an estimate of the real rate of return without inflation.

Flood damage reduction estimates were obtained using the Corps Hydrologic Engineering Center Flood Damage Assessment model (HEC-FDA). This model is consistent with Corps Engineering Manual 1110–2-1619. The estimation procedure involves hydrologic simulation, estimation of physical damage, determination of economic costs, and analysis.

Results suggest that estimated flood damage from 2001 until 2074 is not as severe as anticipated and may be mitigated without engaging in extensive dredging programs beyond the existing navigation-only dredging program. The proposed large dredging programs are expensive with project costs ranging from a net present value of $17.8 million for the 300,000 cubic yards (299 366.5 cubic meters) dredging program with in-water disposal (300/xst./IW), to $256.7 million for the 2 million cubic yards dredging program with upland disposal (2M/xst./UL). Similarly, the values for raising the levee 4, 8, and 12 feet (1.2, 2.4, and 3.7 meters) are very costly; ranging from $15 million for the 4-foot (1.2-meter) raise (Nav/4 ft/IW) to $76.8 million for the 12-foot (3.7-meter) raise (Nav/12 ft/IW). In contrast, the 3-foot (0.9-meter) levee raise option costs much less with the discounted net present value of the costs equal to $2.1 million. These values are all expressed using a 6.875 percent discount rate and discounting over the 74-year time horizon.

The total discounted present value of estimated flood damage in the without-project scenario is $13.58 million using the 74-year time horizon and 6.875 percent discount rate. This figure represents the maximum flood damage that could be reduced by any of the proposed alternatives. Of this value, $8.29 million are from damage to building structures and contents (including cleanup costs) and $5.3 million from other types of flood damage not included in the Corps Hydrologic Engineering Center Flood Damage Assessment model (HEC-FDA) model. These additional damages may include business interruption, emergency expenditures, and public infrastructure damage to roads, underground public utilities, and streetlights.

In studies that quantified additional costs of flooding, such costs range from 30 percent to more than three times the value of structure and content damages. As a conservative approach in this

[1] See section 4.0, Benefit-Cost Analysis, for a more detailed discussion of the calculation of benefits and costs.

study, the additional costs of flood damage were assumed to be 39 percent of the value of the estimated total flood damages.[2]

The estimated maximum potential damage of $13.58 million sets an upper limit on potential benefits of any proposed alternative. The principles of BCA state that for a property to be economically feasible it has to have a benefit-cost ratio greater than or equal to one. It therefore follows that any economically feasible alternative must have costs with a net present value of less than $13.58 million.

Given the maximum potential damages to be reduced, and using a 6.875 percent discount rate, the navigation-only dredging alternatives (both upland and in-water disposal) with a 3-foot (0.9-meter) levee raise are the alternatives most likely to have a benefit-cost ratio greater than one. The 4-foot (1.2-meter) levee raise with in-water disposal and navigation only dredging (Nav/4 ft/IW), also is potentially economically feasible, but only if almost all of the expected damages were reduced by the alternative. The costs of all other alternatives exceed the maximum potential damages to be reduced (see attachment C).

Because the quantity of dredged material in the navigation-only dredging scenario is small, the method of disposal has no bearing on the projected water surface elevations in the future, and the benefits of upland and in-water disposal are identical. The discounted present value of benefits and costs of each potentially economically feasible alternative, over the 74-year project time horizon using a discount rate of 6.875 percent, are displayed in table ES-1. The benefit-cost ratio is the quotient of benefits divided by costs.

Table ES-1
Benefit-Cost Summary of Potentially Economically Feasible Alternatives
2001-2074, Discounted at 6.875 Percent

Alternative	Present Value of Project Benefits	Present Value of Project Costs	Benefit/Cost Ratio
Nav/3 ft/IW	$9,951,518	$2,103,416	4.73
Nav/3 ft/UL	$9,951,518	$4,942,145	2.01
Nav/4 ft/IW	$11,456,584	$15,026,860	0.76

The results show that the Nav/3 ft/IW option and the Nav/3 ft/UL alternative are both economically feasible at a 6.875 percent discount rate over the 74-year time horizon. The Nav/4 ft/IW option is not economically feasible, with a benefit-cost ratio of 0.85. For these two options, the benefit-cost ratio of the in-water disposal alternative is more than twice the value of the upland alternative.

The economic feasibility of each alternative depends in part on the period of analysis and the discount rate. The BCA results for the three potentially economically feasible alternatives are presented below using the 6.875 percent discount rate under the 21-year time horizon

2 See "Other Costs of Flood Damage" in section 3.0, Data and Methods, for details of the review.

(table ES-2); a 3.5 percent discount rate under the 74-year time horizon (table ES-3); and a 3.5 percent discount rate under the 21-year time horizon (table ES-4). For all of the alternatives, the benefit-cost ratios are lower using the 21-year time horizon than with the 74-year time horizon. Also, benefit-cost ratios are much higher with the 3.5 percent discount rate than the 6.875 percent rate. Both results are attributed to the larger values of flood damage reduction benefits many years in the future, and the project costs for construction of levee embankment modifications early in the time horizon.

Table ES-2
Benefit-Cost Summary of Potentially Economically Feasible Alternatives
2001-2021, Discounted at 6.875 Percent

Alternative	**Present Value of Project Benefits**	**Present Value of Project Costs**	**Benefit/Cost Ratio**
Nav/3 ft/IW	$3,703,338	$2,103,416	1.76
Nav/3 ft/UL	$3,703,338	$4,765,797	0.78
Nav/4 ft/IW	$3,703,428	$14,263,277	0.26

Table ES-3
Benefit-Cost Summary of Potentially Economically Feasible Alternatives
2001-2074, Discounted at 3.5 Percent

Alternative	**Present Value of Project Benefits**	**Present Value of Project Costs**	**Benefit/Cost Ratio**
Nav/3 ft/IW	$30,106,483	$2,136,571	14.09
Nav/3 ft/UL	$30,106,483	$5,986,885	5.03
Nav/4 ft/IW	$36,849,002	$15,263,721	2.41

Table ES-4
Benefit-Cost Summary of Potentially Economically Feasible Alternatives
2001-2021, Discounted at 3.5 Percent

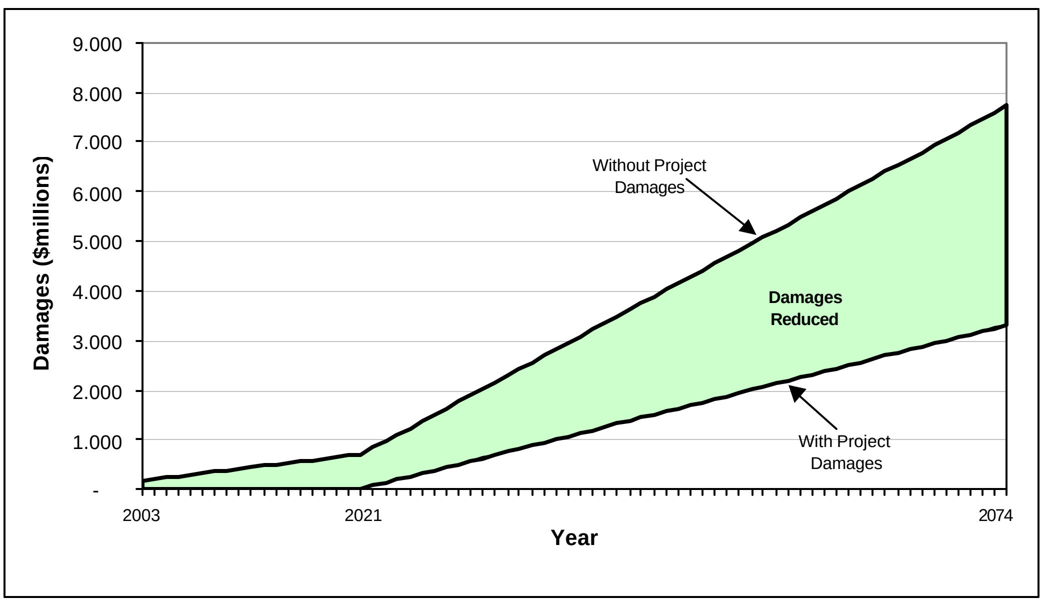
Alternative	**Present Value of Project Benefits**	**Present Value of Project Costs**	**Benefit/Cost Ratio**
Nav/3 ft/IW	$5,376,909	$2,136,571	2.52
Nav/3 ft/UL	$5,376,909	$5,351,448	1.00
Nav/4 ft/IW	$5,377,039	$14,500,138	0.37

These results favor undertaking the project (Nav/3 ft/IW). In both the 74-year time horizon and the 21-year time horizon, using either discount rate, the benefit-cost ratios are all greater than one and are therefore considered economically feasible. In all of the cases where more than one alternative is found to be economically feasible, the Nav/3 ft/IW option offers the highest benefit-cost ratio.

The expected damages to be reduced through time by the adoption of this alternative are portrayed in figure ES-1. The vertical axis in the figure represents the expected annual damages (EAD's), and the horizontal axis shows time in years. It is clear that EAD's will increase through time in both the with- and without-project scenarios. The shaded area in the graph corresponds to the net benefits of the project. The net present value of the shaded area is equal to the $9,951,518 shown as benefits in table ES-1.

In addition to direct effects, secondary economic, institutional, and environmental impacts of the various alternatives were studied and reviewed. None of these secondary impacts significantly alters the outcome of the BCA presented above. The without-project navigation-only dredging program already maintains access to the important recreational services provided in the project areas, and this is not expected to change with the recommended plan. Other considerations such as impacts on habitats, regional economies, or institutions do not vary widely among economically feasible alternatives and therefore do not alter the recommendation of the study.

Figure ES-1
Damages With and Without 3-Foot (0.9-Meter) Levee Raise



1.0 INTRODUCTION

Located at the confluence of the Snake and Clearwater Rivers, the town of Lewiston, Idaho, is protected from flooding by a system of levee embankments that were built as part of the Lower Granite Lock and Dam (Lower Granite) project. Also, several roads and railroads in the Lewiston, Idaho, and Clarkston and Asotin, Washington, areas were relocated as part of the project. Sediment deposition in the Lower Granite pool is reducing channel capacity, which limits the discharge the levee system can contain during flood events. Measures were evaluated to reduce the likelihood of flooding and to reduce the extent of damage. These measures range from dredging additional material to provide adequate channel capacity for flood events to increasing levee heights sufficiently to contain flooding.

The benefit from reduced flood damages may vary depending on the quantity of dredging, the height of modified levees, and the method of dredged material disposal. The purpose of this study is to evaluate the benefits and costs associated with each of the proposed alternatives. Each alternative is a combination of a dredging program (DP), levee modification (L), and disposal method (D).

1.1 Background

The area is within the boundaries of the U.S. Army Corps of Engineers (Corps), Walla Walla District. The Walla Walla District is responsible for generating a Dredged Material Management Plan (DMMP) that will identify and prioritize disposal sites for material projected to be dredged over a 20-year period from the navigable waterways within the Walla Walla District boundaries. The area covered includes Lake Wallula behind McNary Lock and Dam (McNary) on the Columbia River and the reservoirs behind the four lock and dam projects on the lower Snake River: Ice Harbor, Lower Monumental, Little Goose, and Lower Granite. The area extends from McNary, approximately 2.5 miles (4 kilometers) upstream from the community of Umatilla, Oregon, to the upstream end of Lower Granite Lake near the communities of Lewiston, Idaho, and Clarkston, Washington.

The planning study, Dredged Material Management Study (DMMS), is a feasibility-level effort that will include projections of the volume of sediment that will deposit in critical areas in each reservoir over the next 20 years. The DMMS will also include an evaluation of means to reduce required dredging quantities, a comparison of disposal methods and disposal site locations, and a development of a programmatic environmental impact statement (EIS) that evaluates the environmental impacts of those alternatives. The study was started in October 1997 and is scheduled for completion in 2002.

One of the key elements of the study is an economic analysis of alternative methods of managing sedimentation within Walla Walla District. The economic analysis is complicated by conditions in the most upstream reservoir in the system, Lower Granite Lake. It has a large sediment-contributing drainage area that includes the entire Salmon River drainage, and the mainstems of the Clearwater, Grand Ronde, and Imnaha Rivers. Since it is the most upstream of the four lower Snake River dams, the upper reach of Lower Granite Lake serves as a sediment trap for most of the material carried in suspension in the free-flowing reaches of the tributary rivers.

The quantity of sediment that collects in Lower Granite Lake far exceeds the quantities observed in each of the other lower Snake River reservoirs and in the McNary reservoir.

The situation at the upstream end of Lower Granite Lake is further complicated by the location of the cities of Lewiston and Clarkston. The Lower Granite Lake project includes backwater levee embankments that were installed to avoid relocating the business district of Lewiston and other industrial areas in Lewiston and Clarkston. The embankments function as an extension of Lower Granite, and were designed to allow the lake to be maintained at the normal operating pool elevation while protecting Lewiston from inundation during a standard project flood (SPF) event.

The levee embankment was designed to provide a minimum freeboard of 5 feet (1.5 meters) during the SPF event of 420,000 cubic feet per second (11 893.08 cubic meters per second) on the Snake River below the confluence of the Clearwater River. Since the reservoir was filled in 1975, deposited sediment has reduced the channel capacity and has caused the computed water surface elevations associated with a particular discharge to rise. The sedimentation problem has restricted the channel so that a SPF event may seriously encroach upon the levee freeboard and possibly overtop the levees. The Walla Walla District has outlined several alternatives to increase channel capacity. The measures include dredging and raising levee heights, as well as different methods to dispose of sediment. The alternatives have different levels of costs. They also have different levels of benefits, measured primarily as reduced flood damages. Each alternative includes a dredging activity, levee height adjustment, and sediment disposal method.

1.2 Project Area Characteristics

The project area includes the developed areas of Lewiston, Idaho, and Clarkston, Asotin, and Port of Wilma, Washington (see plate 1). The area also includes the downstream region between Clarkston and Lower Granite.

The confluence of the Snake and Clearwater Rivers separates the waterways into three segments for the purposes of the study: Snake River above the confluence, Snake River below the confluence, and Clearwater River. The structures on both banks of each river segment are identified by segment and a specific river mile (RM).

Several significant economic features in the project area might experience flood damage. The Port of Lewiston is situated on the north shore of the Clearwater River. It provides an inland seaport that serves the agricultural community surrounding Lewiston with shipments of regionally grown wheat to export markets. The Port of Lewiston also serves the Potlatch Corporation, which produces paper products. The Potlatch Corporation is located on the south side of the Clearwater River at RM 3, just east of the downtown Lewiston region. The Ports of Wilma and Clarkston are also in the project area and are home to several industrial enterprises such as wood chipping.

The Lewiston levees provide flood protection to the North Lewiston area and the downtown Lewiston area, which has a large number of retail and government buildings. Much of this area is located at approximately the same elevation as Lower Granite Lake, which is maintained at the confluence of the rivers at 733-738 feet (223.4-225 meters) above sea level [national geodetic vertical datum (NGVD) 1929 datum]. Besides flood protection, the levees are a popular recreation area.

1.2.1 Damage Reaches in the Project Area

The study team, made up of Northwest Economic Associates (NEA) consultants, Corps personnel, and HDR Engineering Inc. consultants, delineated the damage reaches essential to HEC-FDA modeling. The study area is divided into subcategories (damage reaches) based on river mile and riverbank to be used in the analysis. Damage reaches are defined based on the beginning and end points of waterways, flood control structures, economic distinctions, and jurisdictional boundaries.

The damage reaches for this study are shown in plate 2. Damage reaches are distinguished by whether or not they have levees, by river segment, and by whether they are in Idaho or Washington. Only three reaches have levees. These are the North Lewiston area, shown as (NLEWISTON on plate 2), the downtown Lewiston area (CONFLUENCE), and the portion of downtown Lewiston that follows the Snake River southward (SNRIVRD). The Clarkston area was divided into two reaches: the Snake River above the confluence (CLARKPARK) and the Snake River below the confluence (CLARKSTON). The portion of the Snake River between downtown Lewiston-Clarkston and Asotin was delineated separately for the Idaho and the Washington sides of the river (ROAD2ASOTIN and HELLSGATE, respectively). Asotin was separated for analytic purposes. Explanation of the indicator points that are also shown in plate 2 can be found in section 3.0, Data and Methods, of this report.

1.3 Study Objectives

This study analyzes the benefits and costs of alternatives with potential dredging, levee modification, and sediment disposal in the study area. Primary objectives of the study are:

- Estimate an expected annual dollar value of flood damages for the Lewiston-Clarkston region under with- and without-project conditions.
- Use the estimated expected flood damage values with estimated costs in an economic analysis of the proposed alternatives.
- Review information related to secondary impacts of the proposed alternatives, including environmental benefits and costs, socioeconomic conditions, and socio-institutional issues.
- Reevaluate the results of the economic analysis in the context of any critical secondary or social impact identified.

Benefits are measured primarily as the reduction of flood damages expected after completion of a proposed alternative plan. Benefits are estimated consistent with Corps Engineering Manual (EM) 1110-2-1619, and are estimated with the aid of the Corps HEC-FDA model. The model simulates flood damage through time based on geographic and economic data describing structures within a floodplain and hydrologic data relative to the probabilities of different flood events. A more detailed description of the procedures used in preparing data and operating the model is in section 3.0, Data and Methods, of this report.

Costs of the various alternatives considered include costs of dredging, raising levees, and disposal of dredged material. All costs for dredging and disposal were provided by the Walla Walla District. These were provided in constant 1999 dollars. Costs for raising levees were provided by HDR Engineering, Inc., in the 1999 report as presented in appendix E.

1.4 Report Organization

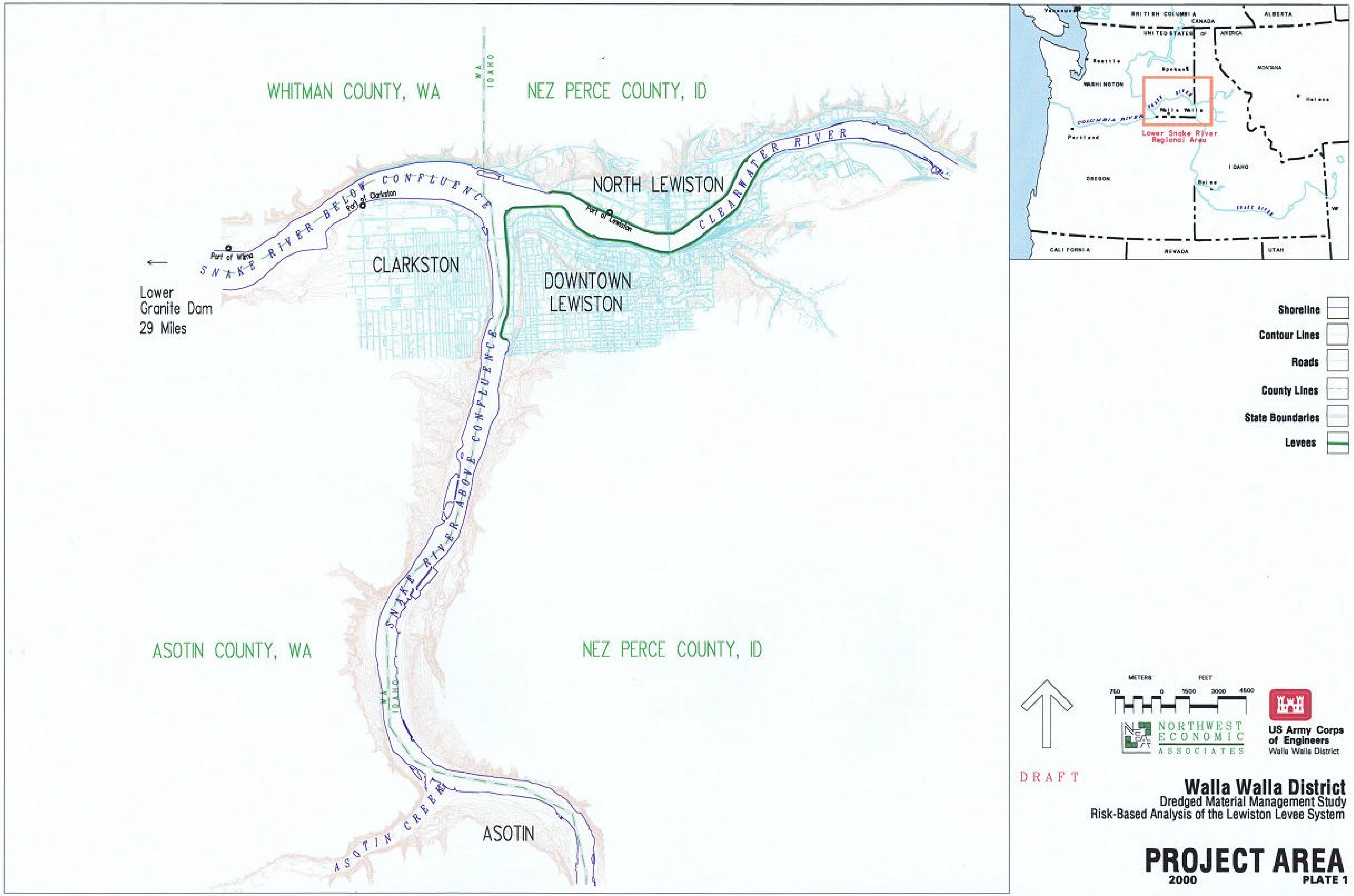
The remainder of this report is organized into five sections. First, section 2.0, Alternatives, describes the alternatives analyzed. Each alternative includes a dredging program, proposed levee height, and method of disposal of sediment. There are four dredging programs, five levee height modifications, and two disposal methods, or a total of 40 alternatives.

Section 3.0, Data and Methods, describes the data and methods used in the analysis. Data on all of the structures in the floodplain were collected for this study, and the development of the database is described. The HEC models and data requirements are discussed. It also includes a discussion of risk and uncertainty, damage analysis, and of the use of Geographic Information System (GIS) data.

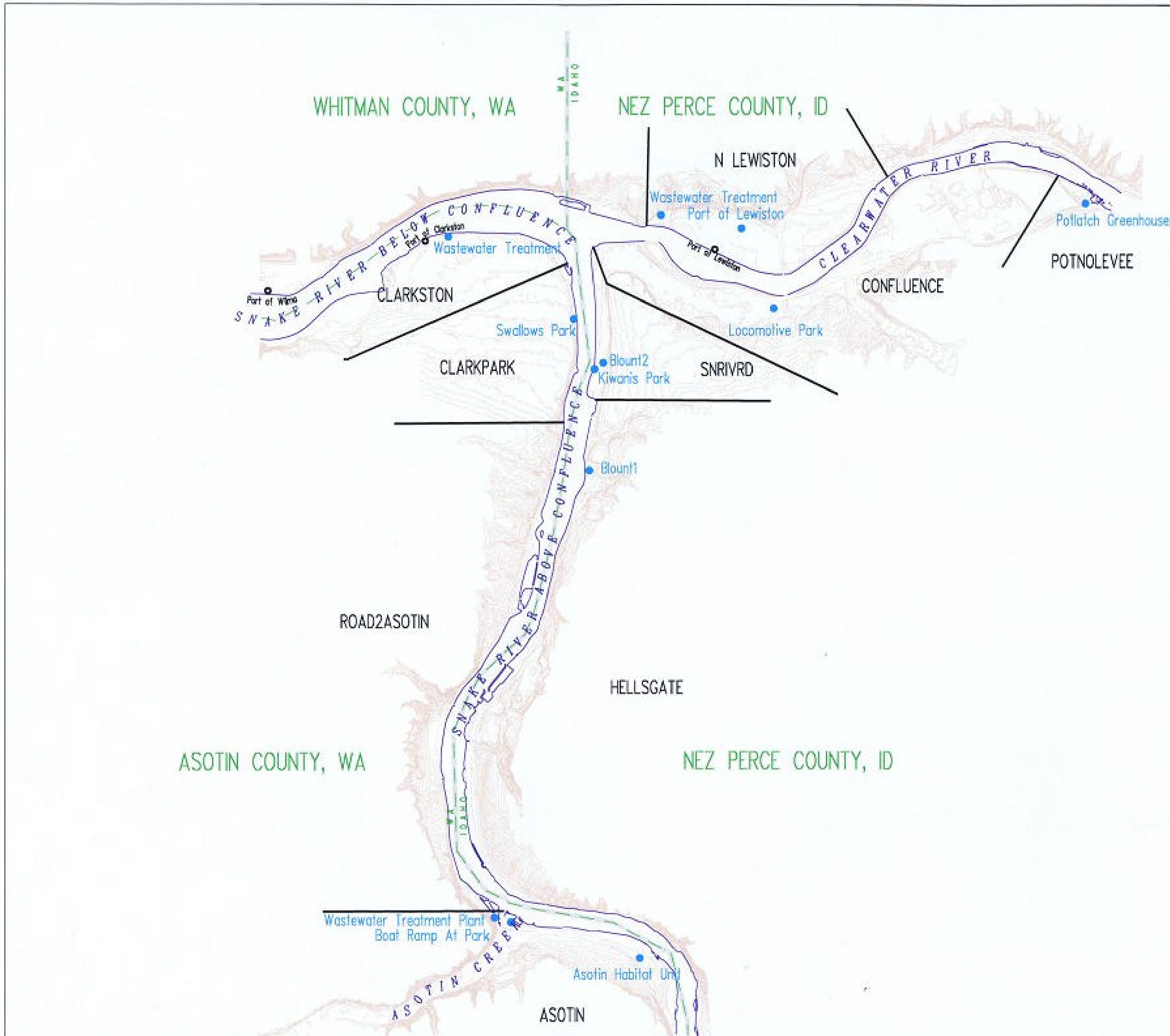
Benefit-cost analysis (BCA) results are then discussed in section 4.0. The benefits and costs of the proposed projects are presented and analyzed. Without-project flood damages are reviewed and used as a basis for comparison of alternative flood damages. Benefit-cost ratios are presented for different time horizons and discount rates, and a specific plan is recommended. Elements of risk and uncertainty are incorporated into a sensitivity analysis.

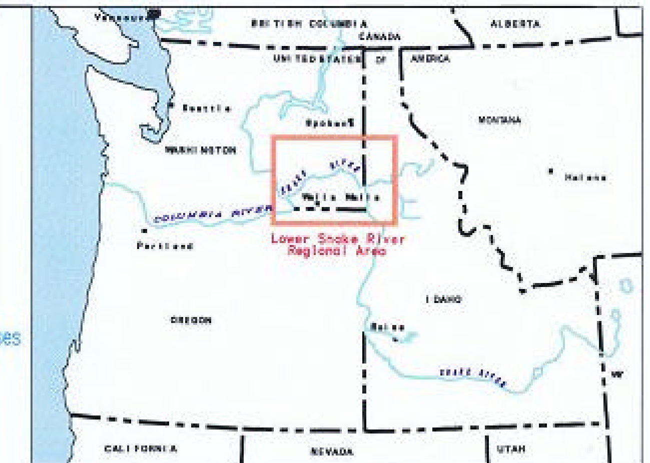
Section 5.0, Conclusions and Recommendations, reviews the results of the BCA and integrates the secondary impacts and social issues. The alternatives are assessed, and a recommendation is made based on the results of the BCA and the secondary and social impacts.

The final section, 6.0 References, contains references pertinent to this appendix. Attachments A-G present supplemental information supporting the analysis in the main body of the report. Attachments A and B show data that was used to develop the damage assessment relationships. Attachment C displays the program costs of the various alternatives under consideration and Attachment D the benefit-cost calculations. Attachments E, F, and G address three areas of secondary issues and social impacts that were taken into consideration prior to concluding the study: environmental costs and benefits, socioeconomic impacts on the Lewiston-Clarkston region, and socio-institutional impacts.



WHITMAN COUNTY, WA
WA
IDAHO
NEZ PERCE COUNTY, ID
NORTH LEWISTON
CLEARWATER RIVER
SNAKE RIVER BELOW CONFLUENCE
Port of Clarkston
Port of Wilma
Port of Lewiston
Lower Granite Dam 29 Miles
CLARKSTON
DOWNTOWN LEWISTON
SNAKE RIVER ABOVE CONFLUENCE
ASOTIN COUNTY, WA
NEZ PERCE COUNTY, ID
ASOTIN CREEK
ASOTIN
BRITISH COLUMBIA
CANADA
ALBERTA
UNITED STATES OF AMERICA
WASHINGTON
MONTANA
COLUMBIA RIVER
SNAKE RIVER
Lower Snake River Regional Area
OREGON
IDAHO
CALIFORNIA
NEVADA
UTAH
Shoreline
Contour Lines
Roads
County Lines
State Boundaries
Levees
METERS
FEET
750
0
1500
3000
4500
NORTHWEST ECONOMIC ASSOCIATES
US Army Corps of Engineers
Walla Walla District
DRAFT
Walla Walla District
Dredged Material Management Study
Risk-Based Analysis of the Lewiston Levee System
PROJECT AREA
2000
PLATE 1





Damage Reach Upstream & Downstream Limits

Indicators

Shoreline

Contour Lines

County Lines

Damage Reach Name

Left-Bank Snake River

CLARKSTON	(Clarkston Area below the confluence)
CLARKPARK	(Clarkston Area above the confluence)
ROAD2ASOTIN	(area between CLARKPARK Reach and Asotin, Idaho)
ASOTIN	

Right-Bank Snake River

SNRIVRD	(Downtown Lewiston Area along Snake River, with levee)
HELLSGATE	(area South of downrown Lewiston)

Left-Bank Clearwater River

CONFLUENCE	(Downtown Lewiston Area, with levee)
POTNOLEVEE	(upstream of Potlatch)

Right-Bank Clearwater River

N LEWISTON	(North Lewiston Area, with levee)

METERS FEET
750 0 1500 3000 4500

NORTHWEST ECONOMIC ASSOCIATES

US Army Corps of Engineers
Walla Walla District

DRAFT

Walla Walla District
Dredged Material Management Study
Risk-Based Analysis of the Lewiston Levee System

DAMAGE REACHES AND INDICATOR POINTS

2000 PLATE 2

2.0 ALTERNATIVES

The Walla Walla District has developed several potential alternative programs to mitigate the increasing sedimentation in the study area. Each alternative includes a quantity of dredging (dredging program, DP), a proposed levee height (L), and a method of disposal (D) in combination. The alternative components are listed below.

2.1 Dredging Programs

- Dredging for maintenance of the navigation channel only (Nav). This dredging program is the basis for the existing conditions.
- Dredging 300,000 (300k) cubic yards (229 366.5 cubic meters) annually.
- Dredging 1,000,000 (1M) cubic yards (764 555 cubic meters) annually during project years 1-10, and subsequently dredging 325,000 cubic yards (248 480.3 cubic meters) annually for years 11-74.
- Dredging 2,000,000 (2M) cubic yards (1 529 110 cubic meters) annually during project years 1-20, and 725,000 cubic yards (554 302.3 cubic meters) annually thereafter for project years 21-74.

2.2 Levee Height Modifications

- No change in the levee height (xst.).
- A nominal 3-foot (ft) (0.9-meter) raise in the existing levee.
- A nominal 4-ft (1.2-meter) raise in the existing levee.
- A nominal 8-ft (2.4-meter) raise in the existing levee.
- A nominal 12-ft (3.7-meter) raise in the existing levee.

2.3 Disposal Methods

- In-water disposal (IW).
- Upland disposal (UL).

Each of the dredging programs is described below. The disposal alternatives are described, as they differ depending on the dredging programs. The levee raise options are described and additional information can be found in appendix E.

The navigation-only dredging plan involves annual dredging of 16,000-300,000 cubic yards (453 to 8 495 cubic meters) of material according to what is needed to maintain a desired template. The template can be thought of as a maximum quantity of allowable sedimentation or a minimum channel size and shape. For the navigation only dredging program with in-water disposal, all material is assumed to be disposed downstream of Centennial Island, 20 miles (32 kilometers) downstream of Lewiston on the Snake River. The material dredged from the template will include some original bed material, likely composed of gravels and cobbles, in addition to accumulated silt material. This dredging program may be employed in conjunction with structure modifications providing either a nominal 3-, 4-, 8-, or 12-foot (0.9-, 1.2-, 2.4-, or 3.7-meter) levee raise.

For the annual 300,000 cubic yards (299 366.5 cubic meters) dredging option, all materials are assumed to be disposed downstream of Centennial Island with in-water disposal. Disposal could also be at the downstream end of this area, near Lower Granite. For the upland or upland disposal option, it was assumed that all dredged material would be permanently removed from the Snake and Clearwater Rivers; disposed of either at a site in the Lower Monumental reservoir or a transfer site on the Lower Granite reservoir. This dredging program could be used in conjunction with structure modifications, providing either a nominal 3-, 4-, 8-foot, or 12-foot (0.9-, 1.2-, 2.4-, or 3.7-meter) levee raise.

For the annual 1,000,000 cubic yards (764 555 cubic meters) dredging option, dredging will be at this rate for the initial 10 years, then decline to a maintenance level of 325,000 cubic yards (248 480.3 cubic meters) annually for the remainder of the study period through the year 2074. It is assumed that all material is disposed downstream of Centennial Island for the in-water disposal option. For the upland disposal option, it was assumed that the material would be disposed of at a transfer site on the Lower Granite reservoir. Each of the levee raise options may be constructed in conjunction with this dredging program.

For the annual 2,000,000 cubic yards (1 529 110 cubic meters) dredging option, dredging will be at this rate for the initial 20 years, then decline to a maintenance level of 725,000 cubic yards (554 302.3 cubic meters) annually for the remainder of the study period through the year 2074. It is assumed that all material is being disposed downstream of Centennial Island for the in-water disposal option. For the upland disposal option, it was assumed that the material would be disposed of at a transfer site on the Lower Granite reservoir. Details of the options for this DP under upland disposal are outlined in appendix D of this DMMP/EIS. Each of the levee raise options may be constructed in conjunction with this dredging program.

In total, there are 40 different DP/L/D combination alternatives. Further descriptions of dredging programs and disposal options can be found in the DMMP/EIS.

3.0 DATA AND METHODS

A team of hydrologists, engineers, economists, planners, geographers, and study managers collaborated in establishing the study data and methods. Both the HEC-FDA user manual and EM 1110-2-1619, stress the importance of cooperation within the multidisciplinary team when conducting this type of a study. The team must pay special attention to areas such as specification of spatial referencing and delineation of damage reaches. While this summary of methods primarily addresses the economic specifications used in the study, hydrologic and geographic data and methods are integral to the estimation procedures and are briefly described.

The following section covers the techniques used in data processing, management, and integration, as well as the methodology used for estimation and analytic purposes. The hydrologic subsection identifies data sources and briefly describes how the data is integrated into the HEC-FDA process. The next subsection covers the structure inventory data, detailing the process that was used to develop the database. A damage assessment subsection describes how damage estimation relationships were developed. The damage assessment parameters were developed based on previous studies and data sources, and so these are briefly reviewed within the subsection. The risk-based analysis approach is presented in a subsection, and the principles of the BCA are summarized in another. Subsection 3.6, GIS Environment, details the use of GIS data and process that was used in data management.

3.1 Hydrology

The Corps HEC has developed several models to facilitate estimation of hydrologic processes. For this study, the Walla Walla District hydrology unit provided NEA with data on the flood elevations in the project area projected to the year 2074 under both the existing conditions and the alternative scenarios. To do so, the research team first employed the HEC-6 model, which simulates the effects of river sediment transport and the resulting changes in river channel cross section geometry. The channel cross section geometry was then used as input into the HEC-2 model, which predicts water surface elevations along a channel. The Walla Walla District hydrology unit also provided historical discharge data, geotechnical failure data for the levees, and guidance on the uncertainty parameters associated with stage discharge functions.

3.1.1 Water Surface Profiles

The Walla Walla District provided water surface profiles (WSP's), consisting of eight different flood event elevations for each set of Snake and Clearwater River cross-sections. The eight flood events consisted of the following: 0.5 probability flood (2-year flood), 0.2 probability flood (5-year flood), 0.1 probability flood (10-year flood), 0.05 probability flood (20-year flood), 0.02 probability flood (50-year flood), 0.01 probability flood (100-year flood), 0.005 probability flood (200-year flood), and the 0.002 probability flood (500-year flood). One WSP was created for each of three different river segments, at two different points of time in the future. A WSP was first produced for the without-project scenario, which consists of navigation only dredging. This profile represents both the in-water and upland disposal methods as the quantity of in-water disposed material does not alter the projected flood elevations. Each of the alternative scenarios was also modeled producing a WSP for each of four dredging programs for each of two disposal methods at each of two points in time in the future.

Because the WSP for the navigation-only dredging program did not change between in-water and upland disposal methods, only six WSP's were created for the baseline scenario (three river segments multiplied by two points in time). For each of the other 3 dredging programs, a total of 12 WSP's were developed (3 river segments multiplied by 2 points in time multiplied by 2 disposal methods). Three WSP's describing the initial conditions as of 1997 were also provided. The initial conditions served as the starting point for all of the future WSP's, both for the without project and the alternative scenarios. The total number of WSP's developed was 45: 3 dredging programs multiplied by 12 WSP's, plus 6 for the navigation only, plus 3 for the initial conditions.

3.1.2 Uncertainty Parameters and Historical Data

The Walla Walla District provided historical data regarding peak discharge frequency curves for the Clearwater River and the Snake River above the confluence. Data from the confluence of the two rivers were used to estimate conditions for the Snake River below the confluence. These data were summarized in statistical parameters including not only mean values, standard deviation, and skew for a Pearson’s Log III distribution, but also the number of years that records had been kept.

The Walla Walla District also provided guidance on the selection of probability distributions and parameters to be used in conjunction with the WSP's for estimation purposes. A sensitivity analysis of the flood damage allows for alternative specification of uncertainty parameters and for the subsequent analysis of the results. The guidance from the Walla Walla District was therefore used as a starting point for the sensitivity analysis. It was decided that the triangular distribution would be used, with the minimum value set to just below the projected water surface elevation, and the maximum value set to 3 feet (0.9 meter) above the WSP elevation.

3.1.3 Geotechnical Failure Data

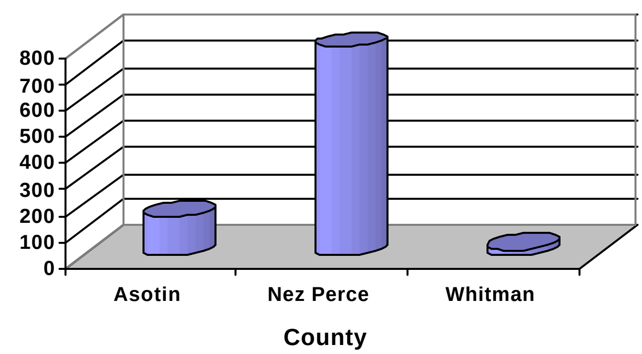
The data provided to the consultant regarding probability of geotechnical failure included identification of the elevation on the levee of the Probable Non-Failure Point (PNP), the Probable Failure Point (PFP), and the associated probabilities of each. The PNP was identified at 5 feet (1.5 meters) below the top of the levee, and the probability of failure below that point as 0.001. The PFP was identified at 1 foot (0.3 meter) below the top of the levee, with a failure probability of 0.15. These values were not accepted into the HEC-FDA model, because the PNP probability was negligible. This may be related to the fact that the Lewiston levee system was not designed for the purpose of providing flood control to the city, but rather the system can be thought of as an upstream extension of the dam. Hence, they were built to dam embankment standards and are less likely to fail than ordinary embankments. Moreover, use of geotechnical failure data is not required for levees that are maintained to Federal levee standards (EM 1110-2-1619, p. 7-3).

3.2 Structure Inventory

The Walla Walla District provided pictures of the main structure occupying each tax parcel located within the floodplain. Tax parcel numbers were used to obtain the assessed value of the structures from the respective county assessors' office and the data were put into a database containing descriptive information about each structure. As shown in figure 1, more than 85 percent of the observations were from Nez Perce County, Idaho.

Pictures of the inventory of structures in the floodplain area were provided on a CD-ROM for computer use. For this study, the pictures were matched with the data from the data input set using GIS Arcview software. The pictures were printed and labeled with picture identification numbers on letter-size paper and placed in two three-ring binders for easier access during the evaluation process.

Figure 1. Number of Tax Parcels by County

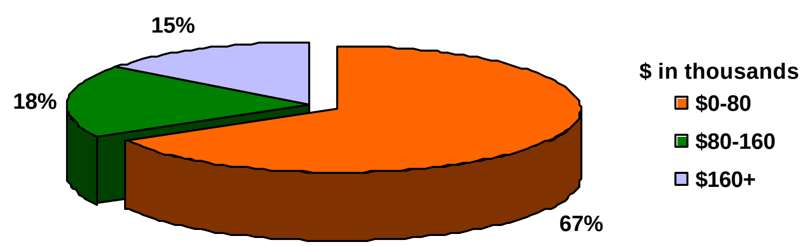


Listed below are the variables available in the structure inventory and in the tax assessor database for Nez Perce County. The data were linked using the tax parcel number (highlighted in the following list). The data for Asotin County followed a similar format, although the assessor data provided additional useful information such as the number of stories in the building, the year built, and the square footage in the structure. Only ten parcels in the floodplain are located in Whitman County. The NEA faxed the tax parcel numbers to the county assessor and requested information on property owners' names and addresses, types of business, and the values. In all three counties, the tax assessors' office used depreciated replacement values (DRV's) in assessments. Consequently, it was not necessary for NEA to convert any assessment data into DRV.

Nez Perce Structure Inventory Data	**Nez Perce County Assessed Valuation Data**
Northing	***Tax Parcel Number***
Easting	Owner Name
First Floor Elevation	Owner Address 1
Ground Floor Elevation	Owner Address 2
Street Address	Owner City
Tax Parcel Number	Owner State
Digital Photo Number	Zip
	Property House Number
	Street
	Zip
	Assessed Value

As shown in figure 2, the majority of structures in the floodplain are valued at less than $80,000, while only 15 percent of the structures have assessed values greater than $160,000. Combined, the total value of all structures in the database is nearly $2 billion.

Figure 2. Percent of Total Tax Parcels by Structure Value Range



Two additional steps were required to complete the input data set. First was to combine data from the three counties into one database consisting of 945 tax parcels. Second was to identify each of the structures with a river mile point along the river center line. This was done using the GIS environment. Data obtained from the GIS database includes: stream name (Snake River above, Snake River below, or Clearwater River), river mile number, and riverbank (left or right). All of these variables are needed for operation of the HEC-FDA model.

3.2.1 Collection of Additional Data

Many of the tax parcels included in the information were owned by government and nonprofit organizations and consequently were listed as "Exempt." These structures were not assessed for tax purposes and therefore had no associated value at the county assessor offices. Values were sought by first identifying a person who could provide the required information through telephone calls to each entity. The individual was then mailed a letter explaining the project and requesting DRV's for structures and contents. The letter also stated that a representative from NEA would call in a few days asking for the values (see example below). Examples of tax exempt structures include those located on land owned by the Port of Lewiston, Port of Whitman, railroad companies, as well as structures housing public offices and services (e.g., schools, prisons, fire stations, park structures, etc.). If the owner of the structure was unable to provide its value, a value was estimated based on values of similar structures included in the database.

(Date)

Dear _____________:

As a representative of the consulting firm, Northwest Economic Associates (NEA), I am currently conducting research for a flood damage assessment project in conjunction with the U.S. Army Corps of Engineers. This project focuses on Lower Granite Lake, which is the uppermost reservoir of the four lower Snake River reservoirs, and the levee system built in Lewiston, Idaho.

NEA is currently evaluating the economic benefits of reduced potential flood damage provided by the lock and dam system region under a variety of alternative scenarios. In order to be as accurate as possible in our assessment, we need the following information for all public buildings in the Lewiston-Clarkston area:

1. What is the total depreciated replacement value of the structure?
2. What is the total depreciated replacement value of the contents of the structure?
3. What percentage of damage might occur to the structure and contents of the building during a flood?
4. Are there other items such as vehicles or storage facilities that would potentially be damaged during a flood?

Our records indicate that ____ owns the property located at ____.

I plan to contact you shortly after you receive this letter, so that I may obtain this information. If you know you will be unavailable in the next few days, could you please leave the information with a designated representative? The information provided by you will be strictly confidential.

Enclosed is my business card. If you wish to contact us for any reason before I call, please feel free to call Gretchen Greene or myself at NEA.

Thank you for your cooperation in this matter.

Sincerely,

In some cases, it was necessary to modify the structure information provided by the Corps in order to assign the appropriate value to a building. In the original data set, several tax parcels contained more than one structure (multiple pictures associated with the same tax parcel). An onsite review of the assessor's database was conducted for these parcels in order to assign a value to each individual structure. Many of these were found to be exempt properties and handled as described above.

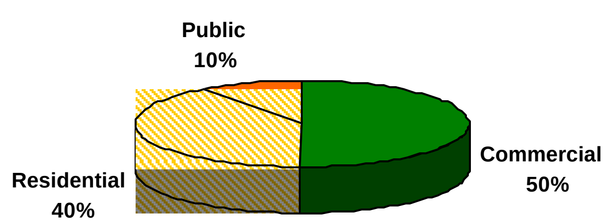
Based on a visit to the study area, NEA researchers identified several important structures that were not included in the original database. These structures were located primarily within the Ports of Lewiston and Whitman. Managers of the ports identified the owners of the buildings. The owners were then contacted by telephone and asked to provide information regarding the value of structures, inventory, and equipment. In addition, maps provided by the ports showing the location of each business were used to create additional points in the GIS database in order to develop the location and elevation information necessary for the HEC-FDA model.

The structures inventory database also included additional tax parcel numbers to account for structures that were located on more than one parcel. The assessor's office assigns the value of a structure to only one tax parcel regardless of the number of parcels a building occupies. Consequently, many of the structures were found to have either no associated assessed value or unreasonably low values when compared with the photos. In most cases, it was possible to identify the tax parcels that contained structure value information by viewing the values and comparing them to the photos and property maps showing the rooflines of the structures. In others, the information was sent to a county assessor's office in order to obtain the commercial parcel type codes and associated values for each tax parcel in question.

3.2.2 Categorizing the Data

Buildings within the structure inventory database were primarily categorized as commercial, residential, or public. The percentage of structures falling into each category is shown in figure 3. Within each of these primary categories, structures were further subdivided by considering the name of the owner and the digital photograph of the structure. The primary division and secondary division correspond to the categorization that is used in the HEC-FDA model as a basis for assigning damage functions.

Figure 3. Tax Parcels by Owner Category



Ultimately, residential buildings were classified into seven categories, by building material and the number of stories of the building. The classifications were based on the photographs. The categories are listed below, along with the number of tax parcels placed in each occupancy type.

- 1 Story Wood 285
- 1.5 Story Wood 2
- 2 Story Wood 64
- 1 Story Masonry 12
- 2 Story Masonry 3
- Mobile Home 6
- Shed 3

Commercial buildings were similarly classified into occupancy types based on the type of business occupying the structure. The name and type of some businesses were clearly visible on signs in the photographs. In other cases, the name in the picture identifies the business but not the type of business. Some buildings have no type of identification on them at all. Additional telephone calls established business identification. Several downtown buildings contain two or more businesses, and again, telephone calls established all businesses in each building. The following table lists the number of tax parcels from the structure inventory included in each damage function category for commercial buildings (table 1).

Public structures were also categorized. Many were placed in the "general" category because of their unusual characteristics (e.g., a picnic facility or a baseball park dugout). The number of observations associated with each public structure occupancy type is shown in table 2.

Table 1
Commercial Structure Categories

Damage Function Category	Number of Parcels	Damage Function Category (continued)	Number of Parcels	Damage Function Category (continued)	Number of Parcels
Appliance Sales	6	Food Processor	1	Pawn Shop	1
Appliance Service	4	Furniture	11	Pet Store	1
Auto Dealer	4	Garage	1	Photo Studio	1
Auto Parts	3	Gas-Butane Supply	2	Physical Fitness	1
Auto Parts-Mufflers	1	General Commercial	41	Plumbing	1
Auto Parts-Tires	3	Golf Course	1	Potlatch Corporation	1
Auto Repair	29	Grocery – Large	3	Printing	1
Auto Service	7	Grocery – Small	5	Private Club	3
Bakery	2	Hardware	6	Radio Station	1
Bank	3	Hardware - Lumber	2	Real Estate Office	3
Boat Sales and Serv.	7	Hobby Shop	1	Recycling - Metal	1
Boat Service	4	Hotel	1	Research Lab	1
Boat Storage	3	Jewelry	2	Restaurant - Café	6
Business	30	Leather Goods	1	Restaurant-Fast Food	3
Car Wash	1	Liquor Store	1	Restaurant-Regular	15
Carpet, Tile, Floor	4	Loading Dock	5	Service Station	7
Cleaners	1	Lock Shop	4	Shoe Store	1
Clothing	3	Lumber Mill	1	Skating Rink	1
Concrete Mfg	4	Lumber Yard	1	Sporting Goods	4
Department Store	11	Mach. Shop - Heavy	3	Tavern	4
Doctor’s Office	5	Mach. Shop - Light	12	Theatre	1
Door Mfg	2	Medical Supplies	1	Transport Co.	7
Drug Store Chain	1	Motel Unit	12	Truck Sales	1
Elect. Equip. Mfg	2	Newspaper Print Plt.	1	Vacant Building	8
Electronic Sales	2	Newspaper Office	2	Vacuum Sales	3
Fabric Store	1	Nursery - Plant	2	Veterinary Clinic	1
Fabrication Shop	5	Office	76	Warehouse	37
Feed Store	7	Oil Storage Tanks	2		
Florist	2	Paint Store	2	***Total***	***475***

Table 2
Public Structure Damage Function Categories

Category	Number of Parcels
General Public	50
Hospital	1
Loading Dock – Public	1
Office – Public	18
Police Station	4
Post Office	3
School	1
Warehouse – Public	7
YMCA	2
Church	1
Fire Station	2
Garage – Public	2
Golf Course – Public	2
Hall – Public	1
Total	**95**

Greater detail regarding the selection of categories is documented in paragraph 3.3.1, Review of Existing Information Sources, of the next section.

Two other categories, automobiles and indicators, were added to the structure inventory database. Automobiles were included to be consistent with the Corps protocol for flood damage assessment. Indicator values were included to better understand a number of critical structures and/or landscape features that might be exposed to flooding. The collection of indicator values includes three wastewater treatment facilities, three parks, one boat ramp, a habitat preservation unit in Asotin, and two industrial sites. The locations of the indicator variables are shown in plate 2. These sites were assigned a low, insignificant value ($100) and damage functions that counted the damage as complete ($100) if there were any flooding in these areas. The purpose of these was to be able to quickly identify whether or not each of these areas was flooding. Each of the indicator observations implied the possibility of indirect social or environmental effects associated with the direct damage to the site.

3.3 Depth Damage Relationships

This subsection includes two topics. First is a review of information related to estimating flood damages to structures, contents, vehicles, and other categories (equipment, landscaping, and clean-up costs) provided by the Corps and the Federal Emergency Management Agency (FEMA). Second is a description of the methods used to calculate flood damages for this study.

There are several methods for estimating flood damages using depth-damage functions (Cannon, et al.). Such functions for physical structures measure the relationship between structure damage (as a percent of structure value) and floodwater levels. Content depth-damage functions measure the same relationship, where content damage is expressed as the percent value of total structure contents. There are similar depth-damage functions for vehicles. Equipment and landscape damages and clean-up costs are usually estimated in absolute terms through direct interviews or data collection.

3.3.1 Review of Existing Information Sources

This review is divided into four parts. The first discusses methods of assessing content values as a percentage of structure values. Structure values as received from the tax assessors' offices are assumed to be accurate, and hence these values are not reviewed here (see subsection 3.2, Structure Inventory, for more information). The second addresses damage functions for structures. The third describes damage function estimates for contents. The fourth subsection deals with a general "Other" damage category that includes vehicles, landscaping, clean-up costs, transportation and utilities, as well as nonphysical damage.

The review is based on reports and documents received from the Corps and other sources. These reports and documents include flood damage estimates for the Wyoming Valley of northeastern Pennsylvania (Kieffer and Willet, 1996); flood damage survey results from the Pearl River Basin, in Mississippi and Louisiana (Gulf South Research Institute, 1982); the Corps, Baltimore District, depth damage functions; Corps, Galveston District, post-flood survey depth-damage relationships; and a flood damage report for Frankfort, Kentucky (Corps, Louisville District, 1981). The FEMA data are also reviewed.

3.3.1.1 Content Value

The Pearl River study is the only one known in which data were collected on the actual value of structure contents. The data are for the value of contents for commercial enterprises classified by Standard Industrial Classification (SIC) code. Other available information on the value of structure contents is in the form of content value-to-structure value (C/S) ratios. The C/S ratio is defined as content value divided by the DRV of a structure. For each SIC code, a table provides information on the maximum, minimum, and average content value as a percentage of structure value. The Wyoming Valley study and the Pearl River data provide C/S ratios by SIC code for specific types of commercial enterprises. The Corps guidance stipulates the use of a standard C/S ratio of 50-55 percent for residential structures (Davis, 1999a).

Kiefer and Willet (1996) have provided a thorough discussion of the types of secondary information that could potentially be useful for estimating content values of commercial structures. Secondary sources include insurance companies, published government statistics, and private commercial data services. No published government statistics identify values for commercial business contents by business category.

Discussions by Kiefer and Willet with insurance company representatives indicated that the industry does not normally apply standard C/S ratios in determining commercial content value because of varying activities among businesses that provide similar services. Furthermore, because several businesses lease or rent space, there is often no direct link between the value of business contents and business structure. Therefore, insurance companies usually estimate content values by a direct inventory. Due to resource constraints, a survey of project area business owners to estimate content value directly was not possible for this study.

Kiefer and Willet also investigated several private companies that provide estimates of business content values. Marshall and Swift (1991) provide the best source of content value estimates. Marshall and Swift, in combination with Oxford Information Technologies, have developed a software package known as Commercial Contents and Inventory (CCI), capable of estimating the value of commercial building contents. The CCI will generate estimates of equipment and inventory replacement costs by four-digit SIC. To generate content values, field data are required for geographic location, annual gross income, building size, year of business start-up, the number of daily production shifts, density of equipment in the building, equipment quality, and the number of employees. Except for geographic location, none of this information was available for this study.

Employing the survey data from Wyoming Valley business owners, Kiefer and Willet developed a log-log regression model to predict the content value of commercial structures.[3] The initial predictive independent variables included: the square footage of structure, the number of employees, DRV of the structure, the number of years at the location, past flood experience, number of buildings at the location, the SIC code, the presence of a basement, number of stories for the structure, and whether or not the owner had flood insurance. The final variables retained for estimating content values included the square footage of the structure, number of employees, and DRV of the structure.

Table 3 shows C/S ratios for the seven primary two-digit SIC commercial enterprises. The seven two-digit commercial functions represent food and grocery stores (SIC 54), automotive dealers and service stations (SIC 55), furniture and home furnishing stores (SIC 57), eating and drinking establishments (SIC 58), miscellaneous retail (SIC 59), personal services (SIC 72), and auto repair, services, and garages (SIC 79).

Structure values reflect total DRV. Ratios are presented for two scenarios: with and without business records. In all but two of the seven enterprises (eating and drinking places and auto repair, services, and garages), the C/S ratios can take on a value of zero within one standard deviation of the mean signifying the wide degree of variation among businesses within the same two-digit SIC code. The C/S ratios were also calculated for 135 three-digit SIC commercial enterprises, but most had only one observation.

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3 Four different forms of the regression model were tested. The log-log version was retained because it had the highest R^2 and F-Value. However, all models had significant F-values, indicating that each had significant explanatory power. No statistical test was conducted to determine if one model had more explanatory power than any other.

Table 3
Content-to-Structure Value Ratios by Two-Digit SIC Code

Two-Digit SIC	Description	Content-to-Structure Ratio (Mean)	Content-to-Structure Ratio (Std. Dev.)
54	Food store	1.90	1.93
55	Auto dealers and service stations	1.36	1.93
57	Furniture and home furnishing stores	2.03	3.92
58	Eating and drinking places	0.50	0.33
59	Miscellaneous retail	1.67	1.81
72	Personal service	1.70	2.44
75	Auto repair, services, and garages	1.23	1.06

The sample mean for the C/S ratio for the seven two-digit SIC enterprises was 1.48. The sample mean for the C/S ratio for all 135 commercial enterprises was reported to be 2.66. In both cases, there is a substantial variation in C/S ratios due to the large degree of heterogeneity between the different types of commercial enterprises. Because of the very small sample sizes at the three-digit SIC level, readers were cautioned about generalizing these disaggregated results to other parts of the country.

The average value of structure contents and C/S ratios for the 29 types of commercial enterprises are taken from the Wyoming Valley study. It is not indicated whether DRV represents structural value or if business records are included as part of content value. The average C/S ratio across all 29 enterprise-types is approximately 1.00.

3.3.1.2 Structure Damage

The Corps provided five sources of information for estimating depth-damage functions for physical structures. In each case, the structure damage function is expressed as a percentage of DRV that is lost due to flooding.

Estimates of structural damages in the Wyoming Valley study are based on the assumption that depth-damage functions are not simple linear relationships that show damages increasing at a constant rate in response to flood depth. Previous research had shown that significant damage occurs at low flood levels with a decreasing rate of damage over each additional foot of floodwater. Kiefer and Willet use a nonlinear model based on negative exponential growth to calculate the percent of structural damage relative to flood depth.[4]

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[4] The general depth-damage function for all commercial structures is represented as Percent structure damage = $0.72 * (1-e^{-0.13*depth} * e^{-0.09*basement})$. Information with respect to flooding depth and the presence of a basement is required to calculate the percent of structural damage.

Structural depth-damage functions are provided for the same seven different types of commercial enterprises defined above in paragraph 3.3.1.1, Content Value, above (see table 3). One function is defined for public structures that house membership organizations. A general depth-damage function representing all commercial enterprises is also developed. Each of the seven two-digit commercial category functions represents several different types of businesses for that category. For example, the depth-damage function for automotive dealers and service stations (SIC 55) is applicable to new and used motor vehicle dealers, auto and home supply stores, gasoline service stations, and recreational vehicle dealers. Most of the SIC categories are represented by over 30 individual firms.

Another source of estimates of damage for commercial structures is available from the Pearl River study (1982). These functions are based on five categories of construction material: metal; brick, concrete or cinder block on slab; brick on piers; brick veneer on wood frame or piers; and brick veneer on wood frame on a slab. Tables for each category of construction material provide the percentage of structural damage according to flood depth ranging from (-2) feet (-0.6 meters) below the first-floor elevation to 15 feet (4.6 meters) above. There is no information to indicate whether these functions account for basements or the number of stories. Table 4 provides an example of depth-damage estimates (in percentage terms) for metal buildings.

Table 4
Depth-Damage Estimate for Metal, Non-Residential Structures

Depth to Flooding Feet (Meters)	Percent Damage to Structure
-2.0 (-0.6)	0
0.0 (0.0)	0
2.0 (.6)	2
4.0 (1.2)	6
6.0 (1.8)	6
8.0 (2.4)	8
10.0 (3.0)	9
12.0 (3.7)	9

The Institute for Water Resources (IWR) of the Corps (Davis, 1999b) provided percentage flood damage estimates for 241 commercial and public structures in Galveston, Texas. The commercial structures are organized by SIC code. The majority of the structures are commercial enterprises, but public structures are also included. Percentage damage estimates are provided for each structure for flood depths ranging between 1 and 25 feet (0.3 to 7.6 meters). It is not specified whether the estimates include basements or structures exceeding one story.

The Frankfort, Kentucky, information was also provided by the IWR. The data include damage estimates for residential structures for depths ranging from 0 to 20 feet (0 to 6.0 meters) (Corps, Louisville District, 1981). These estimates are provided for structures that are one story or from

1 1/2 to 2 stories. In both cases, damage estimates are given for structures with and without basements.

The Baltimore District damage guidance chart applies only to residential structures. The chart provides percentage damage estimates according to building type and flood depths ranging from 0 to 8 feet (0 to 2.4 meters). There are different combinations of houses, garage configurations (attached, unattached, and size), sheds, and barns. Houses are differentiated according to building material, the number of stories, and whether or not there is a basement.

The FEMA provided representative nationwide estimates of damage ratios (in percent) for structures that could be classified as residential or commercial (Hays, 1999). No distinction is made between the two categories. These estimates are complemented by actual flood claims representing the period from 1978 to 1997. Both the percentage damage estimates and the actual flood claims are referred to as the 1998 Flood Insurance Rate Review.

Estimates of percentage structural damage are given for four building types that are distinguished by the number of stories. These estimates apply equally to commercial, residential, or public structures. The building types include single-story, two-story, split-level, and mobile structures. Percentage damage estimates for split-level and two-story structures are further distinguished on the basis of whether there is a basement. Damage estimates are given for increments of 1 foot (0.3 meter), ranging between (-4) and 18 feet (-1.2 and 5.5 meters) of flood depth.

3.3.1.3 Content Damage

A primary objective of the Wyoming Valley study was to construct content depth-damage functions for selected commercial enterprises. The study demonstrates how to estimate flood damages to the contents of commercial structures using generalized mathematical models and local survey data. The study estimated content depth-damage functions for commercial enterprises flooded by Tropical Storm Agnes in 1972. These functions were estimated using 1992 survey data collected from business owners. The data included content and depreciated replacement structure values, building characteristics, previous flood damage, and expected damages from hypothetical floods. Content value was defined as the sum of the values of equipment, supplies, inventory, raw materials, and business records kept inside the structure.

There were four primary types of survey data. First was the structure characteristics that would have an impact on flood damages to contents (building size, number of stories, existence of a basement, damage mitigation measures used, amount of warning time, and length of time the business was closed). Second was hypothetical content damage estimates provided by owners at four discrete flood depths (1, 4, 8, and 12 feet) (0.3, 1.2, 2.4, and 3.7 meters), based on experience from Tropical Storm Agnes. Third was owner-estimated damage to building contents, including equipment, inventory, business records, and vehicles. Fourth was the DRV for commercial structures estimated using the Marshall and Swift Commercial Estimator Worksheet. The worksheet provides a format for assessing building structure value based on construction material, condition, type of heating and cooling system, and occupancy number.

Two content damage functions were calculated for each commercial enterprise on the basis of whether the structure was a single- or multi-story building. Kiefer and Willet state that "Although this research provides convenient tools for assessing important components of (commercial) flood damages, the results of this study may not be very transferable outside of the Wyoming Valley sample. Potential differences in damage and value estimates by geographic region, as well as the composition of the nonresidential business sector in other floodplains potentially restrict the use of these results for other regions of the nation. Readers are urged to verify the results of this study wherever possible through the use of local surveys and other available sources" (Kiefer and Willet, 1996)

The regression models developed in the Wyoming Valley study are based on business owners' estimates of damages. Normally, researchers should be cautious in using data where there is a possible motivation on the part of the respondent to answer in a strategic way. In the case of the Wyoming Valley study, this type of bias may have been minimized by comparing owners' estimates with real damages and because owners based their estimates on the real costs from Tropical Storm Agnes.

The Pearl River report contains percentage content damage estimates for both commercial and residential structures. Content depth-damage estimates are presented for 29 commercial enterprises by flood depth.[5] One content damage estimate is reported for religious meeting places. Commercial enterprises are defined by SIC category, and content depth-damage functions are reported for individual firms that fall within each of these categories. For each firm, information on the dollar estimate of content value, the percentage of C/S ratios, and the percent damage to contents as a result of floodwater over the ground floor of the building is included. Flood depth ranges from 0.5 to 15 feet (0.1 to 4.6 meters) in increments of 0.5 foot (0.1 meter). However, the Pearl River data does not distinguish damage estimates according to building material or whether the structure has a basement or not.

The Galveston database includes content depth-damage functions for 241 commercial and public structures classified by type of commercial firm and SIC code. Content damages are expressed as a percentage of content value for depths ranging between 0 and 24 feet (0 and 7.3 meters), in increments of 1 foot (0.3 meter). Content damage estimates are not distinguished for the existence of a basement or for the number of stories for the structure. Even though there are separate estimates, structure contents include both inventory and equipment (Davis, 1999c), excluding such cases as automobile dealers where the inventory is located outside of any structures.

The FEMA provided representative nationwide estimates of content damage ratios (in percent) based on a 1973 study (Hays, 1999). These estimates are complemented by actual flood claims data from 1978 to 1997. Percentage content damage estimates are distinguished on the basis of two criteria. The first distinguishes between whether the structure is a commercial or residential building. The second distinguishes between structures with one floor or multiple floors, or

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5 Commercial enterprises include general grocery and specialty food stores, eating and drinking establishments, banking, real estate and insurance, medical and drug facilities, contractors, machinery and equipment, automotive service and repair, several types of department and specialty stores, cleaning and maintenance, and transportation.

whether it is a mobile home/office. Content damage is not distinguished on the basis of whether there is a basement. Damage estimates are given in increments of 1 foot (0.3 meter), ranging between (-4) and 18 feet (-1.2 and 5.5 meters) of flood depth.

Residential content damages are estimated for depths ranging from 0 to 20 feet (0 to 6 meters) based on the Frankfort data (IWR 1981). Percentage damage estimates are provided for structures that are one story and 1 1/2 to 2 stories. In both cases, content damage estimates are provided for structures with and without basements.

The Baltimore depth-damage guidance chart is relevant only to the contents of residential structures. The chart provides the expected percentage of damage to contents according to building type and flood depths ranging from 0 to 8 feet (0 to 2.4 meters). There are different combinations of house and garage configurations (attached, unattached, and size), sheds, and barns. Houses are differentiated according to construction material, the number of stories, and whether or not there is a basement.

Content damage functions are provided in the Baltimore guidance chart in the same format as commercial structures and are categorized according to two criteria. The first criteria is based on five dwelling types that include mobile homes and homes that are either single-family single-story, single-family two-story, multi-family single-story, or multi-family two-story. The second criterion is based on the estimated *sales* value of a residence. Sales categories correspond to ranges of $0 to $19,000; $20,000 to $29,999; $30,000 to $44,999; $45,000 to $64,999; $65,000 to $89,999; and $90,000 and up. There is no information to indicate whether sales value is equivalent to DRV.

3.3.1.4 Other Damages

The Corps provided guidance for estimating dollar damages to residential vehicles. Two assumptions form the basis of these estimates. First, it is assumed that most homeowners in the floodplain have more than one vehicle but that only one would be subject to flood damage. It is also assumed that the average value of a flooded vehicle is $8,000. Auto damages are estimated at 10 percent for a flood depth of 1 foot (0.3 meter), 20 percent for 2 feet (0.6 meter), 30 percent at 3 feet (0.9 meter), and 80 percent at 4 feet (1.2 meters).

Although residential landscaping incurs economic damages from flooding, no direct survey data or estimated damage functions from secondary sources exist that would permit the calculation of these damages. Similarly, no direct survey data or damage functions exist that would permit the calculation of clean-up costs in residential areas.

The Pearl River tabular data for 29 types of commercial enterprises include estimated clean-up costs, which is the only available information. The study does not report the source of those data, but it is assumed for this study that they represent the owners' estimates based on previous flood experience.

The Frankfort study divides flood damages into three categories: emergency costs, physical damages, and nonphysical damages. The physical damages subsection contains the utility and transportation calculations required in this study for "Other Costs."

3.3.2 Approach Used in This Study

Following review of the existing sources of damage function estimation procedures for structure, contents, and "other" categories, NEA assessed the available data for the Lewiston study and matched it with damage functions and uncertainty parameters from the appropriate sources detailed above. The following paragraph details the methodology selected for use in the HEC-FDA model and in the BCA. Value specifications are developed for structure, contents, and "other" damages. In addition, damage function and uncertainty parameters are required for both structure and content damages.

3.3.2.1 Structure Value and Uncertainty

Geographic data for commercial, residential, and public structures in the project floodplain were obtained from the Walla Walla District. The DRV data for the structures were obtained from the tax assessor offices in Nez Perce, Asotin, and Whitman counties. See the "Structure Inventory" subsection for additional information.

The HEC-FDA model allows for the incorporation of uncertainty into the structure damage estimate. However, the data supplied by the tax assessor offices were assumed to be accurate, and no uncertainty bounds were applied.

3.3.2.2 Content Value and Uncertainty

For each commercial damage category, the value of contents in the structure (as a percent of structure value) was determined using survey data from the Pearl River flood study. The percent value of contents and depth-damage relationship were provided for each business surveyed by SIC code. The average content value for all businesses surveyed was used in the Lewiston/Clarkston study for businesses that did not match any of the categories used in the Pearl River study.

As specified in Corps EM 1110-2-1619, a measure of uncertainty should be applied to the content-to-structure value ratios to account for variation among businesses within each damage function category. To accomplish this, the data from the Pearl River flood survey were used to calculate the standard deviation of the percent value of contents within each category as a measure of uncertainty around the value in the model (see attachment A). The Pearl River data were entered into a spreadsheet for analysis purposes and are shown in attachment A. Electronic copies of this information are available from NEA.

Content value for residential structures was obtained, in part, from the Baltimore District Guidance Chart. This source recommends using a content value between 50 and 55 percent of the structure value. A value of 55 percent was applied following corroboration using the residential data contained in the Pearl River flood study. The standard deviation of the percent value of contents within each residential category was calculated from the Pearl River flood survey data.

The content values and uncertainty for public structure damage categories were obtained using the same sources and methods as described for commercial contents.

3.3.2.3 Other Costs of Flood Damage

Estimated clean-up costs for selected commercial enterprises are taken from the Pearl River study. Clean-up costs are calculated by dividing the average of the total clean-up costs by the average of the total structure and contents values. The data suggests average clean-up costs represent 2 percent of the value of the building and contents. Based on this estimate, NEA calculated 2 percent of the value of contents and structure damage to account for clean-up costs.

The Frankfort, Kentucky, flood damage study includes detailed information on other flood costs. This study uses the Corps (Louisville District, 1981) report as the main information source and provides documentation for the assessment of "other costs" involved in a theoretical Lewiston flood.

Understandably, a Lewiston flood would not create an identical flood situation to the one in Frankfort, Kentucky. Therefore, this study makes the following assumptions:

- Actual costs cannot be compared because the Kentucky report uses 1978 prices, and this study performs calculations using 1999 prices. Instead of values, ratios of the flood category costs to the total flood costs are used.

- The Lewiston flood may generate higher percentages of damages in some areas and lower percentages in other areas, but the overall total "other cost" percentage will be similar.

Emergency costs encompass five areas:

- Protection of life, health, and property;
- Evacuation, transition, and reoccupation;
- Emergency and mass care;
- Emergency preparedness; and
- Administrative cost of emergency.

The researchers contacted public agencies and nonprofit organizations involved with the above emergency costs to determine the cost of supplies and labor. "Emergency Costs" were found to represent 13.4 percent of total flood damages, transportation costs 5.0 percent, and total utility costs 0.6 percent.

The NEA provided an employee at the Traffic Division in the city of Lewiston with the projected flood boundary description. He provided the following information on replacement costs of traffic lights and signposts:

1,725 signs and posts at an average cost of $35 each	$ 60,375
14 signals at $10,000 each	140,000
Total cost of traffic implements in flood area	$200,375

This cost represents a portion of the 0.6 percent of utility costs listed above.

The nonphysical damages section (Corps, Louisville District, 1981) lists the same five categories used in physical damages: residential, commercial, public, transportation, and utilities. However, these costs originate from problems such as lost wages, additional living expenses, lost income, temporary opening and closing costs for businesses, alternate routes for traffic, public infrastructure, etc. The nonphysical damages account for 20 percent of total flood costs.

A detailed list of "Other Costs" relative to total flood costs was developed on the basis of the Kentucky report. The figures are shown below.

Category	Percentage of Total Flood Costs
Emergency Costs	13.4%
Transportation Costs	5.0%
Utility Costs	0.6%
Nonphysical Damages	20.0%
Total "Other Costs"	39.0%

An additional damage category not accounted for in the structure analysis is damage to parking lots. The pictures of Lewiston businesses reveal approximately 225 parking lots that show some type of asphalt surfacing. Flooded parking lots would need resurfacing but would not need rebuilding. A Lewiston area asphalt and paving company furnished 1999 prices for repairing and/or building new parking lots. In the local area, this company charges $65 per ton ($72 per metric ton) for asphalt, and $18 per ton ($20 per metric ton) for rock. It takes 1.3 tons (1.2 metric tons) of asphalt to cover 100 square feet (9.2 square meters) of a parking lot. Total labor and materials costs for a 12,000-square-foot (111.5-square-meter) parking lot would be about $10,600. The total costs for repairing the 225 parking lots would be about $2,385,000. This information was included as an additional observation in the structure inventory.

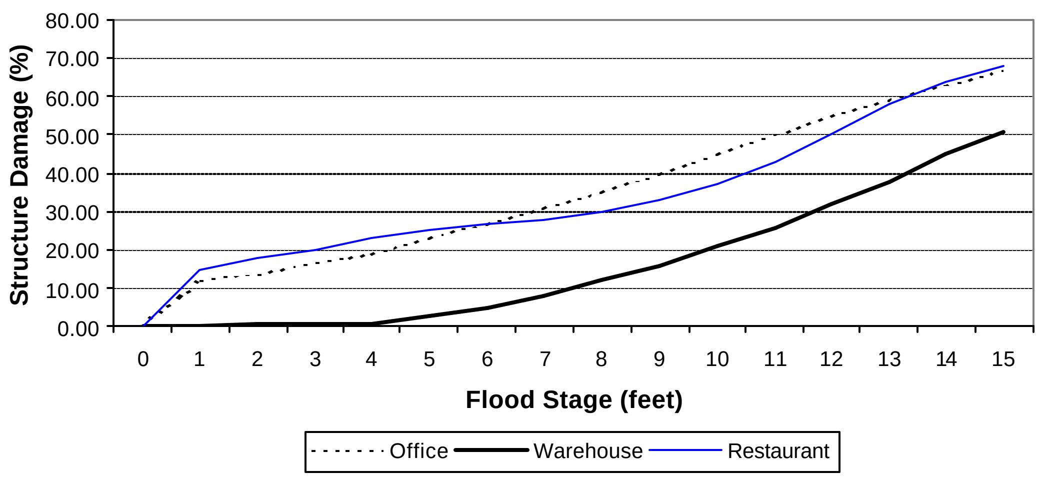
3.3.2.4 Structure Damage Function and Uncertainty

The commercial structure damage function was taken directly from the Galveston study (see attachment B). A "general" damage function was used in situations where building occupant information could not be found or where the occupant did not fit a specific damage function category included in the Galveston study.

The following graph provides a sample of commercial structure damage functions used in this analysis. As shown on the chart, warehouses experience less structural damage at each flood stage than office buildings or restaurants.

The structure damage functions shown in figure 4 are not known with certainty. In order to account for this and to be consistent with guidelines specified in Corps EM 1110-2-1619, uncertainty measures were incorporated into the structure damage functions. Reported average standard deviations for structure depth damage functions from the Wyoming Valley survey were used to incorporate uncertainty with respect to the commercial structure damage functions in the HEC-FDA model (IWR Report 96-R-12). These values were applied to each of the commercial damage function categories.

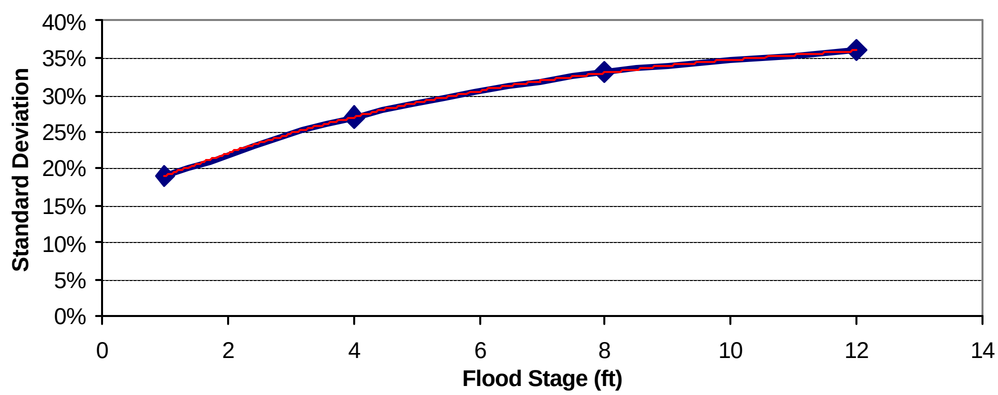
Fig. 4 Commercial Structure Damage Functions for Representative Categories



The figure below (figure 5) depicts the relationship between flood stage and the uncertainty surrounding the percent damage to commercial structures based on data from the Wyoming Valley study. As shown, the standard deviation of reported structure damage increases with flood stage at a decreasing rate.

The relationship illustrated in figure 5 was incorporated into the model for all commercial categories.

Figure 5. Standard Deviation of Percent Commercial Structure Damage by Flood Stage

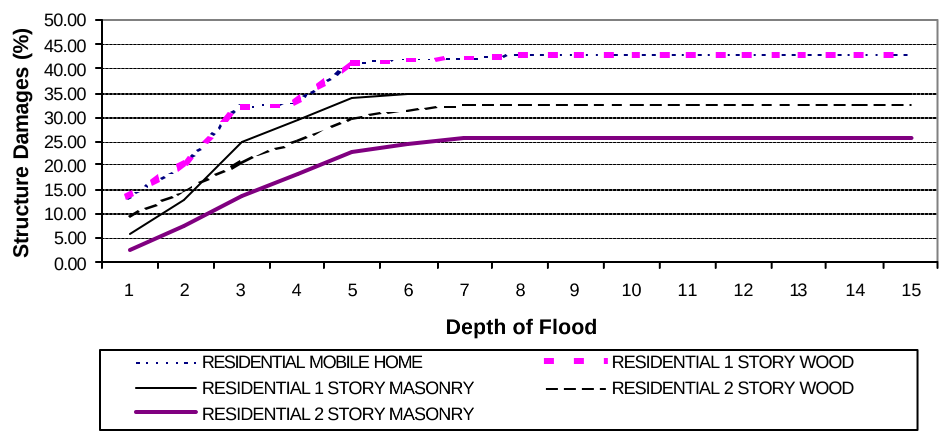


Source: Data obtained from IWR Report 96-R-12

Damage functions for residential structures corresponding to the seven categories were obtained from the Baltimore District Guidance Chart. Figure 6 depicts the structure depth damage functions used in this analysis.

All of the damage functions increase with flood stage but at a decreasing rate. As expected, mobile homes and single-story wood structures (which share the same damage function) have the highest percent damages at each flood stage, while two-story brick structures have the lowest. Beyond flood levels of 8 feet (2.4 meters), the percent damage to the structure increases only slightly.

Fig. 6 Percent of Residential Structure Damages by Category and Flood Stage



Source: Baltimore District Guidance Chart

The damage functions for public structures were developed in a similar fashion to commercial structures.

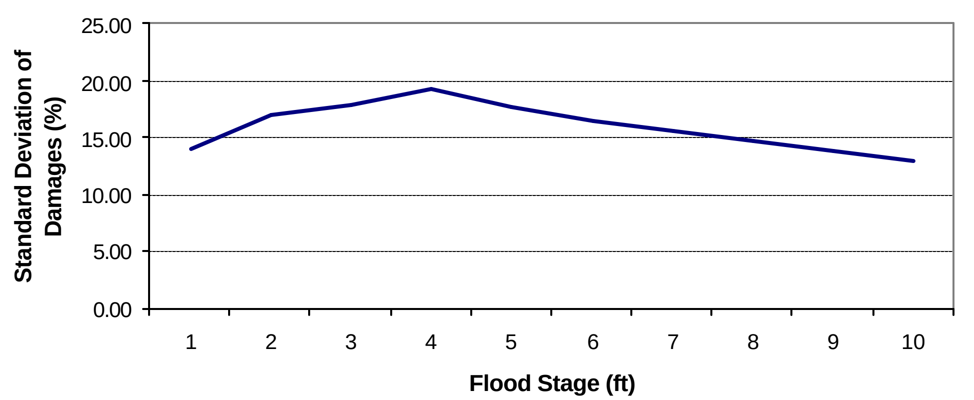
3.3.2.5 Content Damage Function and Uncertainty

The commercial contents damage function was developed from the inventory and equipment damage functions provided by the Galveston study (see attachment C). Both the inventory and equipment damage functions published in the Galveston study describe damage to contents of commercial structures. Therefore, in order to create a single content damage function for use in the HEC-FDA model, the two were averaged for each flood stage. Specifically, in cases where either the inventory or equipment damage functions from the Galveston study contained all zeros (i.e., damage function did not apply to the commercial category), the values listed in the other damage function were used as the content damage function. For example, if the inventory damage function contained zeros at all flood stages, the equipment damage function was used.

Uncertainty with respect to the content depth damage functions was also included in the HEC-FDA model based on the Pearl River flood survey data. For each of the 34 categories in that study, the standard deviation of reported percent content damage was calculated for each flood stage and applied to the content depth damage function taken from the Galveston study. As before, the average from all categories was applied to those categories from the Galveston study that did not correspond well with the categories from the Pearl River study.

Figure 7 shows the average standard deviation of commercial content damages reported in the Pearl River flood survey. In general, the variation surrounding reported percent content damage tends to increase initially with flood stage and then steadily decline at flood levels beyond 4 feet (1.2 meters).

Fig. 7 Average Standard Deviation of Reported Damages to Commercial Contents



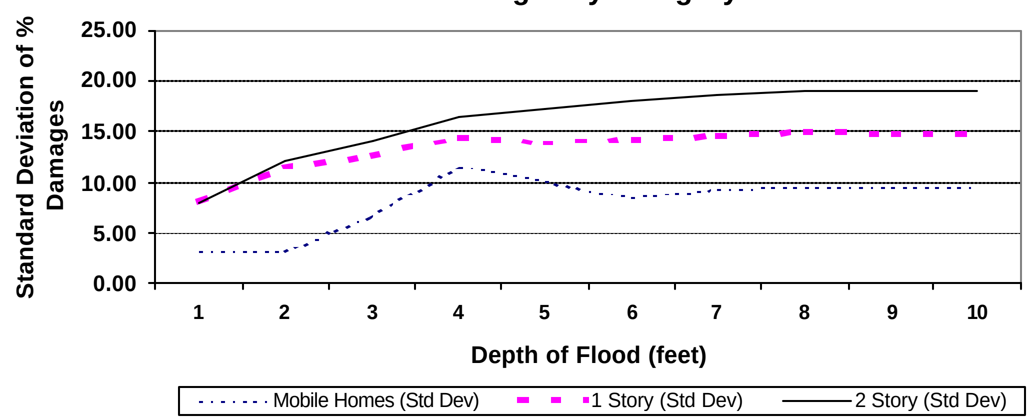
Source: New Orleans Flood Survey Data

Uncertainty surrounding the residential contents depth damage function was developed from the Pearl River data set in a fashion similar to the commercial structures. No information was available concerning the uncertainty surrounding the structures depth damage functions. A constant standard deviation of 20 percent was applied to residential structure depth damage functions based upon information obtained for commercial structures.

As shown in the figure 8, the standard deviation of reported content damages tends to increase with flood stage. Two-story homes have the highest variation in contents damages, followed by single-story and mobile homes.

Content damage functions and uncertainty for public structures were developed using identical data sources and methods as described for commercial structures above.

Fig. 8 Standard Deviation of Residential Content Damages by Category



Source: New Orleans Flood Survey Data

3.3.2.6 Automobile Damage Functions

Depth damage functions for vehicles were calculated by assuming that each household has one automobile that experiences flood damage and that it is worth an average of $8,000. Based upon Corps studies, auto damages are estimated at 10 percent for a flood depth of 1 foot (0.3 meter), 20 percent for 2 feet (0.6 meter), 30 percent at 3 feet (0.9 meter), and 80 percent at 4 feet (1.2 meter).

3.3.2.7 Summary

The following tables summarize the sources of information for structure values, damage functions, and uncertainty used in this study.

Table 5
Method Used for Residential Structures

Data Type	Initial Value	Depth-Damage Functions	Uncertainty
Structure	Depreciated Replacement Value - County Tax Assessor	Percent of Structure Damage by Depth of Flood - Baltimore	- NEA Estimate
Content	Percent of Structure Value 55% as recommended by IWR and confirmed with Pearl River data.	Percent of Content Damage by Depth of Flood - Baltimore	- Pearl River
Other	• Automobiles – Average Value, Corps protocol • Landscaping – None • Clean-up costs – 2%	• Automobiles Corps protocol	

Table 6
Method Used for Commercial Structures

Data Type	Initial Value	Depth-Damage Functions	Uncertainty
Structure	Depreciated Replacement Value - County Tax Assessor	Percent of Structure Damage by Depth of Flood - Galveston	- Wyoming Valley
Content	Percent of Structure Value - Developed from Pearl River Flood Study.	Percent of Content Damage by Depth of Flood - Galveston	- Pearl River
Other	• Landscaping – None • Clean-up Costs • Pearl River • Outdoor Inventory - by phone calls	• Outdoor Inventory - by phone calls	

Table 7
Method Used for Public Structures

Data Type	Initial Value	Depth-Damage Functions	Uncertainty
Structure	Depreciated Replacement Value - By phone	Percent of Structure Damage by Depth of Flood - Galveston	- Wyoming Valley
Content	Percent of Structure Value - Developed from Pearl River Flood Study.	Percent of Content Damage by Depth of Flood - Galveston	- Pearl River
Other	• Automobiles – None • Landscaping – None • Clean-up costs – 2%	• Outdoor Inventory - by phone calls	

3.4 Risk-Based Approach

The risk-based approach used in this study is an approach that encompasses the variability that is inherent in many physical and socioeconomic processes (IWR Report 99-R-2, p. 1). This variability is usually incorporated into the model by the specification of a statistical distribution around an input, rather than specifying a single point. The risk-based approach is increasingly popular because it enables researchers to more accurately predict outcomes, and by using variability of inputs, to also predict the variability of outcomes. This information is generally viewed to be more technically accurate and is useful to decision-makers involved in planning.

For this study, the specification of uncertainty around flooding events and the damages those floods are likely to inflict on structures, are some of the input variables that are expressed using statistical distributions instead of single points. When a great number of input variables all possess uncertainty, the relationships between the input variability and the output variability become very complex. A technique called Monte Carlo simulation employed in the HEC-FDA model is an effective way to manage this complexity. Using random numbers, the procedure reproduces collections of data that conform to the distributions specified. The model then simulates the probabilistic events interacting in the way that produces the outcome. The variability of these simulated outcomes is then analyzed. Thousands of simulated outcomes are analyzed until the model can ascertain that the results are within a specified small range.

All flood damage reduction studies performed by the Corps have adopted the risk-based analysis approach (ER 1105-2-101). The key to specifying distributions of probabilistic variables in such studies is to be guided by the objectives of the study.[6] For this study, the key variables for which

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6 The following guidance is found in ER 1105-2-101: "The ultimate goal is a comprehensive approach in which the values of all key variables, parameters, and components of flood damage reduction studies are subject to probabilistic analysis. Not all variables are critical to project justification in every instance. In progressing toward the ultimate goal, the risk-based analysis and study effort should concentrate on the uncertainties of the variables having the largest impact on study conclusions," p. 3.

statistical distributions were specified are: stage-discharge functions, probability exceedance functions, depth-damage functions (see the previous subsection), and structure to content ratios. The variability of outputs is expressed in the reporting of risk-based analysis results. Results are presented for the changes in probabilities that the Lewiston levees would be overtopped by either the Snake River or Clearwater River.

3.5 Benefit-Cost Analysis

A BCA analysis framework was used to analyze the results of the flood damage reduction estimation with respect to the costs of the different alternatives. This framework allows decisions to be made about projects based on the projected benefits and costs through time. In order to study the adoption of a project, the BCA framework requires that a "without project" scenario be specified at the outset, and the costs and benefits of this scenario be studied to provide a departure point for the rest of the analysis. In this study, the without-project scenario is navigation-only dredging, with the existing levee, and employing in-water disposal of the dredged material. Using this as a basis, all flood damage that can be reduced (i.e., a reduction in damages from the expected damages in the without-project scenario) are considered benefits of the project. Similarly, all costs over and above the costs of the navigation-only dredging program are considered the costs of the alternative. These costs and benefits are evaluated for each year of the project.

Benefits and costs are then discounted into a present value of benefits and costs, so that the present time is given greater emphasis than the future. This occurs for several reasons. One reason is that people tend to have a preference for the present over the future. Another reason is that financially, capital can usually be used to gain interest, and is worth more in the future than it is in the present. Hence, any expenditure of capital must be considered against another use of the capital, namely gaining interest. Another reason future benefits and costs are discounted is that the future always contains an element of uncertainty that the present does not.

The process of discounting future benefits and costs for use in BCA involves a few fairly simple equations. Consider an anticipated benefit, *b*, that is expected to arrive *n* years in the future. What is the benefit worth to someone today? Using a discount rate *r*, the present value (PV), of this benefit is equal to:

$$PV = \frac{b_n}{(1+r)^n}$$

For a stream of benefits, the present value of a stream of benefits over a number of years can be summed. For example, the present value of a stream of benefits over the next 20 years into the future can be written:

$$PV = \sum_{n=0}^{20} \frac{b_n}{(1+r)^n}$$

Because there is a baseline scenario (a without-project scenario) from which benefits and costs of alternative are measured, one way to think about benefits and costs is in terms of differences between the baseline and the alternative. If the total benefits and costs of the without-project scenario are written, b^0, and c^0, and the total benefits and costs incurred under the alternative scenario are written as b^1, and c^1, then the present value of the benefits of the alternative (*BA)*, and present value of the costs of the alternative (*CA*) can be written as follows:

$$PV_{BA} = \sum_{n=0}^{20} \frac{\left(b_n^1 - b_n^0\right)}{\left(1+r\right)^n} \qquad PV_{CA} = \sum_{n=0}^{20} \frac{\left(c_n^1 - c_n^0\right)}{\left(1+r\right)^n}$$

A benefit-cost ratio is simply the ratio of the two, with a economically feasible alternative being identified as an alternative with a benefit-cost ratio that is greater than one:

$$BC\ ratio = \frac{PV_{BA}}{PV_{CA}}$$

A selection criterion is often used in conjunction with the evaluation of benefits and costs. The maximum benefit-cost ratio is often used as the selection criterion when benefit-cost ratios are being considered. Another selection criterion sometimes used is maximum net benefits. This provides another way to evaluate alternative projects. Maximum net benefits are used when net benefits are calculated by subtracting the present value of costs from the present value of benefits. Using the net benefits method, economically feasible alternatives are identified as projects that have positive net benefits. When choosing among several economically feasible alternatives, maximum net benefits, or maximum benefit-cost ratio are two-selection criterion that might be identified, and the two do not necessarily yield the same result.

Still another way to look at project costs and benefits is to convert the present value of costs and benefits into an average annual equivalent by using the amortization factor, or capital recovery factor (IWR Report 93-R-12, pp. 55, 80):

$$Annual = \frac{PV_{NC}\left(r\left(1+r\right)^n\right)}{\left(1+r\right)^n - 1}$$

Program cost data will be presented using this factor.

Regardless of the selection criterion used, the outcome of a BCA still depends on many factors. Two factors that can critically affect the outcome are the period of analysis, and the selection of an appropriate discount rate to use. For purposes of this study, two different time periods will be used, 2001-2074, and 2001-2021, as well as two different discount rates, 3.5 percent and 6.875 percent. The selection criterion is of less importance, because there is primarily one alternative under consideration. In this case, the focus of the analysis is whether or not the alternative is economically feasible. Both net benefit calculations, and benefit-cost ratio calculations yield the same results in terms of feasibility. All of the results will be presented.

3.6 GIS Environment

The GIS environment was built from the Lewiston, Idaho, topographic data sets provided by the Walla Walla District and HDR Engineering, Inc. River mile monuments ranged from the confluence of the Snake and Clearwater Rivers to RM 7.8 on the Clearwater River. On the Snake River, river mile monuments were used from the Lower Granite to above

Asotin, Washington. The river mile segments represent a consecutive listing of sediment ranges with coordinate conversions for both the left and right banks. Two grid systems were provided for each of the northing, easting, and elevation coordinates, North American Datum (NAD) 1927, NGVD 1929 (Washington South State Plane Zone); and NAD 1983, NAVD 1988 (Idaho West State Plane Zone). These coordinates provided the beginning and ending points for the river transects. The database for the structures inventory provided northing and easting coordinates in the NAD 1927, NGVD 1929 (Washington South State Plane Zone) grid system. Additional attributes included the first floor and ground floor elevation, street address, tax parcel number, and a digital photo identification number. Point coverages were generated from the above data sets and imported into ARC/INFO.

The center line data for the Clearwater and Snake Rivers (NAD 1927, NAVD 1988) were provided by HDR Engineering, Inc. Using a series of ARC/INFO commands, the center line was incremented at 10-foot (3-meter) intervals. Each increment was assigned a river mile value respective to each river segment. The range of the river mile values was unique to each segment based on the range of the starting and ending river transects. The spacing for each increment remained constant on both center lines.

To assign the closest river mile value to each structure, the "near" function was executed in ARC/INFO. This function computed the distance from each point in the structure coverage to the nearest point in the river mile point coverage. The river mile value was assigned to the structure attribute table. Some editing of the river mile assignments, due to predetermined river flow analysis, was done to those structures at the confluence of the Snake River and the Clearwater River.

The GIS coverages SET1, SET2, and SET3 (NAD 1927, NAVD 1988) provided by HDR Engineering, Inc., contained all the planimetric and topographic features from aerial photos. Within these coverages, we extracted the elevation values for the top of the levee. The coverages provided a series of arc and point coverages for contours, roads, ground floor control points, and other features. To identify the arcs best representing the levee top, the top of the levee was mapped using a Global Positioning System (GPS) while driving or walking the top of the levee. The GPS line was overlaid on top of the existing coverage to use as an indicator of which arcs represented the levee top. Arcs were selected that were continuously the highest elevation in that near vicinity. In most areas, the contour of the arcs displayed the levee top shape.

During the quality assurance check of the structures inventory, it was determined that some of the existing structures were not included in the original inventory. At that time, the final database was imported from Minister Glaeser Surveying, Inc., and the "near" function calculations were repeated using the same editing functions for the structure river mile assignments at the confluence of the Snake and Clearwater Rivers. Working maps were developed to map the damage reaches and to research the levee top.

4.0 BENEFIT-COST ANALYSIS

This section reviews the BCA for the project. The benefits and costs of each alternative are compared to the "without-project" scenario, which includes navigation only dredging, no levee modification, and in-water disposal (Nav/xst./IW). Results are shown for two time horizons, 21 years (2001-2021, inclusive) and 74 years (2001-2074, inclusive). For each, cumulative benefits are shown undiscounted and at discount rates of 3.5 percent, and 6.875 percent. Additional detail on the benefit-cost framework is found in the previous section.

Flood damage assessments were developed with the HEC-FDA model. The model links the projected flood elevations to structures in the floodplain and calculates total expected damages by stage of flood. The HEC-FDA uses a risk-based approach to flood damage analysis, one that captures the probability and uncertainty conditions which characterize flood events. It employs Monte Carlo simulations to create realistic flooding through time. The results depict both the mean and variance of expected annual damages (EAD's) over the project time horizon. The variance of expected damage estimates reflects the probabilistic nature of flood events and the uncertainty common to damage estimation.

The section is divided into four subsections. The first covers the estimation of without project, or baseline damages. Next is a discussion of the costs of the proposed alternatives. The third section addresses the BCA of the alternative scenarios. The recommended alternative is identified in this subsection. Finally, some of the risk-based analysis results are presented along with a sensitivity analysis.

4.1 Without Project Flood Damage Assessment

The base scenario flood damage estimates (without project) are critical in determining the outcome of the BCA because they establish the level of damage targeted for reduction by the various alternatives. Because the riverbed changes during dredging operations and will alter with disposal methods, the HEC-FDA model was used to estimate EAD's for the years 2001, 2021, and 2074. Equivalent annual damages were calculated for two time periods, from 2001 through 2021, and from 2021 through 2074. The damage estimates are linearly interpolated between each set of two end points and discounted accordingly.

The structure inventory includes all structures under 760 feet (231.6 meters) above sea level (NAVD 1929 datum). However, simulations with the HEC-FDA model indicate that no structures on the Snake River damage reaches below the confluence would be flooded. At the extreme, no flood damage is likely even during a flood with an occurrence probability of 0.002 in any given year (once in 500 years). Essentially, this means that the Clarkston region and the Port of Wilma are likely protected from flood damage now and through the year 2074 without the project.

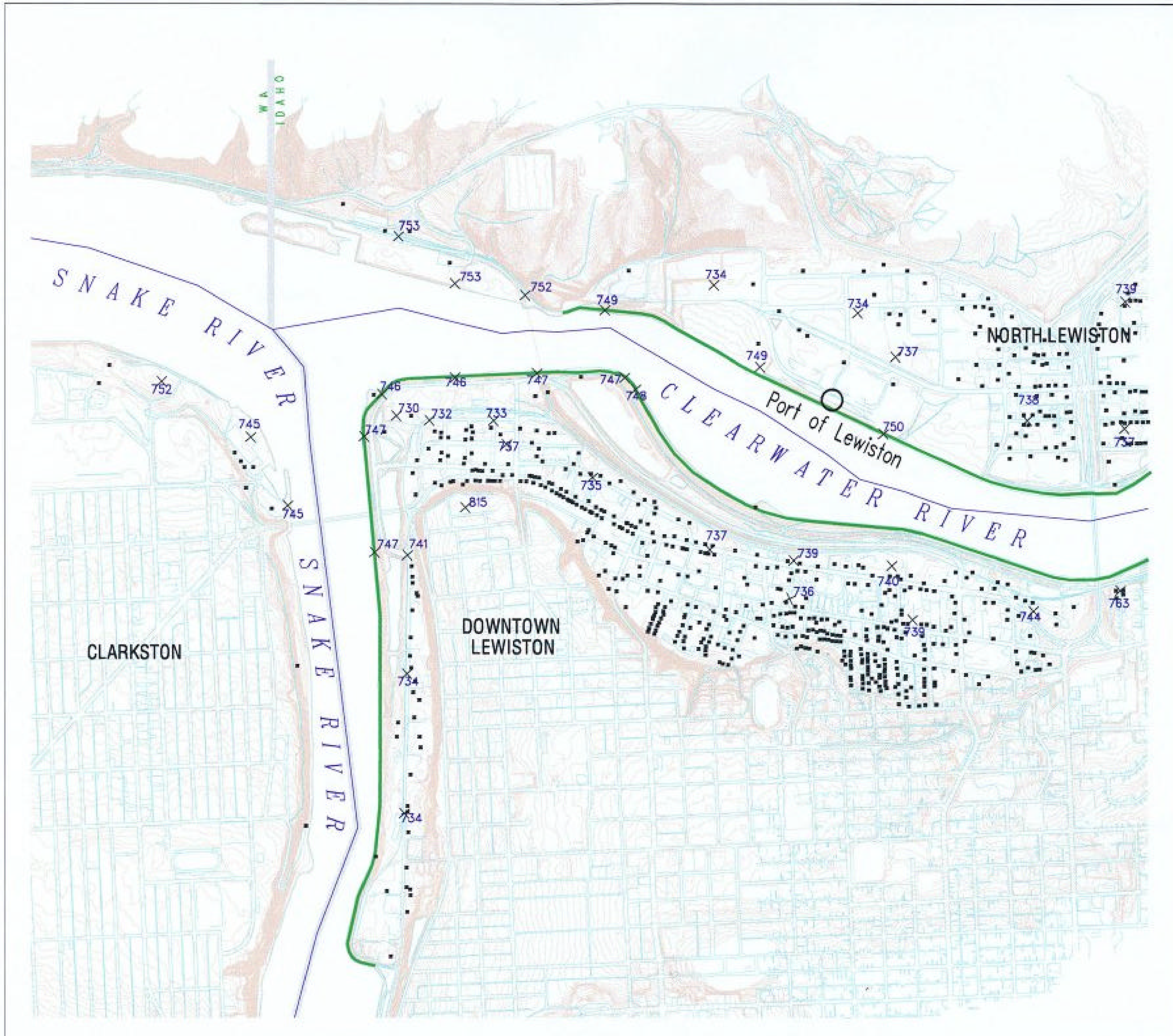
The Lewiston and North Lewiston regions of the floodplain are situated in the most vulnerable locations because they are at lower elevations than Clarkston or the Port of Wilma. Both of these reaches are protected from flooding by levees, as is the portion of Lewiston that is adjacent to the Snake River, just upstream of the confluence. Consequently, these are the critical areas for flood damage analysis. These areas also contain the largest number of structures in the floodplain inventory (see plate 3).

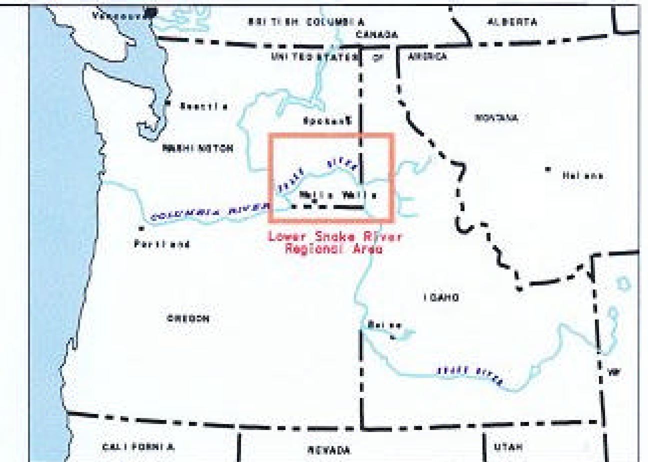
The area behind the levee is identified as one damage reach and the lowest point on the levee was identified as the "index point" for the damage reach and used to determine the depth of flooding behind the levee. Based on the design of the levees and the calculated WSP's, if the levee is overtopped at any point along the river, the elevation of the water surface behind the levee will reach one of two elevations. Either it will rise until it reaches the elevation of the low point on the levee, or to the elevation of the water surface in the river adjacent to the low point on the levee - whichever is greater. For example, the estimated water surface elevation for a 0.004 probability flood (one in 250 years) on the Clearwater River at the index point is 746.9 feet (227.6 meters) above sea level (based on 1988 NAVD). In this case, the event would likely overtop the lowest elevation of the levee, which is 746.3 feet (227.5 meters) above sea level at the index point. Because most of the structures in the town of Lewiston are below this elevation, the overtopping would create significant flooding (see plate 4).

The WSP's, upon which the flood damage estimations are based, show that the only flood events that explicitly overtop the levee in the base scenario are the 0.002 probability and the 0.004 probability floods in the year 2074. The HEC-FDA model may simulate many other probability flood events during the simulation process that overtop the levees, but these events occur rarely. In addition, the simulations of the various scenarios include a human response to discharge at Lower Granite. Because dam management is required to maintain a certain pool elevation at the confluence of the Snake and Clearwater Rivers, much flooding is pre-empted by the management strategies. The damage modeling assumes that Snake River flooding would impact structures behind the levee that are situated in the Clearwater River damage reach, and that Clearwater River floods would impact structures located in the Snake River damage reach.

Expected base scenario annual flood damage to structures and contents in the Lewiston-Clarkston region in 1999 dollars, including clean-up costs, are estimated with the aid of the HEC-FDA model. The EAD values are developed within the model by simulating floods and flood damage for a particular year hundreds of thousands of times. The EAD value is the mean of the damage that occurred over the many simulated river flows for that year. The EAD values for the base scenario (without project) are as follows:

EAD 2001:	$ 75,893
EAD 2021:	$ 430,674
EAD 2074:	$ 4,713,695





Structures in Flood Plain

Elevation Markers (NAVD 1988)

Levees

River Centerline

Contour Lines

Roads

State Boundaries

DRAFT

NORTHWEST ECONOMIC ASSOCIATES

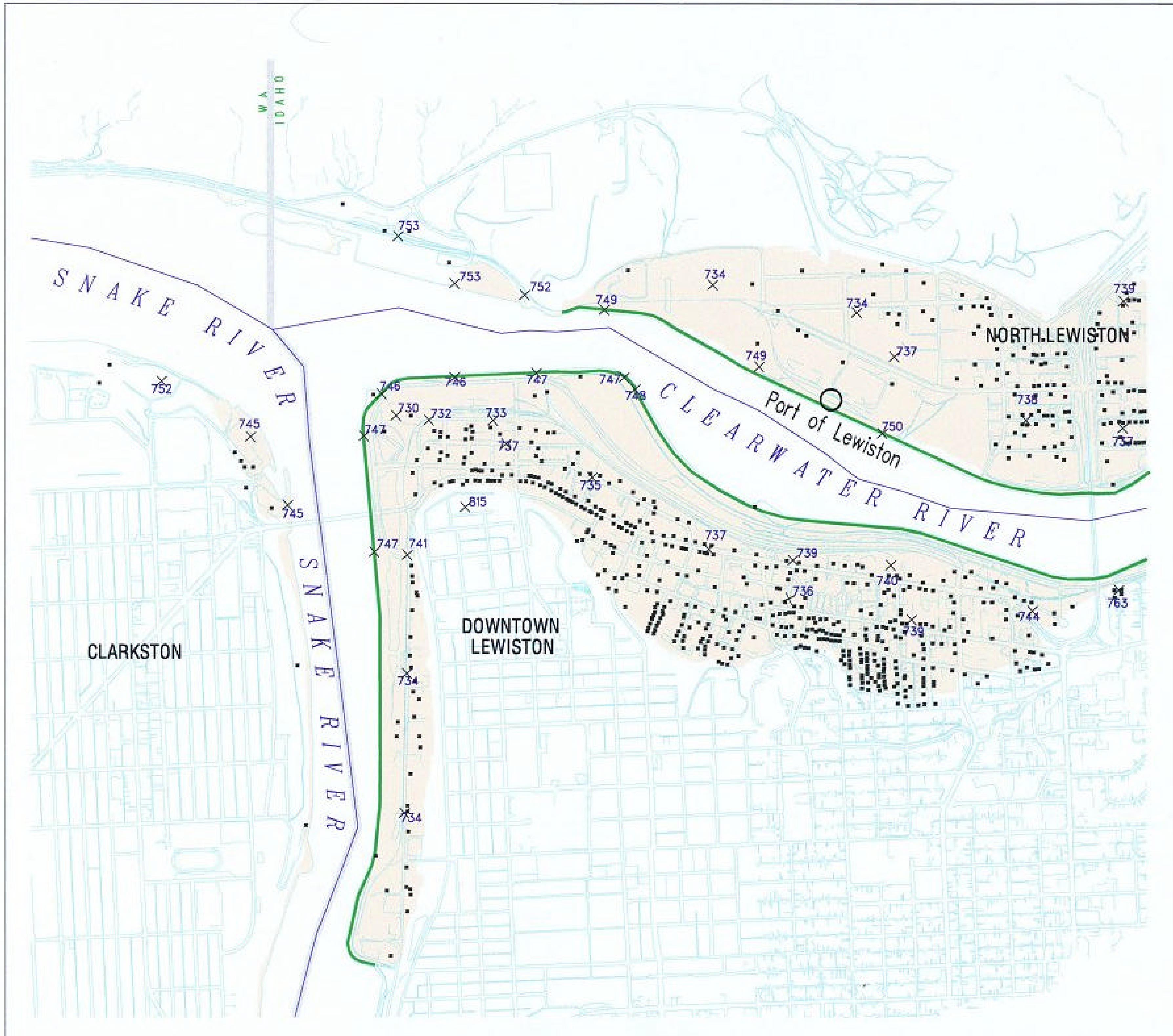
US Army Corps of Engineers
Walla Walla District

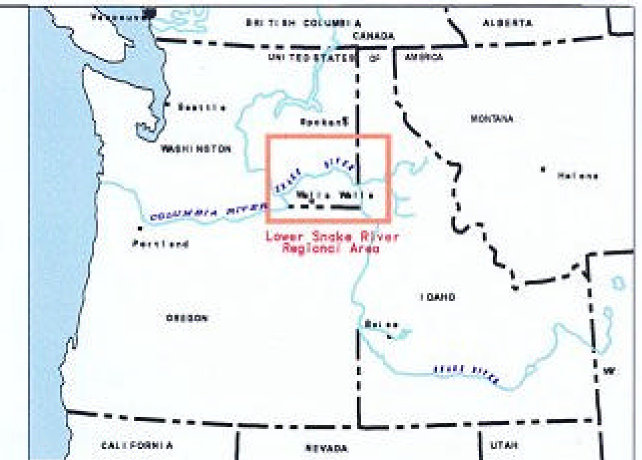
Walla Walla District
Dredged Material Management Study
Risk-Based Analysis of the Lewiston Levee System

CRITICAL AREA FOR FLOOD DAMAGE ANALYSIS

2000

PLATE 3





- .004 Probability (250 year) Flood Plain
- Structures in Flood Plain
- Elevation Markers (NAVD 1988)
- Levees
- River Centerline
- Roads
- State Boundaries

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Walla Walla District
Dredged Material Management Study
Risk-Based Analysis of the Lewiston Levee System

.004 PROBABILITY (250 YEAR) FLOOD PLAIN

2000

PLATE 4

The results show that, in the without-project scenario, expected annual flood damages increase over time because of sedimentation. The results also show that relatively little flood damage is likely in the Lewiston-Clarkston floodplain in the near future in spite of the increasing sedimentation. Expected damages in 2001, at $75,893, are less than 2 percent of the expected damages in 2074.

Expected annual damages are a useful way to assess changes over a range of years. For this study, there are three points in time considered, each with a different WSP due to the increasing sedimentation. The HEC-FDA model incorporates an assumption that damages increase linearly between each two points in time. For the first time period (2001-2021), expected damages to structures and contents total $5,318,960 in constant 1999 dollars (undiscounted). For the period 2001-2074, total expected damages to structures and contents including clean-up costs are $143,912,458. The undiscounted values of these damage totals and the discounted (at 3.5 percent and 6.875 percent) values are shown in table 8.

It is clear that discounting over long time horizons reduces damage estimates significantly. For example, at a 6.875 percent discount rate, the 20-year discounted value is 46 percent of its original value. At the same discount rate, the 74-year discounted value is less than 6 percent of its original value.

Table 8
Without Project EAD's to
Structure and Content Values Only, Undiscounted and Discounted

Time Period	**Undiscounted Expected Annual Damages**	**Discount Rate 3.5%**	**Discount Rate 6.875%**
2001-2021	$5,318,960	$3,515,592	$2,472,698
2001-2074	$143,912,458	$27,541,411	$8,286,312

Several types of damages, other than those to structures and structure contents, may occur under different flooding scenarios. Examples are emergency costs, loss of income, and traffic and business interruption. If a proposed project is expected to reduce or eliminate these other damages, they should be included in project benefits. In the Frankfort, Kentucky, report, these damages were an estimated 39 percent of total flood costs.

The conditions and assumptions of this study are comparable to those in the Frankfort study. Hence, it is assumed that additional damages are 39 percent of the total and structure and content damages are 61 percent. The resulting values of total expected flood damages are shown in table 9.

Table 9
Total Expected Damages
Without Project Conditions

Time Period	Undiscounted	Discount Rate 3.5%	Discount Rate 6.875%
2001-2021	$8,719,608	$5,763,274	$4,053,603
2001-2074	$235,715,207	$45,149,855	$13,584,118

The total discounted dollar damage represents the maximum potential damage to be reduced and thus sets an upper limit of potential benefits of any proposed alternative. Only alternatives that cost less than this figure are potentially economically feasible. For example, at a discount rate of 6.875 percent for 74 years, the maximum potential damages to be reduced are $13.58 million. In this case, no alternative with discounted present value of costs greater than $13.58 million will be economically feasible.

4.2 Program Costs

Each of the 40 scenarios developed involves costs of dredging, raising levees, and disposal of dredged material. All costs for dredging and disposal were provided by the Walla Walla District in constant 1999 dollars. Costs for raising levees were provided by HDR Engineering, Inc. (appendix E). The two sources of costs were summed by NEA, and a table of annual expenditures was prepared, given the frequency of dredging. These expenditures are presented in attachment C. Costs are shown for each scenario, by year, for each project time horizon. Costs are then discounted over 74 and 21 years. Costs are shown in undiscounted form and discounted at both 6.875 percent and 3.5 percent. The discounting procedure is discussed in the previous section.

4.2.1 Dredging and Disposal Costs

The Corps calculated the costs for each dredging program and disposal combination (DP/D) alternative from 2001 through 2074. Costs were presented in conjunction with disposal method, either in-water, or upland. Upland disposal involves removal and transport costs for the materials, in addition to costs for the construction of a disposal site. For upland disposal, construction of a transfer station site is required for all dredging programs with the exception of navigation only.

In-water disposal includes disposal of the sediment in the rivers in the area. Operational costs are considerably lower for in-water than for upland disposal. Summaries of the dredging and disposal costs are provided in attachment C (tables C-2 and C-3). For more information regarding the specific disposal options, see the appendix D in the DMMP/EIS.

4.2.2 Raising the Levee

The HDR Engineering, Inc., estimated costs for raising the levee to each of four different heights. In addition to the existing height (i.e., no change), costs were developed to raise the levee by 3, 4, 8, and 12 feet (0.9, 1.2, 2.4, and 3.7 meters). The costs include several key categories: road removal and construction; levee excavation and fill; bridge adjustments; modification of sewage treatment plants, port facility protection, the Potlatch Greenhouse area protection, and private property acquisition. Recreational costs, including cleanup of Corps operated parks in the event of flooding, are included in the HDR report, but for purposes of this study were excluded from total costs. The reason for this exclusion is that the flooding of these lands and implied clean-up costs are considered part of the without-project scenario and do not change for a with-project scenario. A summary of the construction costs is displayed in table C-1 of attachment C. For more information on the costs of raising the levees, see appendix E.

Construction time increases with the number of feet to be added to the levee. Raising the levee either 3 or 4 feet (0.9 or 1.2 meters) will require 2 years. Raising it 8 feet (2.4 meters) will require 3 years, and raising it 12 feet (3.7 meters) will require 5 years. There is a noticeable increase in costs between the 3- and 4-foot (0.9- and 1.2-meter) increase, because the 4-foot (1.2-meter) raise requires bridge adjustments while the 3-foot (0.9-meter) raise does not. The operation and management costs for the 3- and 4-foot (0.9- and 1.2-meter) raised levees are assumed to be the same, as the walking paths and parks will be maintained under each scenario.

4.2.3 Cost Summary

Total costs and project costs are summarized in table 10. Project costs are the total costs of the proposed alternative, minus the without-project costs. The project cost for each alternative is discounted at 3.5 percent and 6.875 percent over the 74-year time horizon. An annualized value is shown for each at a discount rate of 6.875 percent. Annualized costs are those which would be incurred if the with-project costs were spread evenly throughout the 74-year time horizon.

The costs of the different programs vary widely. The project cost of the least expensive alternative is $2.27 million and includes navigation-only dredging, raising the levee 3 feet (0.9 meter), and in-water disposal (Nav/3 ft/IW). In contrast, the project cost of the 2,000,000 cubic yard (1 529 110 cubic meters) program, with the 12-foot (3.7-meter) levee raise and upland disposal (2M/12 ft/UL) is $916.35 million. Discounted at 6.875 percent over the 74-year time horizon, these costs are, respectively, $2.20 million and $320.96 million. The annualized costs are, respectively, $152 thousand, and $22.23 million.

As shown in the table, in-water disposal is much less costly than upland disposal for an otherwise identical program. For example, the total cost of the 300,000 cubic yard (299 366.5 cubic meter) program with a 4-foot (1.2-meter) levee raise with in-water disposal (300k/4 ft/IW) is $102.87 million, while the same alternative with upland disposal is more than three times as much, at $342.63 million. Across all dredging programs, the upland disposal option is between two and five times as expensive as in-water disposal.

4.3 Benefits and Costs of Alternative Scenarios

Benefits from the alternatives are measured as reduced damages from floods relative to the without-project condition. The principles of BCA state that a project must have a benefit-cost ratio greater than one to be economically feasible. Given the maximum potential present value of damages to be reduced of $13.58 million (using a 6.875 percent discount rate), the alternatives including navigation-only dredging with a 3-foot (0.9-meter) levee raise (and both upland and in-water disposal) are the most likely to attain a benefit-cost ratio greater than one. The 4-foot (1.2-meter) levee raise with navigation dredging and in-water disposal (Nav/4 ft/IW) alternative also could possibly attain a benefit-cost ratio greater than one, though this is less likely. Because the discounted present values of the costs of these alternatives are all less than $13.58 million, they are the only alternatives that potentially are economically feasible using BCA. The costs of all other alternatives exceed the maximum potential damages to be reduced (see table 10). While it is not clear whether the Nav/3 ft/IW or the Nav/3 ft/UL alternatives will provide a greater value of damage reduction than their respective costs, they are the most likely. The Nav/4 ft/IW alternative also may be economically feasible, but only if almost all of the expected damages are reduced by the alternative.

Because of the small quantity of dredged material in the navigation-only scenario, the method of disposal has no bearing on the projected water surface elevations in the future. Hence, the benefits of upland and in-water disposal are identical.

The present value of benefits and costs of each potentially economically feasible alternative, discounted over 74 years at a discount rate of 6.875 percent, is displayed in table 11. The benefit/cost ratio is the quotient of benefits divided by costs.

The results show that the Nav/3 ft/IW option and the Nav/3 ft/UL alternative are both economically feasible. The Nav/4 ft/IW option, with a benefit-cost ratio of 0.85, is not economically feasible. For the two economically feasible options, the in-water disposal alternative benefit-cost ratio is more than twice the value of the upland alternative, at 4.52 for in-water disposal and 1.97 for upland disposal.

4.3.1 Benefit-Cost Ratios for Different Time Horizons and Discount Rates

The feasibility of each alternative depends in part on the period of analysis and the discount rate. The BCA results for the three potentially economically feasible alternatives are presented below using the 6.875 percent discount rate under the 21-year time horizon (table 12); a 3.5 percent discount rate under the 74-year time horizon (table 13); and a 3.5 percent discount rate under the 21-year time horizon (table 14). For all of the alternatives, the benefit-cost ratios are lower using the 21-year time horizon than the 74-year time horizon. Also, benefit-cost ratios are much higher with the 3.5 percent discount rate than the 6.875 percent rate. Both results are attributable to the larger values of flood damage reduction benefits many years in the future, and the project costs for construction of levee embankment modifications early in the project.

Table 10
Cost Summary in Millions of Dollars
Discounted and Annualized over the 2001-2074 Time Horizon

SCENARIO	Year Benefits Begin	Total Costs	Project Costs	Discounted @ 3.5%	Discounted @ 6.875%	Annual @ 6.875%
Nav/xst./IW	1	$3.112	$0.000	$0.000	$0.000	$0.000
Nav/3 ft/IW	3	$5.285	$2.173	$2.137	$2.103	$0.146
Nav/4 ft/IW	3	$18.638	$15.526	$15.264	$15.027	$1.041
Nav/8 ft/IW	5	$53.780	$50.668	$48.974	$47.479	$3.288
Nav/12 ft/IW	6	$90.442	$87.330	$81.620	$76.795	$5.318
Nav/xst./UL	1	$10.199	$7.087	$3.850	$2.839	$0.197
Nav/3 ft/UL	3	$12.372	$9.260	$5.987	$4.942	$0.342
Nav/4 ft/UL	3	$25.725	$22.613	$19.114	$17.866	$1.237
Nav/8 ft/UL	5	$60.867	$57.755	$52.824	$50.317	$3.485
Nav/12 ft/UL	6	$97.529	$94.417	$85.471	$79.633	$5.515
300k/xst./IW	1	$88.874	$85.762	$31.499	$17.800	$1.233
300k/3 ft/IW	3	$91.047	$87.935	$33.636	$19.903	$1.378
300k/4 ft/IW	3	$104.400	$101.288	$46.763	$32.826	$2.273
300k/8 ft/IW	5	$139.542	$136.430	$80.473	$65.278	$4.521
300k/12 ft/IW	6	$176.204	$173.092	$113.119	$94.594	$6.551
300k/xst./UL	1	$288.932	$285.820	$116.589	$72.211	$5.001
300k/3 ft/UL	3	$291.105	$287.993	$118.726	$74.314	$5.147
300k/4 ft/UL	3	$304.458	$301.346	$131.853	$87.237	$6.042
300k/8/ ft/UL	5	$339.600	$336.488	$165.563	$119.689	$8.289
300k/12 ft/UL	6	$376.262	$373.150	$198.210	$149.005	$10.319
1M/xst./IW	1	$106.080	$102.968	$43.430	$27.596	$1.911
1M/3 ft/IW	3	$108.253	$105.141	$45.567	$29.699	$2.057
1M/4 ft/IW	3	$121.606	$118.494	$58.694	$42.622	$2.952
1M/8 ft/IW	5	$156.748	$153.636	$92.404	$75.074	$5.199
1M/12 ft/IW	6	$193.410	$190.298	$125.050	$104.390	$7.230
1M/xst./UL	1	$463.181	$460.069	$187.556	$115.551	$8.003
1M/3 ft/UL	3	$465.354	$462.242	$189.692	$117.654	$8.148
1M/4 ft/UL	3	$478.707	$475.595	$202.820	$130.578	$9.043
1M/8 ft/UL	5	$513.849	$510.737	$236.530	$163.029	$11.291
1M/12 ft/UL	6	$550.511	$547.399	$269.176	$192.345	$13.321
2M/xst./IW	1	$216.838	$213.726	$93.931	$59.620	$4.129
2M/3 ft/IW	3	$219.011	$215.899	$96.067	$61.724	$4.275
2M/4 ft/IW	3	$232.364	$229.252	$109.194	$74.647	$5.170
2M/8 ft/IW	5	$267.506	$264.394	$142.905	$107.099	$7.417
2M/12 ft/IW	6	$304.168	$301.056	$175.551	$136.415	$9.447
2M/xst./UL	1	$846.270	$843.158	$393.510	$256.697	$17.778
2M/3 ft/UL	3	$848.443	$845.331	$395.647	$258.800	$17.923
2M/4 ft/UL	3	$861.796	$858.684	$408.774	$271.724	$18.818
2M/8 ft/UL	5	$896.938	$893.826	$442.484	$304.175	$21.066
2M/12 ft/UL	6	$933.600	$930.488	$475.130	$333.491	$23.096

Table 11
Benefit-Cost Summary of Potentially Economically Feasible Alternatives
2001-2074, Discounted at 6.875 Percent

Alternative	Present Value of Project Benefits	Present Value of Project Costs	Benefit/Cost Ratio
Nav/3 ft/IW	$9,951,518	$2,103,416	4.73
Nav/3 ft/UL	$9,951,518	$4,942,145	2.01
Nav/4 ft/IW	$11,456,584	$15,026,860	0.76

Table 12
Benefit-Cost Summary of Potentially Economically Feasible Alternatives
2001-2021, Discounted at 6.875 Percent

Altemative	Present Value of Project Benefits	Present Value of Project Costs	Benefit/Cost Ratio
Nav/3 ft/IW	$3,703,338	$2,103,416	1.76
Nav/3 ft/UL	$3,703,338	$4,765,797	0.78
Nav/4 ft/IW	$3,703,428	$14,263,277	0.26

Table 13
Benefit-Cost Summary of Potentially Economically Feasible Alternatives
2001-2074, Discounted at 3.5 Percent

Alternative	Present Value of Project Benefits	Present Value of Project Costs	Benefit/Cost Ratio
Nav/3 ft/IW	$30,106,483	$2,136,571	14.09
Nav/3 ft/UL	$30,106,483	$5,986,885	5.03
Nav/4 ft/IW	$36,849,002	$15,263,721	2.41

Table 14
Benefit-Cost Summary of Potentially Economically Feasible Alternatives
2001-2021 Discounted at 3.5 Percent

Alternative	Present Value of Project Benefits	Present Value of Project Costs	Benefit/Cost Ratio
Nav/3 ft/IW	$5,376,909	$2,136,571	2.52
Nav/3 ft/UL	$5,376,909	$5,351,448	1.00
Nav/4 ft/IW	$5,377,039	$14,500,138	0.37

The selection of an appropriate discount rate is a complicated issue that inspires much discussion among economists and government decision-makers alike. Both of the non-zero discount rates used above are within the commonly used range. It should be noted, however, that in this study all calculations are made in constant 1999 dollars. Accordingly, a real discount rate should be used, one corrected for inflation (55 FR 2590). While much current governmental policy supports the idea that 3–4 percent is a reasonable real rate for natural resource based projects (61 FR 20584, 61 FR 453, and 57 FR 53519) many government water related projects must still be evaluated using the rate recommended by the Bureau of Reclamation (6.875 percent).

A complete display of the results of the BCA is shown in table form in attachment D. These tables delineate both costs and benefits for each project year for each program. Yearly costs and benefits are also presented in discounted terms. For purposes of comparison, the results are presented for the 300k dredging program in addition to the three alternatives analyzed above.

4.3.2 Recommended Plan

The results suggest that the (Nav/3 ft/IW) project should be undertaken. In both in the 74- and 21-year time horizons, using either discount rate, the benefit-cost ratios are all greater than one. Moreover, the benefit-cost ratios of this option were greater than all other alternatives. For this alternative, EAD's (in 1999 dollars) are shown in table 15. The benefits begin in the year 2003, by which time the 3-foot (0.9-meter) raise will have been completed.

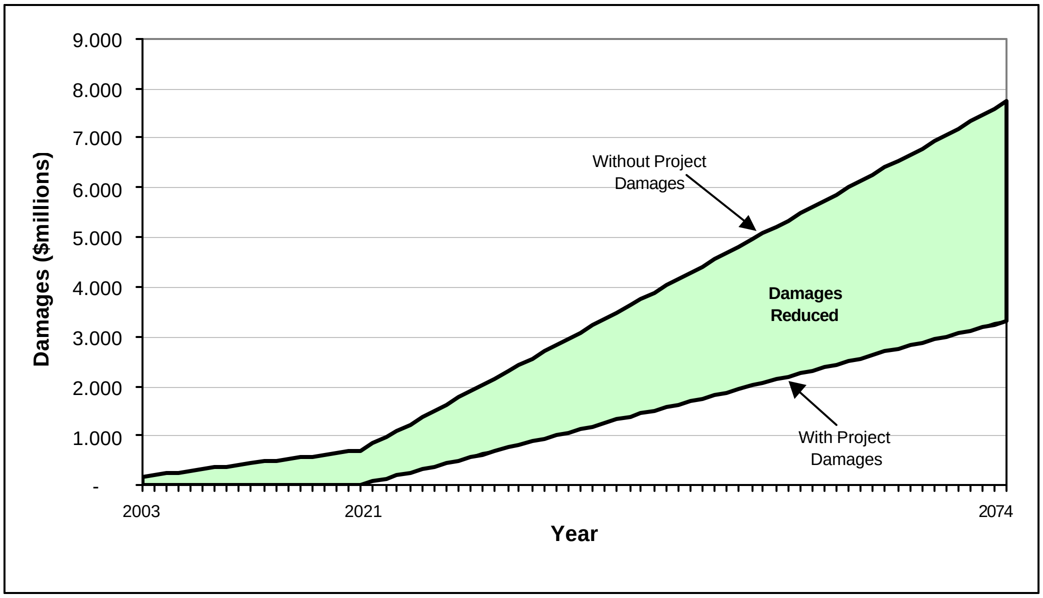
Table 15
Summary of EAD's
With and Without Project Through Time

	EAD's		
Year	**Without Project**	**With 3-Foot (0.9-Meter) Raise**	**Damages Reduced**
2003	$182,576	$7,224	$175,352
2021	$706,024	$10,284	$695,740
2074	$7,727,369	$3,314,131	$4,413,238

By the year 2021 more than 98 percent of the damages ($695,740 of $706,024) are reduced with the construction of the 3-foot (0.9-meter) increase in the levee height. By 2074, when the magnitude of damages has increased significantly, the 3-foot (0.9-meter) raise still reduces over 57 percent of the damages anticipated.

The value of annual damages with and without project, are displayed graphically in figure 9. When viewing the graph it is particularly clear that the dollar values of both damages and damages reduced are anticipated to increase at a greater rate between the years 2021 and 2074.

Figure 9
Damages With and Without 3-Foot (0.9-Meter) Levee Raise



Another set of simple diagrams illustrates why the 3-foot (0.9-meter) levee raise is so effective in eliminating estimated damages. As discussed earlier, the levee that protects the critical flood area of downtown Lewiston is only as effective as its lowest point. This low point is still higher than the 0.01 (one in 100 years) probability flood event for both the Snake River (figure 10) and the Clearwater River (figure 11). For both rivers, however, the levee is lower than the 0.004 (one in 250 years) probability and the 0.002 (one in 500 years) probability flood events. Though these events are both fairly rare, such low probability events account for most of the damages estimated. Thus, if the levee were raised 3 feet (0.9 meter) at this low point, it would not likely be overtopped for the 0.004 probability event on either river, nor would it likely be overtopped by the 0.002 flood event on the Clearwater River. The 0.002 probability event would still likely overtop the Snake River levee. More importantly, many of the other low probability discharges that would overtop the levee in the without-project scenario (between 0.004 and 0.002 probability) would not overtop a 3-foot (0.9-meter) higher levee.

It is useful to remember that the nominal 3-foot (0.9-meter) levee raise does not necessarily imply a 3-foot (0.9-meter) raise throughout the entire length of the levee. Because the terrain varies and the "low point" determines whether or not the town floods, it is most effective to construct a levee that is more or less parallel to the anticipated water surface during floods. For this reason, the nominal 3-foot (0.9-meter) raise will actually raise the low point of the levee 3 feet (0.9 meter), and raise the rest of the levee accordingly so that it becomes parallel to the water surface.

Figure 10
Comparison of Levee Height to Flood Events, Snake River

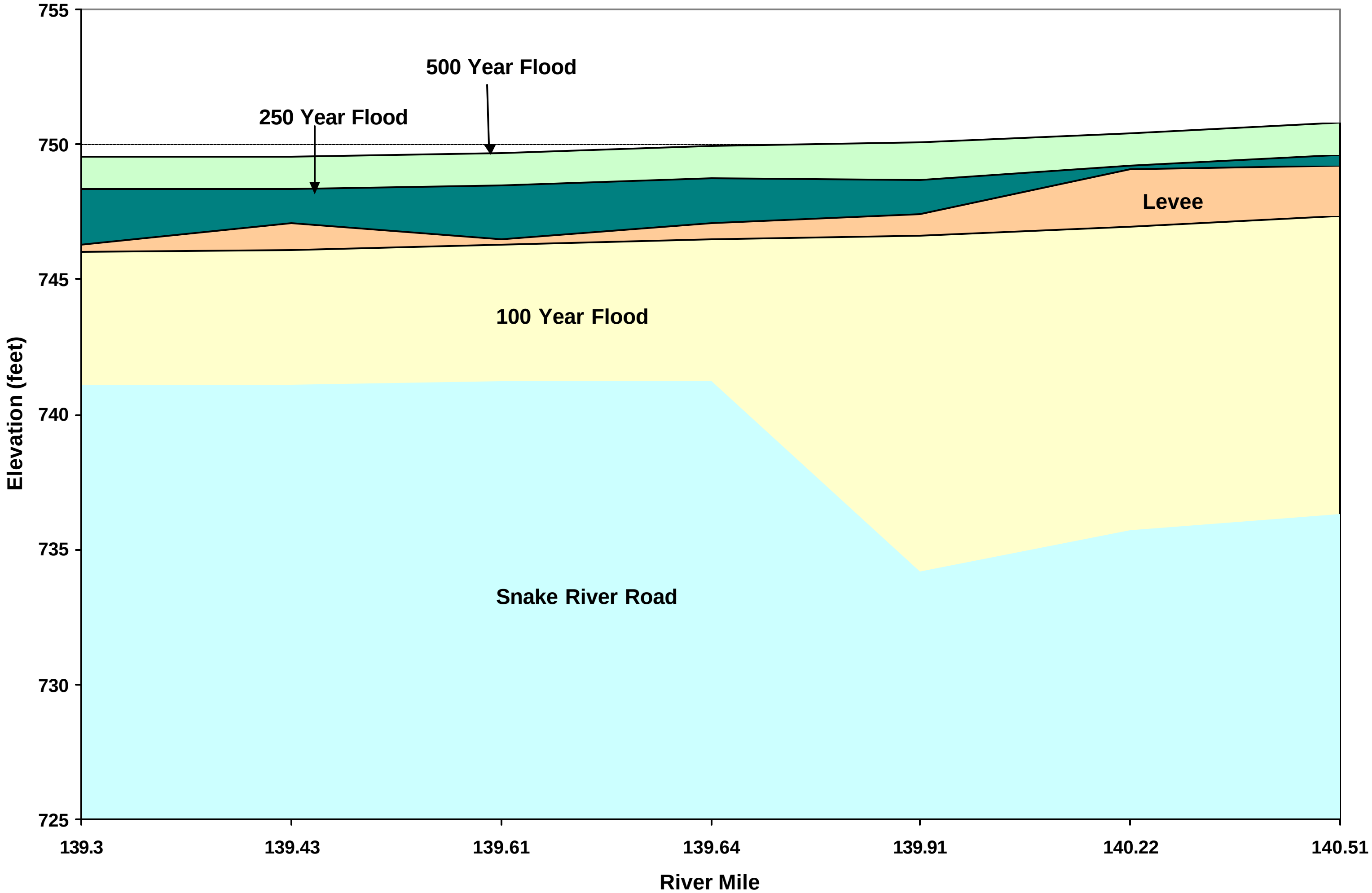
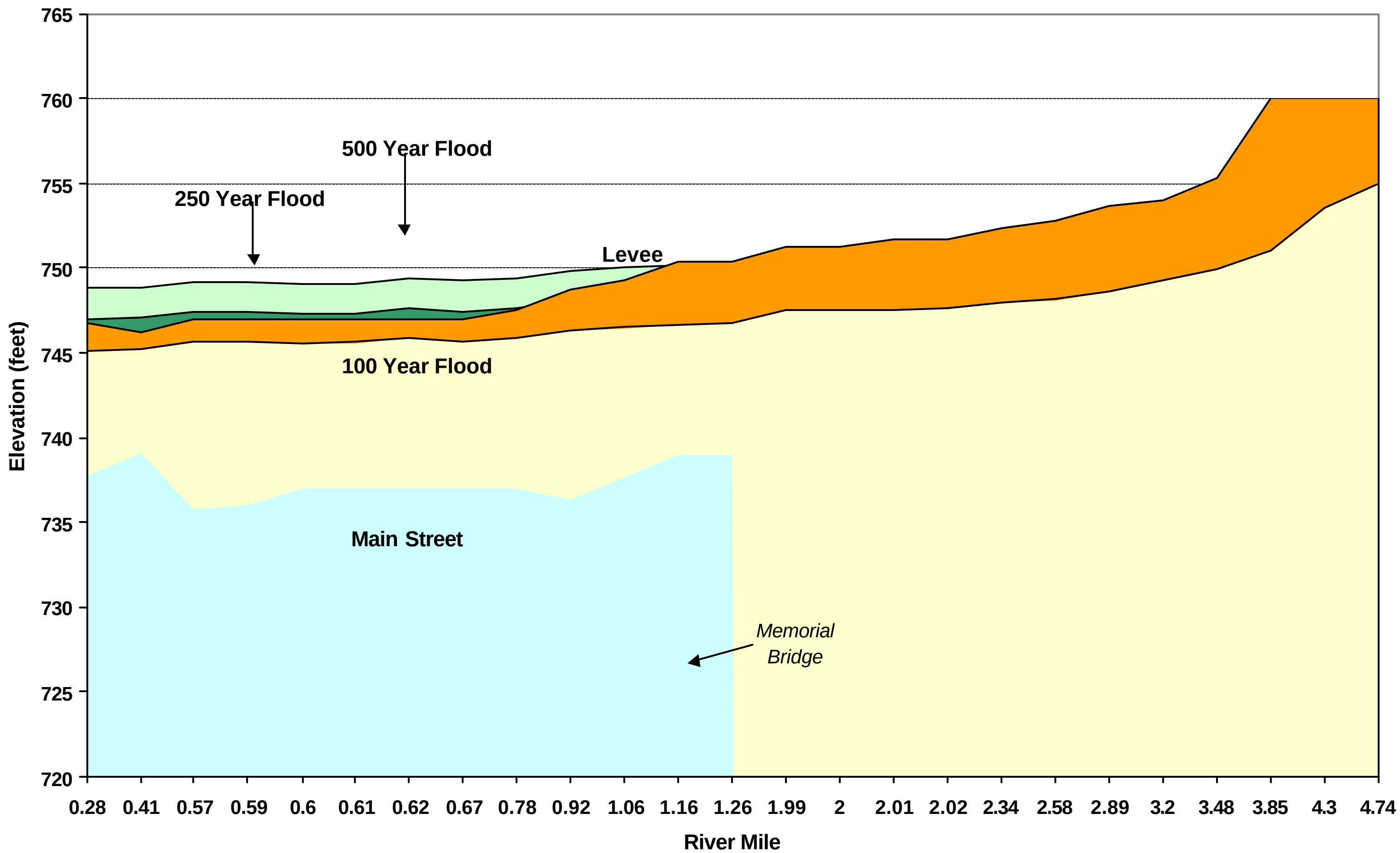


Figure 11
Comparison of Levee Height to Flood Events, Clearwater River



4.4 Risk-Based Analysis

Risk-based analysis is defined by the Corps as "an approach to evaluation and decision-making that explicitly, and to the extent practical, analytically incorporates considerations of risk and uncertainty" (ER 1105-2-101). The discussion below applies this concept to the flood protection performance of the proposed option.

The following three tables help portray the risk reduction that is likely to occur with adoption of a 3-foot (0.9-meter) levee modification. Table 16 portrays the annual probability that a target stage, or target elevation, is exceeded. For the alternative under consideration, the damage reaches of interest are those that are affected by a 3-foot (0.9-meter) levee raise. For each reach, the probability that the levee is overtopped is given for both the without-project case and with the levee modification. For example, by the year 2021, the mean and median probabilities of overtopping the levee at reach SRIVRD with no project are 0.006 and 0.002, respectively. The mean and median probabilities with the 3-foot (0.9-meter) levee raise are 0.002 and 0.001, respectively.

Table 17 shows how the probabilities of an overtopping event change over the long term with the 3-foot (0.9-meter) higher levee. For the Confluence damage reach, the without-project long-term exceedance probabilities are 0.144, 0.321, and 0.726 for 10-, 25-, and 50-year periods, respectively, given the sedimentation level projected for the year 2074. With the proposed project, these probabilities are reduced to 0.056, 0.136, and 0.253, respectively. Hence, by 2074, sedimentation will have increased to such a point that in a given 10-year period, there is a 14.4 percent probability that the levee would be overtopped at least one time in that 10-year period. However, with a 3-foot (0.9-meter) levee raise, the probability that the levee is overtopped at least once in a given 10-year period is reduced to 5.6 percent.

Table 18 displays the conditional non-exceedance probabilities for both the with-project and without-project scenarios for a particular flood event. For example, in the SRIVRD damage reach, the probability that the levee holds during a 0.01 probability flood event (100-year flood) is estimated at 75.7 percent. With the project, the probability of non-failure for this particular event and damage reach improves to 99.7 percent.

Table 16
Target Stage Annual Exceedance Probability

		Median		**Expected**	
Year	**Damage Reach**	**W/O**	**With**	**W/O**	**With**
2021	CONFLUENCE	0.001	*	0.002	*
	NLEWISTON	0.001	*	0.001	*
	SRIVRD	0.002	0.001	0.006	0.002
2074	CONFLUENCE	0.06	0.001	0.015	0.006
	NLEWISTON	0.005	0.001	0.012	0.006
	SRIVRD	0.013	0.004	0.026	0.008

* Denotes that the probabilities are too low to estimate.

Table 17
Long Term Risk

		10 Years		25 Years		50 Years	
Year	**Damage Reach**	**W/O**	**With**	**W/O**	**With**	**W/O**	**With**
2021	CONFLUENCE	0.015	*	0.038	*	0.074	*
	NLEWISTON	0.014	*	0.034	*	0.067	*
	SRIVRD	0.054	*	0.131	*	0.244	*
2074	CONFLUENCE	0.144	0.056	0.321	0.136	0.726	0.253
	NLEWISTON	0.116	0.056	0.266	0.135	0.461	0.252
	SRIVRD	0.223	0.081	0.468	0.191	0.717	0.345

* Denotes that the probabilities are too low to estimate.

Table 18
Conditional Non-Exceedance Probability by Events

		10%		4%		2%		1%		0.4%		0.2%	
Year	**Damage Reach**	**W/O**	**With**	**W/O**	**With**	**W/O**	**With**	**W/O**	**With**	**W/O**	**With**	**W/O**	**With**
2021	CONFLUENCE	1.000	1.000	1.000	1.000	0.996	0.999	0.979	0.995	0.962	0.992	0.942	0.988
	NLEWISTON	1.000	1.000	1.000	1.000	0.999	0.999	0.995	0.995	0.991	0.992	0.987	0.988
	SRIVRD	1.000	1.000	0.999	1.000	0.967	1.000	0.757	0.997	0.532	0.993	0.311	0.989
2074	CONFLUENCE	0.999	1.000	0.928	0.992	0.737	0.943	0.371	0.752	0.200	0.589	0.090	0.417
	NLEWISTON	1.000	1.000	0.956	0.992	0.807	0.943	0.471	0.755	0.280	0.590	0.139	0.426
	SRIVRD	0.997	1.000	0.825	0.992	0.459	0.918	0.100	0.587	0.027	0.338	0.005	0.149

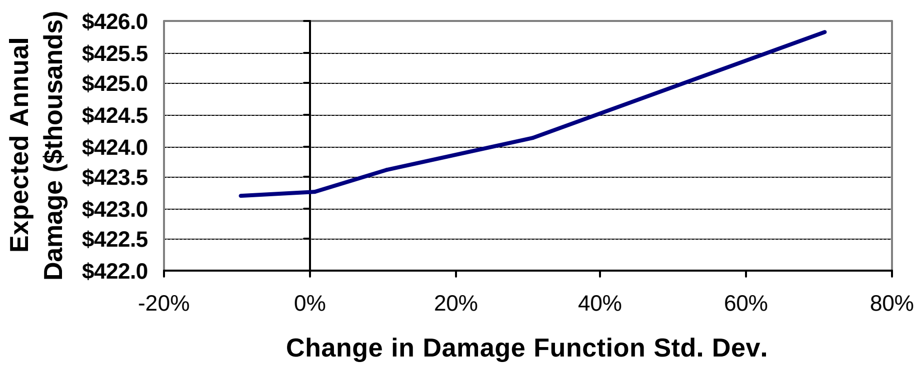
4.4.1 Sensitivity Analysis

Sensitivity analysis allows a researcher to alter the assumptions used in the modeling process or the input data set and to evaluate the resulting change in the output. This is an important step in understanding risk and uncertainty in modeling (USACE, ER 1105-2-100, 1990). For this study, it was important to analyze assumptions about the uncertainty in damage functions and the flow of the floodwater behind (the interior side of) the levee. In particular, because every flood study deals with a different geographic area and unique structures, contents, and building materials, it is difficult or impossible to accurately predict damages using damage functions from other areas. Furthermore, factors such as velocity, duration, sediment, frequency, and flood warning may have a dramatic effect on the damages that occur. Researchers can, however, evaluate the quality of results by analyzing the changes that would occur under different assumptions.

For this study, a sensitivity analysis was performed for the error specification in damage functions. The results from varying the standard errors on the depth damage functions proved to be very slight. Figure 12 displays the relationship between changes in the error specifications (given in percentage change), and changes in the EAD's (given in thousands of dollars). While the relationship is positive (that is, the greater the error, the greater the damages), the dollar value of changes is very small.

Additionally, the assumption that the entire levee in the downtown Lewiston area should be modeled as one damage reach was questioned, because the upstream Clearwater River portions of the levee were facing water surfaces several feet higher than the water surfaces at the lowest point of the levee. Hence, the assumption was modified to separate the upstream southern portion of the levee, east of Memorial Bridge, into a separate damage reach. The results of this estimation showed that numbers were slightly lower (less than 1 percent) using the modified assumption.

Figure 12. Sensitivity Analysis, Navigation Only (2021)



5.0 CONCLUSIONS AND RECOMMENDATIONS

Much understanding was gained through the detailed process of studying the potential future flooding at the confluence of the Clearwater and Snake Rivers in Lewiston, Idaho. While the increasing sedimentation does increase the potential damage from flooding in the area over time, the risk is neither severe nor immediate. This is probably due to the effectiveness of the existing levee embankment system and the ongoing navigation-only dredging program. Levee modifications greater than the 3-foot (0.9-meter) raise and dredging programs in addition to the navigation-only dredging are unwarranted at this time.

One alternative considered, the 3-foot (0.9-meter) levee modification with navigation-only dredging and in-water disposal, is an economically feasible and recommended alternative. This alternative is anticipated to bring a discounted net present value of $9,951,518 in damage reduction to the Lewiston-Clarkston region over the project lifetime, which ends in 2074. These benefits will be attained at a discounted present value of $2,201,373 in costs. The benefit-cost ratio is estimated to be 4.52.

The next two potentially economically feasible alternatives, Nav/3 ft/UL and Nav/4 ft/IW, are both much more costly than the recommended alternative. At the same time, neither of these alternatives provides benefits that are significantly greater than the Nav/3 ft/IW alternative. For this reason, neither of these options is recommended. None of the other options are potentially economically feasible, because the discounted present value of the costs of each of the other alternatives exceeds the value of the potential damages to be reduced. The present value of damages to be reduced is estimated to be $13.58 million over 74 years, at 6.875 percent discounting.

The risk-based analysis approach used in this study facilitates understanding of the probabilistic nature of so many events that surround flood damage. Stage-discharge relationships, probability exceedance functions, economic damages, and environmental factors all vary to a large extent, and so will the damages that result from any flood. The study does not pretend to predict the value of damages that will occur, but rather predict the probability that certain damages might occur at any point. It is these predictions that are combined statistically and summarized to form the basis of the values used in the BCA.

The same risk-based approach is used to answer one question that is particularly important in the case of the Lewiston study. That is, what is the probability that the Lewiston Levee system is overtopped, and how does that probability change through time? While the Lewiston levee has a low probability of being overtopped now (0.002 or two-tenths of 1 percent), this value does increase by 2074 to a probability of 0.012 (1.2 percent annually) on the Clearwater River side. On the Snake River side of the levee, the current probability of overtopping is estimated at 0.001, with this increasing to 0.025 by the year 2074. These values can be reduced to 0.006 in 2074 for the Clearwater River (a reduction by half), and 0.008 for the Snake River (a reduction by 75 percent) with the construction of the 3-foot (0.9-meter) raise in the levee.

5.1 Results in Light of Secondary Economic and Social Issues

In addition to the direct effects analyzed with BCA, other economic factors are also important in the decision-making process. Environmental quality issues have often been neglected in economic decision-making process, because they are difficult to measure. Similarly, secondary economic impacts are difficult to measure precisely due to the complexity of economic systems. Nonetheless, these impacts are often critically important to the affected communities. Finally, values and preferences held by a community are many times reflected in the laws and regulations enacted by the community. These laws and regulations play an important economic role, because they regulate and constrain economic decisions. To address these issues, the three topics were studied, and the results of the study are reported in attachments E, F, and G.

The anticipated environmental impacts of the Nav/3 ft/IW option are not very different from the without-project, or baseline, scenario. In this sense, the economic impacts of environmental change will be small. Some loss of recreation access to the walking paths on the levees during the construction phase is anticipated. However, this loss may be mitigated by a number of substitute paths available, such as the walking paths along the Snake River on the Washington side. Also, Kiwanis Park and many of the walking paths located on the interior side of the levee will benefit from reduced flood risk with the adoption of the alternative. Any environmental costs or benefits deriving from the in-water disposal method and the navigation-only dredging program are considered part of the baseline scenario and will not change with the adoption of the preferred alternative.

The regional economic impact of the Nav/3 ft/IW alternative will be small compared to the other alternatives because the cost of the alternative is smaller. However, this does not affect the conclusions derived from the BCA. The low cost of the alternative was the primary reason the alternative was identified as an economically feasible option.

A number of socio-institutional authorization issues face any water-related project. Because the economically optimal choice (Nav/3 ft/In) does not involve a major departure from the existing levee system and operation, the socio-institutional constraints faced with this alternative are not anticipated to inhibit the project.

5.2 Further Considerations

One of the unique results of this study is that the expected damages in the without-project scenario greatly increase in the distant future. In the 21-year time horizon, it is clear that only the 3-foot (0.9-meter) raise is considered an economically feasible project. This is primarily explained by the fact that the magnitude of the damages is still relatively small over the next 21 years. However, by increasing the time horizon to 74 years, even the 4-foot (1.2-meter) raise, which is over six times as costly as the 3-foot (0.9-meter) raise in discounted terms, becomes much more attractive according to BCA. The benefit-cost ratio of this option becomes 0.85 under the 6.875 percent discount rate, and the option becomes economically feasible, with a ratio of 2.68 using the 3.5 percent discount rate. This result comes from the magnitude of the damages by the year 2074.

Two recommendations for further study can be made based on this fact. The first is that at some time in the future, when the damages will have increased in magnitude, a similar study might be performed. At such a point in time (perhaps in 15 years), the discounted present value of damages would be greater, and a more costly program of dredging or levee alteration might prove economically feasible. Whether or not such a program would be selected or be preferred among similar alternatives remains to be seen.

The second recommendation is related to the nature of the increases in estimated damages. As shown in figure 9, and in figure E-1, the damage estimations used in this study were based on linear interpolations between WSP's at two future points in time: 2021, and 2074. This linear interpolation might be improved by estimating WSP's at a greater number of points in time in the future. For example, it might be that the damages through time occur at an increasing rate, with large values of damages only occurring after the year 2050. Alternatively, the value of annual damages might increase rapidly after 2021, and then slow down between 2050 and 2074. These types of relationships could be very important to the results of a study taking place in 2015.

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