# MD of Lesser Slave River No. 124: Cost-Benefit Analysis of Flood Disaster Risk Management Strategy

Submitted to:

MD of Lesser Slave River No. 124

Submitted by:


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# 1. Executive Summary

**Background**

The Municipal District of Lesser Slave River No. 124 (MDLSR) has contracted Associated Engineering Ltd. (AE) to develop a flood disaster risk management strategy, which includes a risk treatment options analysis (RTOA) for 12 flood mitigation options. To support this work, Nichols Applied Management (Nichols) was engaged to undertake cost-benefit analyses (CBAs) for the six most promising mitigation options (with Option 1 being the status quo/baseline scenario for comparison purposes) to better inform a recommendation to the MDLSR.

**Methods**

A cost-benefit analysis (CBA) is a generally accepted methodology for establishing the net social benefit of a particular project, policy, or economic activity. The approach involves weighing the social benefits and social costs (including financial costs and benefits) of a given activity and determining whether the former outweigh the latter. The present value of all benefits less all costs is referred to as the Net Present Value (NPV). A positive NPV indicates that society will be made better off as a result of the project, and a negative value indicates that it will be worse off.

Although simple in concept, the act of pricing all costs and benefits is complicated. For goods and services that trade in markets, values are relatively straightforward to discern. If, however, the policy or project has impacts on elements that do not typically trade in markets, estimates of these non-market costs and benefits are derived using a variety of statistical methods that vary in their accuracy. As some of the benefits of flood mitigation are not market goods (e.g., reduced anxiety/worry) the Study Team relied on non-market values from published studies where needed.

**Cost-Benefit Analyses**

*Standing and Forecast Period*

The benefits of the flood mitigation options under consideration for the MDLSR are anticipated to primarily impact stakeholders within the MDLSR (specifically those within the Hamlet); however, the costs associated with the flood mitigation options under consideration have the potential to impact stakeholders outside of the Hamlet depending on the source of the expenditures. As a result, the Study Team chose to take a provincial perspective in this analysis; thus, only costs and benefits affecting residents of Alberta are measured.

The lifespan of flood mitigation infrastructure is typically 50-75 years. The Study Team has selected a 50-year time frame for this analysis (2022 – 2071). It was assumed that a flood mitigation option would be implemented in 2023 with associated benefits and costs extending through 2071.

*Discount Rate*

Costs and benefits that occur in the future must be discounted back to a present value and expressed in equivalent dollar terms using an appropriate discount rate. Conceptually, the discount rate represents society's time value of money. The Study Team chose to conduct the CBAs in this work using discount rates of 8%, 4%, and 3%.

*Social Benefits of Flood Mitigation*

The primary social benefit of flood mitigation activities is the value of flood damages that are avoided. These avoided damages include both market damages and non-market damages. Market damages are those for which market values exist. These include direct damages to residential and non-residential structures and contents, damages to infrastructure, as well as indirect damages such as residential displacement and emergency response costs. Non-market damages are damages for which market values do not exist. These include damages to natural assets (i.e., loss of ecosystem services), as well as health impacts on affected residents (e.g., anxiety, worry). The average annual damages associated with flooding up to a 100-year event in the Hamlet that would be avoided under mitigation activities were estimated to be $762,467.

*Social Costs of Flood Mitigation*

The social costs of flood mitigation options in the MDLSR include the direct costs of implementing the mitigation activities, potential damages to environmental assets that may occur as a result of the mitigation activities, as well as any reclamation costs associated with demolishing and reclaiming residential and municipal properties. Each of the six mitigation options differs in its estimated costs depending on the extent of infrastructure required, the potential for environmental impacts, and the number of residential buyouts/reclamation activities required. It is important to note that the construction and operating costs related to mitigation infrastructure used in this work are considered Class D engineering estimates that should be considered within a margin of error of ±50%.

**Results**

The results of the CBAs under 8%, 4%, and 3% discount rates are summarized below in Table 1-1. The results indicate that only one flood mitigation option yields a positive NPV. Option 2 (North Side Flood Protection Dike) and Option 5 (Room for the River with Dikes) both result in positive NPVs under 3% and 4% discount rates. Mitigation Options 3, 4, and 6 all yield negative NPVs under all discount rates and baseline assumptions, suggesting that these mitigation options and are likely not in the public interest.

Table 1-1 Estimated Net Present Value for Flood Mitigation Options 2-6 ($ millions)

| Mitigation Option | 8% Discount Rate | | | 4% Discount Rate | | | 3% Discount Rate | | |
|---|---|---|---|---|---|---|---|---|---|
| | PV Benefits | PV Costs | NPV | PV Benefits | PV Costs | NPV | PV Benefits | PV Costs | NPV |
| Option 2 – North Side Dikes | $8.6 | $13.1 | **-$4.5** | $15.5 | $14.2 | **$1.3** | $18.7 | $14.6 | **$4.1** |
| Option 3 – North and South Side Dikes | $8.6 | $17.9 | **-$9.3** | $15.5 | $19.7 | **-$4.2** | $18.7 | $20.4 | **-$1.7** |
| Option 4 – Diversion to Oxbow with Dikes | $8.6 | $17.2 | **-$8.6** | $15.5 | $18.9 | **-$3.4** | $18.7 | $19.5 | **-$0.8** |
| Option 5 – Room for the River with Dikes | $8.6 | $11.2 | **-$2.6** | $15.5 | $12.0 | **$3.5** | $18.7 | $12.2 | **$6.5** |
| Option 6 – Managed Retreat | $8.6 | $20.9 | **-$12.3** | $15.5 | $21.8 | **-$6.3** | $18.7 | $22.0 | **-$3.3** |

# 2. Introduction

The Municipal District of Lesser Slave River No. 124 (MDLSR) is seeking to better understand the costs and benefits associated with options to mitigate flooding in the Hamlet of Marten Beach (the Hamlet) and Diamond Willow campground. The MDLSR has contracted Associated Engineering Ltd. (AE) to develop a flood disaster risk management strategy, which includes a risk treatment options analysis (RTOA) for 12 flood mitigation options. Nichols Applied Management (Nichols) has been contracted by AE to support this work by undertaking cost-benefit analyses (CBAs) for six mitigation options (with Option 1 being the status quo/baseline scenario for comparison purposes) to better inform a recommendation to the MDLSR.

The balance of this report includes:

- **Section 3:** Background information on the flood mitigation options and results of AE's RTOA for the MDLSR.
- **Section 4:** An overview of our methods.
- **Section 5:** A description of the accounting stance, forecast period, and discount rate chosen for the CBAs.
- **Section 6:** A description and quantification of the social benefits of flood mitigation.
- **Section 7:** A description and quantification of the social costs of flood mitigation.
- **Section 8:** A CBA of each flood mitigation option.
- **Section 9:** Sensitivity and breakeven analyses for each CBA scenario.
- **Section 10:** Study conclusions and limitations.

# 3. Background

Marten Beach is located within the MDLSR approximately 35 kilometers north of the Town of Slave Lake. The population of the Hamlet fluctuates throughout the year; the estimated permanent population of the Hamlet is 80 residents while the estimated secondary population is 222 residents. Of these, 60 permanent residents and 71 secondary residents reside within a 100-year return period floodplain. Flooding is a common occurrence in the Hamlet, particularly during periods of heavy precipitation. The Hamlet has experienced some relatively large flooding events in recent years (2018 and 2019) causing damages resulting in costs to both residents and the MDLSR.

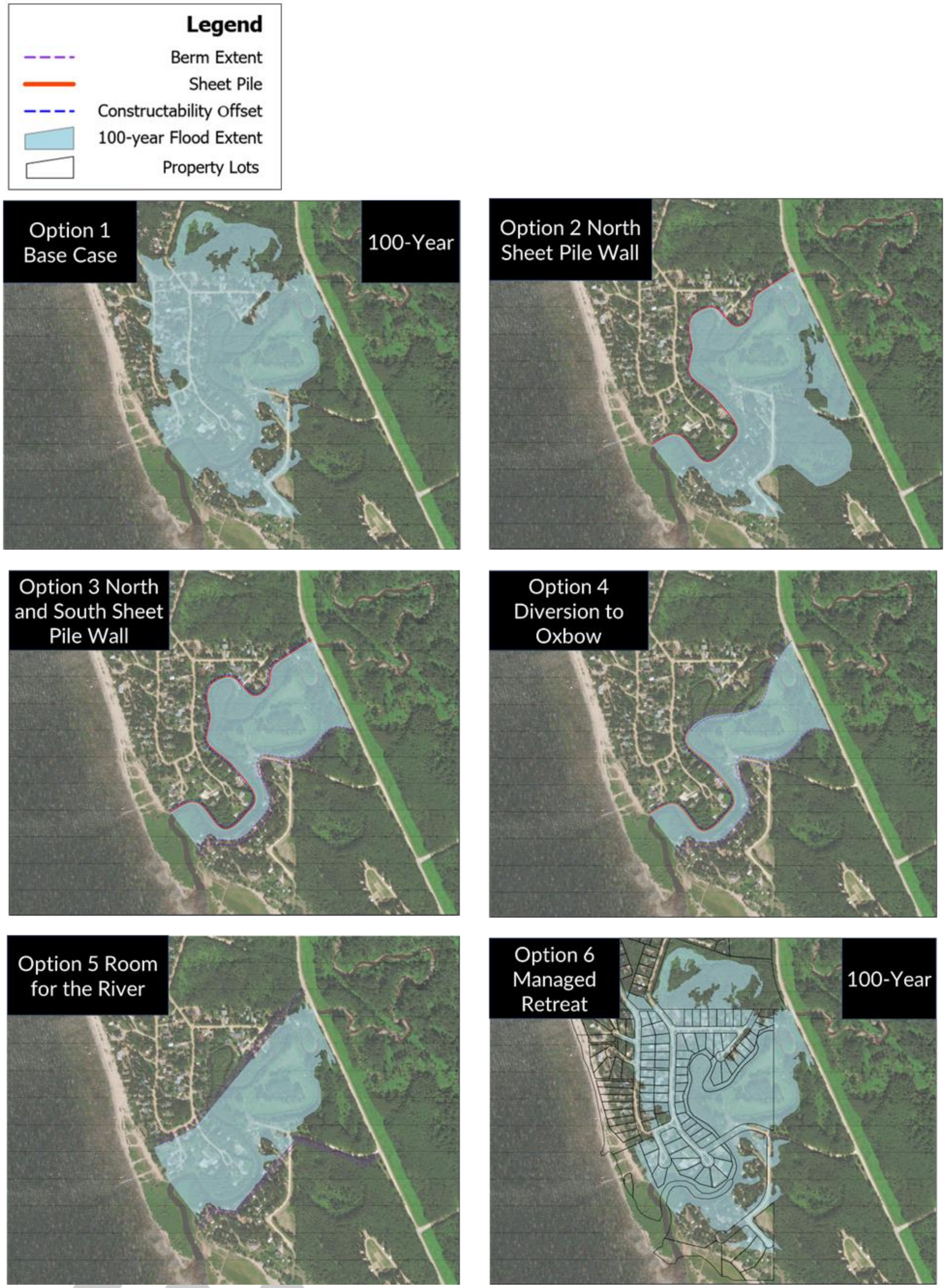
The MDLSR has previously engaged several consulting firms to evaluate and recommend possible flood mitigation options for the Hamlet, but a final decision on the most appropriate flood risk treatment option has not been made to date. To this end, AE has been engaged to conduct an RTOA for 12 flood mitigation options in the Hamlet, and Nichols has been engaged to conduct CBAs for the six most promising mitigation options to better inform a recommendation to the MDLSR.

The flood mitigation options analyzed in this work include:

- **Option 1 – Base Case:** The baseline scenario where no flood mitigation activities are employed. This is the scenario to which the costs and benefits of all other options are compared.
- **Option 2 – North Side Dikes:** A sheet pile wall on the north side of the river. No flood protection for the south side.
- **Option 3 – North and South Side Dikes:** A sheet pile wall on the north side of the river and an earthen berm on the south side of the river. A wider floodplain on the upstream portion and a smaller "funnel" downstream.
- **Option 4 – Diversion to Oxbow with Dikes:** The old oxbow is reactivated for "normal" flows. A sheet pile wall and earthen berm on the north side and an earthen berm on the south side of the river are constructed with the north berm along the current channel.
- **Option 5 – Room for the River with Dikes:** The river's natural meander is re-established, the floodplain is widened, earthen berms are constructed on both sides of the river, and residents within the existing river meander are relocated.
- **Option 6 – Managed Retreat:** Removal of all properties within the 100-year return period floodplain. Re-establishes the natural floodplain.

A depiction of each mitigation option is provided in Figure 3-1 below.

## Figure 3-1 Flood Mitigation Options for Cost-Benefit Analysis




Source: AE 2022a.

# 4. Methods

## 4.1 Overview

A cost-benefit analysis (CBA) is a generally accepted methodology for establishing the net social benefit of a particular project, policy, or economic activity. The approach involves weighing the social benefits and social costs of a given activity and determining whether the former outweigh the latter. Our work draws on:

- Guidelines for Cost-Benefit Analysis published by the Treasury Board of Canada (Treasury Board of Canada Secretariat 2007).
- *Cost-Benefit Analysis, Concepts and Practices* by Boardman et al. (2018) – widely regarded as the authoritative text on CBA.
- Our professional experience teaching CBA at the University of Alberta and working as consulting economists.

Conceptually, a CBA consists of weighing all the anticipated market and non-market (e.g., environmental, health, etc.) costs and benefits expected to flow to individuals and society from an implemented policy or project (in this case, flood risk treatment options) and determining if the former outweigh the latter. A robust CBA typically involves eight key steps, outlined below.

1. Identifying the parameters of the project or policy to be examined.
2. Establishing whose costs and benefits are included in the analysis. Only the costs and benefits accruing to individuals and groups said to have standing in the CBA are considered. This step involves mapping bio-physical pathways through which a policy or program might impact end-point users.
3. Identifying the social benefits associated with a policy or project. Social benefits are typically focused on non-financial impacts on directly affected entities.
4. Identifying the social costs associated with a policy or project. Social costs include not only the financial cost of implementing the policy or project, but also foregone opportunity costs associated with any prohibited activities.
5. Assigning a dollar value to each of the identified costs and benefits. Costs and benefits are not always goods or services traded in markets. As an example, the implementation of a flood mitigation activity may result in benefits in the form of avoided mental health impacts to affected residents. These avoided impacts (e.g., anxiety, worry related to recurring flooding) require non-market valuation methods to estimate a quantitative value. A variety of statistical techniques or existing academic literature can be used to arrive at estimated values for non-market costs and benefits. In some cases, a qualitative discussion of selected costs and benefits may be appropriate.
6. Adjusting the value of costs and benefits that occur over time. Costs and benefits that occur in the future are discounted back to a present value and expressed in equivalent dollar terms using an appropriate discount rate. Treasury Board Guidelines recommend discount rates of 8% and 3% (Treasury Board of Canada Secretariat 2007).
7. Subtracting the total social costs of the project or policy from the total social benefits. If the total social benefits outweigh the costs, the activity is said to be of a net benefit to society and considered to be an economically efficient and socially desirable undertaking. A key metric stemming from this step is the net

present value (NPV) of the activity. The NPV is a measure of the absolute value (i.e., benefits less costs) of a given activity. An NPV greater than zero is considered to provide a net social benefit.

8. Undertaking a sensitivity analysis to determine how robust the study results are to changes in key assumptions or parameters (e.g., the discount rate).

The inclusion of economic costs and benefits in a CBA can be confusing, particularly when compared to economic impact assessment (EIA), another frequently used impact analysis methodology. The generally accepted methodology for a robust CBA outlines well-defined benefit and cost categories that should be included in the analysis. In general, a CBA aims to take the position of a social planner who is concerned with benefits and costs that accrue to all members of society considered to have standing in the CBA. Key principles relied upon in identifying costs and benefits are as follows:

- An analyst shall focus solely on the impacts resulting directly from the policy or program being evaluated. Impacts in secondary markets can be disregarded provided that no market distortion exists.
- Transfers or transactions that represent a cost to one party and a gain to another (e.g., taxes), have the effect of netting to zero. These transfers effectively appear as both a cost and a benefit in the CBA and therefore do not need to be included.
- In the case where a policy or project may result in the cessation or prohibition of an activity, the foregone benefits to society of the prohibited activity represent costs of the policy or project. In other words, should a policy or project require an activity be prohibited, the opportunity cost of that prohibition (measured as the foregone stream of profits that otherwise would have accrued from that activity) are included in the CBA as a cost of the policy or project.
- Financial benefits will be evaluated net of the cost of production. Specifically, the profit derived from a business activity represents the net value to society of the good being produced or the service being provided, not the total revenues of the activity.

Note that a CBA does not rely on estimates of economic activity, in contrast to an EIA. For example, measures such as GDP describe a level or volume of activity, not the net benefit derived by society from a particular activity. Only the profit component of GDP that is directly tied to a policy or project being evaluated would be appropriate to include in a CBA. Similarly, the inclusion of jobs as a cost or benefit is challenging. Employment should only be included when the people being employed by a project would have otherwise been unemployed. In a “fully employed” economy, the redistribution of employed labour from one industry to another is not a cost or benefit. A fully employed labour market maintains a natural rate of unemployment as workers transition between jobs or are unwilling to work at a certain point in time. The exact value of the natural rate of unemployment is debated by economists, but typically labour markets with unemployment rates of 5-7% are considered fully employed.

# 5. Standing, Forecast Period, and Discount Rate

## 5.1 Standing

An important element of a CBA is determining whose costs and benefits will be considered in the analysis, or who has "standing". For example, studies can take a national, provincial, or regional perspective wherein the impacts to residents for a given geographical scope are contemplated. The benefits of the flood mitigation options under consideration for the MDLSR are anticipated to primarily impact stakeholders within the MDLSR (specifically those within the Hamlet); however, the costs associated with the flood mitigation options under consideration have the potential to impact stakeholders outside of the Hamlet depending on the source of the expenditures. For example, if a mitigation project is funded by the provincial government, the stakeholders bearing this cost would include all Albertan taxpayers. As a result, the Study Team has chosen to take a provincial perspective in this analysis; thus, only costs and benefits affecting residents of Alberta are measured.

It is important to note that CBAs do not inherently deal with issues of sub-regional inequities. As noted here, the benefits of any flood mitigation activity in the MDLSR will accrue almost entirely to residents of the Hamlet as well as the MDLSR. Depending on how a flood mitigation activity is funded, the social costs of that activity may be borne by stakeholders elsewhere in Alberta. As such, we acknowledge that there is a potential discrepancy between who reaps the benefits and who bears the costs of flood mitigation in the MDLSR. Whether this discrepancy is considered "fair" or in the public's best interest is not addressed in this work.

## 5.2 Forecast Period

The lifespan of flood mitigation infrastructure is typically 50-75 years. The Study Team has selected a 50-year time frame for this analysis (2022 – 2071). It is assumed that a flood mitigation option would be implemented in 2023 with associated benefits and costs extending through 2071.

## 5.3 Discount Rate

As noted in Section 4, costs and benefits that occur in the future must be discounted back to a present value and expressed in equivalent dollar terms using an appropriate discount rate. Conceptually, the discount rate represents society's time value of money. High discount rates suggest that benefits and costs that occur earlier in the forecast period matter relatively more than those that occur later as compared to lower discount rates. The selection of a discount rate in CBAs has been a notoriously contentious issue amongst economics and social scientists. Indeed, the discount rate assumption can play a large part in determining whether a given policy or project yields a positive NPV. Some argue that the discount rate should reflect the opportunity cost of forgone investment, while others argue that it should reflect purely society's preference for current consumption over future consumption (Treasury Board Secretariat 2007). The most recent Treasury Board Guidelines recommend a discount rate of 8% for the evaluation of regulatory interventions but suggests that the social time preference rate in Canada is around 3% (Treasury Board of Canada Secretariat 2007). Work by Boardman et al. (2010)[1], has argued that the Treasury Board's 8% discount rate recommendation is too high, and that analysts conducting CBAs in Canada should use a social discount rate of 3.5%. Previous CBA work related to flood events in Alberta has relied on a discount rate of 4% (see IBI Group and Golder Associates 2017a).

The Study Team has chosen to conduct the CBAs in this work using discount rates of 8%, 4%, and 3%.

[1] We note that Boardman is the lead author of what is widely regarded as the authoritative text on CBA: Cost-Benefit Analysis, Concepts and Practices (by Boardman et al. (2018)).

# 6. Social Benefits of Flood Mitigation

The primary social benefit of flood mitigation activities is the value of flood damages that are avoided. These avoided damages include both market damages and non-market damages (Table 6-1). Market damages are those for which market values exist. These include direct damages to residential and non-residential structures and contents, damages to infrastructure, as well as indirect damages such as residential/commercial displacement, traffic delays, and emergency response costs. Non-market damages are damages for which market values do not exist. These include damages to natural assets (i.e., loss of ecosystem services), as well as health impacts on affected residents (e.g., anxiety, worry).

## Table 6-1 Flood Damage Categories

| Damage Category | Description |
|---|---|
| Market Damages | **Direct Damages**<br>*Residential damages*: Direct damages to residential structures and contents.<br>*Non-residential damages*: Direct damages to commercial (e.g., retail, office), industrial, and institutional structures and contents.<br>*Infrastructure damages*: Direct damages to municipal or private infrastructure (e.g., roadways, bridges, etc.)<br>**Indirect Damages**<br>Other market costs associated with flooding (e.g., residential/commercial displacement, traffic delays, waste disposal, etc.). |
| Non-market Damages | Non-market damages (or “intangible” damages) such as mental health impacts (e.g., anxiety, worry), loss of ecosystem goods and services from environmental assets, etc. |

The damages of flooding will differ depending on the size of the precipitation event, with more extreme events (e.g., 100-year flood) being more damaging than less extreme events (e.g., 2-year flood). To estimate avoided damages associated with flood mitigation options in a given year, economists often calculate average annual damages (AAD) for a series of flood events in a study area. Average annual damages represent the expected value of damages from flooding in a year given the likelihood and size of damages associated with any given flood event.

## 6.1 Direct Damages

The direct damages of flood events in the Hamlet consist primarily of damages to permanent and secondary dwellings and damages to municipal assets.

### 6.1.1 Damages to Dwellings

Hydraulic analysis was conducted by AE to estimate the direct residential damages associated with flooding during flood events ranging from 2-year to 100-year (AE 2022a) (Table 6-2). The extent of flooding simulated during the largest flood event (100-year) is estimated to result in over $6 million in direct residential damages to dwellings within the affected area.[2]

The extent of flooding simulated during the smallest flood event (2-year) is not expected to result in significant direct residential damages. Surface flooding depths during a 2-year are anticipated to be less than 0.30 m and it is assumed that no flooding occurs within the interior of the dwellings. Further, it is assumed that the dwellings do not have basements and any damage to crawl spaces would be negligible. We note that some damages could occur to the surrounding landscape and articles outside of the dwellings during the 2-year flood event.

### Table 6-2 Direct Residential Damages, Marten Beach (2-Year to 100-Year Events)

| | 2-Year | 5-Year | 10-Year | 20-Year | 50-Year | 100-Year |
|---|---|---|---|---|---|---|
| Number of dwellings impacted | 20 | 29 | 34 | 40 | 42 | 48 |
| Average inundation depth (m) | 0.03 | 0.14 | 0.24 | 0.33 | 0.48 | 0.54 |
| Maximum inundation depth (m) | 0.29 | 0.49 | 0.62 | 0.73 | 0.88 | 0.98 |
| **Residential damages** | **$-** | **$627,830** | **$2,317,550** | **$3,930,331** | **$5,217,066** | **$6,430,917** |

Source: AE 2022a.

#### 6.1.2 Damages to Municipal Assets

Flooding in the Hamlet can also result in direct damages to municipal infrastructure. Disaster Recovery Program (DRP) claims by the MDLSR suggest that flood damages to municipal roadways (including a bridge) in 2018 were approximately $1.1 million.[3] While this flood was slightly smaller than a 100-year event, the damages to municipal infrastructure were substantial. We therefore use the $1.1 million estimate as our upper bound on direct municipal damages for a large event (100-year). Estimated damages to municipal infrastructure for smaller flood events were scaled down based on the direct residential damage estimates (Table 6-3).

### Table 6-3 Direct Infrastructure Damages, Marten Beach (2-Year to 100-Year Events)

| | 2-Year | 5-Year | 10-Year | 20-Year | 50-Year | 100-Year |
|---|---|---|---|---|---|---|
| Municipal infrastructure damages | $- | $107,390 | $396,414 | $672,278 | $892,372 | $1,100,000 |

## 6.2 Indirect Damages

Indirect damages of flooding in the Hamlet are assumed to primarily consist of displacement of residents who cannot remain in their homes, and disruption costs to the MDLSR. Other potential indirect damages such as business disruption and traffic disruption are less applicable to this study area as the Hamlet does not host major businesses and is not subject to traffic concerns as would be the case in a larger metropolis.

[2] Data with respect to what properties in the 100-year event floodplain host dwellings and what properties are vacant was not available. As such, AE identified which properties have dwellings using aerial photography. It is noted that tree cover and photo quality may limit the accuracy of these counts.
[3] No infrastructure damage costs were claimed by the MDLSR through DRP for the 2019 flood event.

### 6.2.1 Residential Displacement

Following a flood event, residents may need to relocate to temporary accommodations and incur costs associated with this relocation. As noted above, within the affected area of a 100-year flood event, there are 48 dwellings: 28 dwellings with permanent residents and 20 dwellings with secondary residents. The number of permanent and secondary dwellings and residents impacted by flooding for various event sizes is described below in Table 6-4.

#### Table 6-4 Affected Permanent and Secondary Dwellings and Residents (2-Year to 100-Year Events)

| | 2-Year | 5-Year | 10-Year | 20-Year | 50-Year | 100-Year |
|---|---|---|---|---|---|---|
| Permanent Dwellings | 10 | 17 | 20 | 22 | 23 | 28 |
| Secondary Dwellings | 10 | 12 | 14 | 18 | 19 | 20 |
| **Total Dwellings** | **20** | **29** | **34** | **40** | **42** | **48** |
| Permanent Residents | 20 | 35 | 42 | 48 | 51 | 60 |
| Secondary Residents | 27 | 43 | 52 | 65 | 68 | 71 |
| **Total Residents** | **47** | **78** | **94** | **113** | **119** | **131** |

During a 100-year flood event it is expected that a total population of 131 will be affected, of which 60 are permanent residents and 71 are secondary residents. Residents of secondary dwellings in the affected flood area within the Hamlet are not expected to bear any displacement costs during flood events as they are assumed to have a primary dwelling to return to during these periods. For permanent residents, we make the following assumptions:[4]

- No residents are displaced after a 2-year flood event as residential damages for this event are negligible (see Table 6-2).
- Half of the Hamlet's displaced permanent residents for any flood event greater than a 2-year event (as per Table 6-4) will find accommodations with family or friends.
- Half of the Hamlet's displaced permanent residents for any flood event greater than a 2-year event (as per Table 6-4) will have to pay for alternative accommodations. It is assumed that these residents will:
  - Spend two weeks in a hotel at $150 per night regardless of the size of the flood event.[5]
  - Require rental accommodations for between three and six months depending on the size of flood event (see Table 6-5).[6] The average monthly cost for rented dwellings in the Town of Slave Lake in 2021 ranged between $895 – $1,206 depending on apartment size (Alberta Seniors and Housing 2021); a monthly cost of $1,206 is used here.

[4] These assumptions are drawn from work prepared by IBI Group and Golder Associates (2017). The assumptions are intended to err on the high side so as to ensure costs borne by residents of the Hamlet are not unfairly underestimated. Overall, these costs (which will represent avoided damages of flooding) are experienced by a relatively small number of residents and are unlikely to have a substantial impact on the results of the CBAs.

[5] At the time of writing, hotel prices in the Town of Slave Lake ranged from $90 to $144.

[6] Engagement by AE with residents of the Hamlet revealed that residents displaced during the 2018/2019 flood events were displaced for between two months to one year. As such, we believe the six-month displacement period applied to a 100-year event as per Table 6-5 is reasonable.

## Table 6-5 Permanent Resident Displacement Days, Marten Beach (2-Year to 100-Year Events)

| | 2-Year | 5-Year | 10-Year | 20-Year | 50-Year | 100-Year |
|---|---|---|---|---|---|---|
| Average inundation depth (m) | 0.03 | 0.14 | 0.24 | 0.33 | 0.48 | 0.58 |
| Displacement days | 0 | 90 | 105 | 120 | 160 | 180 |

Source: Interpolated data from Exhibit 4.8 of IBI Group and Golder Associates 2017b.

Given the above-listed assumptions, annual displacement damages are estimated to range between about $36,000 for a 5-year event to over $110,000 for a 100-year event (Table 6-6).

## Table 6-6 Indirect Displacement Damages, Marten Beach (2-Year to 100-Year Events)

| | 2-Year | 5-Year | 10-Year | 20-Year | 50-Year | 100-Year |
|---|---|---|---|---|---|---|
| Hotel costs | $- | $17,850 | $21,000 | $23,100 | $24,150 | $29,400 |
| Rental costs (annual) | $- | $18,100 | $35,900 | $48,200 | $70,800 | $83,200 |
| **Total displacement damages** | **$-** | **$35,950** | **$56,900** | **$71,300** | **$94,950** | **$112,600** |

### 6.2.2 Municipal Disruption

Flooding in the Hamlet can also result in indirect damages to the MDLSR in the form of emergency service costs and flood remediation/cleanup costs. Following the 100-year flooding event in 2019, the MDLSR claimed about $190,000 in costs associated with emergency operations and remediation/cleanup.[7,8] We therefore assume $190,000 in indirect damages associated with municipal disruption for a 100-year event. Estimated indirect municipal damages for smaller flood events were scaled down based on the direct residential damage estimates (Table 6-7).

## Table 6-7 Indirect Disruption Damages, Marten Beach (2-Year to 100-Year Events)

| | 2-Year | 5-Year | 10-Year | 20-Year | 50-Year | 100-Year |
|---|---|---|---|---|---|---|
| Municipal disruption damages | $- | $18,549 | $68,471 | $116,121 | $154,137 | $190,000 |

## 6.3 Intangible Damages

Intangible (non-market) damages of flooding in the Hamlet are assumed to primarily consist of public health damages (e.g., mental health impacts) and environmental damages. There are a variety of techniques to estimate

[7] No municipal disruption costs were claimed by the MDLSR through the DRP for the 2018 flood event.

[8] We would note that we are relying on MDLSR DRP claims from the 2018 flood event to estimate direct damages to municipal infrastructure and claims from the 2019 flood event to estimate indirect damages in the form of municipal disruption. It is unclear why the 2018 flood event did not result in DRP claims associated with emergency services or remediation/cleanup, or why the 2019 flood event did not result in DRP claims associated with municipal infrastructure. There may be an issue in terms of the timing of the reported data; if not, it is possible that some municipal-related damages are double counted in this work.

the non-market value of damages such as mental health impacts or environmental damages. Economic valuation attempts to measure the social welfare derived from non-market goods and services and is typically expressed in monetary units. For assets that are exchanged in conventional markets, valuation is relatively straightforward as we can more easily observe consumers' willingness to pay (WTP) for a market good using available data (e.g., prices, demand curves). For goods that are not traded in markets (non-market assets) however, other valuation techniques must be used. The economic literature outlines three generally accepted techniques for estimating non-market values:

- The **revealed preference (RP)** approach involves examining transactions in a market in order to infer a value for an ecosystem service that is related to the transaction but not explicitly traded. For example, one can examine the costs that individuals are willing to incur (e.g., travel costs) to enjoy an activity (e.g., fishing) to provide insight into the value associated with a natural asset (e.g., a lake).
- The **stated preference (SP)** approach involves designing surveys or choice experiments in which participants are explicitly asked to express their WTP to conserve a natural asset that provides a bundle of ecosystem services that are not traded in markets. For example, some SP studies involve asking participants what they would be willing to pay to avoid intangible impacts of flood events. These studies typically identify a bundle of impacts and elicit a household or individual's WTP to avoid those impacts (e.g., worry of lost house values, worry of future flooding, etc.).
- The **benefit transfer (BT)** approach allows for the value of non-market goods to be established through a review of published studies that contain estimates of values for comparable assets in similar jurisdictions. This approach is best suited for cases where primary data collection and analysis using RP or SP approaches are not practical or feasible.

Undertaking primary data collection and analysis in the form of a RP or SP study is beyond the scope of this work. Instead, the Study Team employed a BT approach whereby appropriate non-market values for public health and environmental impacts of flooding from the literature were applied to the study area. Where valuation was not possible, a detailed qualitative assessment of impacts was undertaken.

### 6.3.1 Public Health Impacts

The public health impacts associated with natural disasters can be substantial. Flood disasters can contribute to a variety of public health impacts including, but not limited to:

- mortality,
- injury,
- disease or infection, and
- psychological or mental health effects (IBI Group and Golder Associates 2017b).

Impacts such as mortality and injury are more likely to occur during particularly severe flood events (e.g., severe flash flooding); neither of these health impacts have been identified as a concern in recent flood events in the MDLSR. Disease and infection impacts may occur because of water contamination as flooding can cause nutrient runoff or other undesirable chemicals from agricultural or industrial operations to enter waterways (Du et al. 2010). During recent flood events in the Hamlet, septic tanks overflowed, and a substantial amount of raw sewage was released into the floodwaters. The "sludge" that remained post-flood was essentially contaminated sewage. Indeed, Alberta Health Services (AHS) noted that concerning levels of bacteria can exist in a community following a flood if sewage is released during the event. The extent to which sewage runoff contributes to an increased incidence of disease and infection in the community is unknown. No major incidences of disease or infection were reported in the recent major flood events. As the community has experience dealing with flood events, it is possible that residents are sufficiently equipped to avoid contact with contaminated waters. However, it is likely that the prevalence of sewage runoff in floodwaters contributes to increased anxiety and worry amongst residents during and following flood events. Contaminated flood waters certainly pose a risk to those undertaking cleanup activities following an event. The value associated with those risks is inherently captured in the municipal cleanup costs described in Section 6.2.2.

In a robust literature review conducted by Stanke et al. (2012), the authors asserted that apart from physical impacts, flooding can have significant impacts on people's mental health, relationships, and overall welfare. Impacts such as anxiety, stress, and post-traumatic stress disorder (PTSD) can affect people of all ages and persist for a substantial period after the flood event (Stanke et al. 2012). Human-induced climate change is expected to contribute to more frequent and extreme weather events, including flooding (IPCC 2022). As such, the intangible mental health impacts of flooding can be expected to continue to increase as well. Engagement conducted by the Human Environment Group and AE revealed that psychological/mental health impacts have been a major concern in the Hamlet. Residents of the Hamlet have noted that the recent floods of 2018 and 2019 have contributed to increased stress, worry, and ongoing trauma that has made it difficult to continue living in the area in the absence of a flood prevention plan. Of particular concern is the general uncertainty residents have faced as a result of a lack of flood mitigation planning or resolution strategy. Mental health impacts were noted as being more prominent amongst permanent residents of the community as compared to secondary homeowners; however, a strong sense of community/belonging was found to resonate amongst all residents, and the mental health impacts of recent flood events have permeated throughout the Hamlet during the several years since the latest event.

The published literature on the value of intangible impacts of flood events on public health is relatively sparse. However, there have been several studies that have attempted to estimate household WTP to avoid intangible health impacts associated with flood events. For example, there have been two WTP studies conducted in the United Kingdom (UK) with respect to intangible impacts of flooding. In 2002, the UK Department for Environment, Food, and Rural Affairs (DEFRA) conducted an SP survey to elicit household WTP values to avoid health impacts associated with flooding (DEFRA 2004). The results of this study suggested that households would be WTP approximately £200 per year ($670 in 2021 CAD) to avoid the health impacts of flood events. A more recent DEFRA survey (DEFRA 2015) conducted following severe flood events in 2007 found a mean WTP value of approximately £653 per household per year ($1,430 in 2021 CAD). Previous CBA work related to flood events in Alberta have used an average value of $1,000 per household per year to represent intangible public health impacts of flooding (see IBI Group and Golder Associates 2017b).

For this work, we have chosen a value of $1,430 per household per year, in keeping with the most recent DEFRA valuation work (DEFRA 2015) and to err on the high side to ensure flooding costs borne by residents of the Hamlet are not unfairly underestimated. The same value of intangible damages ($1,430 per household per year) is assumed for all 48 households in the affected area within the Hamlet and for all flood events.[9]

[9] We note that although direct residential damages from 2-year flood events are considered negligible, intangible damages may still be associated with this size of event as the incidence of floodwaters in the community contribute to increased anxiety/worry amongst residents.

Table 6-8 Intangible Public Health Damages, Marten Beach (2-Year to 100-Year Events)

| | 2-Year | 5-Year | 10-Year | 20-Year | 50-Year | 100-Year |
|---|---|---|---|---|---|---|
| Intangible public health damages | $68,640 | $68,640 | $68,640 | $68,640 | $68,640 | $68,640 |

### 6.3.2 Environmental Impacts

The extent of damages to environmental assets and accompanying ecosystem services from flooding depend on the severity of the flood event. Severe flood events (e.g., large flash floods) can result in substantial erosion of riverbanks and riparian areas, and the long-term loss of various ecosystem services such as wildlife habitat provision, climate regulation, water quality/quantity regulation, recreation, etc. Light to moderate flood events do not typically result in permanent damage to environmental assets provided infrastructure is not in the way of natural river erosion processes; flooding is a natural event that can help maintain river structures and ecosystems without causing permanent loss of ecosystem services (IBI Group and Golder Associates 2017b).

Engagement with residents of the Hamlet revealed that ecosystem service losses as a result of flooding are not a major concern. The residents identified short-term sediment deposition as an environmental impact of the recent flood events. Residents do not rely on much of the floodplain area for ongoing recreational activities and did not identify other ecosystem services as being of particularly high value. Given that the geographical scope of this work is provincial, should severe flooding in the Hamlet result in the permanent loss of environmental assets, stakeholders outside of the Hamlet may experience lost value for the associated ecosystem services. Flood mitigation activities that avoid these losses would therefore represent a benefit in the CBA.

Estimating the value of avoided damages to environmental assets from flooding in the Hamlet would require data and information regarding the types of landcover impacted by flooding as well as the permanence of damage to ecosystem services associated with flood events. This data and information were unavailable at the time of writing and are likely to be relatively small, therefore a quantitative value for intangible environmental impacts of flooding was not estimated.

## 6.4 Average Annual Damages

Together the average avoided direct, indirect, and intangible damages of flooding in the Hamlet are used to represent the social benefit of each flood mitigation option evaluated. A summary of the estimated damages for various flood events in the Hamlet is provided in Table 6-9 below.

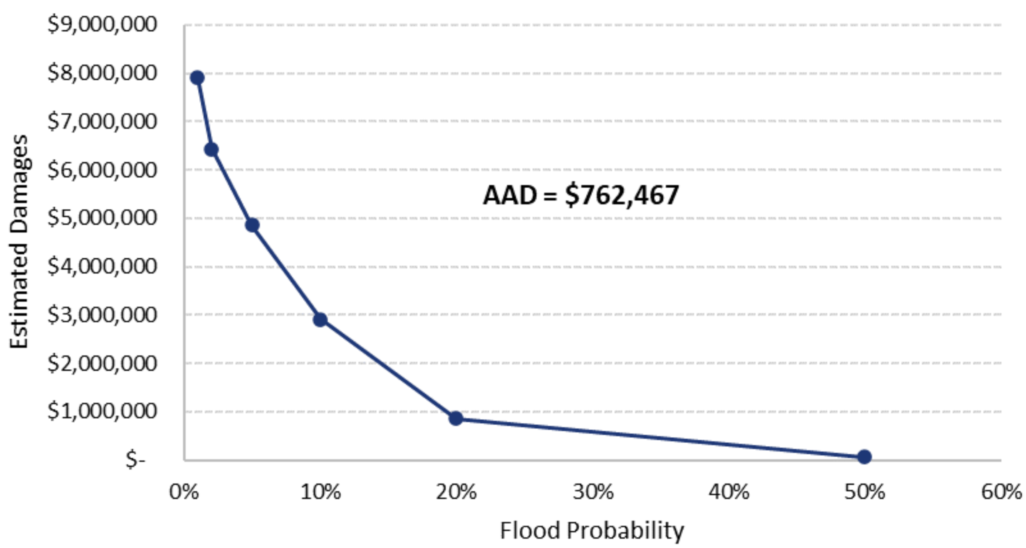
Table 6-9 Total Estimated Damages, Marten Beach (2-Year to 100-Year Events)

| Damage Category | | 2-Year | 5-Year | 10-Year | 20-Year | 50-Year | 100-Year |
|---|---|---|---|---|---|---|---|
| **Direct Damages** | Residential | $- | $627,830 | $2,317,550 | $3,930,331 | $5,217,066 | $6,430,917 |
| | Non-residential /Infrastructure | $- | $107,390 | $396,414 | $672,278 | $892,372 | $1,100,000 |
| **Indirect Damages** | Residential displacement | $- | $35,950 | $56,900 | $71,300 | $94,950 | $112,600 |
| | Municipal disruption | $- | $18,549 | $68,471 | $116,121 | $154,137 | $190,000 |
| **Intangible Damages** | Public health | $68,640 | $68,640 | $68,640 | $68,640 | $68,640 | $68,640 |
| | **Total Damages** | **$68,640** | **$858,359** | **$2,907,975** | **$4,858,670** | **$6,427,165** | **$7,902,157** |

The largest component of flood damages in the Hamlet is direct residential damages. For a 100-year event, direct residential damages represent about 81% of total damages, while indirect and intangible damages make up much smaller portions of total damages in the Hamlet (about 5% for a 100-year event).

The same summary of estimated damages for various flood events in the Hamlet is depicted in the damage probability curve below (Figure 6-1). The Hamlet's AAD from flooding (the expected value of damages from flooding in a year given the likelihood and size of damages associated with any given flood event) is obtained by integrating the area under the damage probability curve (IBI Group and Golder Associates 2017b). The estimated AAD for flooding in the Hamlet is $762,467.[10]

Figure 6-1 Damage Probability Curve, Marten Beach (2-Year to 100-Year Events)




[10] To provide additional context to this estimate, we refer to a recent flood damage study for the Hamlet of Walsh conducted by IBI Group and Golder Associates (2019). In this work the authors estimated an AAD of approximately $638,000 for up to a 1,000-year event and approximately $558,000 for up to a 100-year event. As per the 2021 federal census, the Hamlet of Walsh hosts 50 residents in 26 of its 32 total private dwellings (Statistics Canada 2021).

For each CBA, the Study Team makes the following assumptions regarding social benefits of flood mitigation:

- All flood mitigation options (i.e., Option 2 through Option 6) would effectively mitigate flooding up to and including a 100-year event.
- Annual social benefits of each mitigation option are equal to the Hamlet's estimated AAD of flooding – in other words, the benefit of the mitigation option is the avoidance of the AAD of flooding.
- Benefits of flood mitigation begin in the third year of the forecast period following implementation of the mitigation activity (i.e., 2024).

# 7. Social Costs of Flood Mitigation

The social costs of flood mitigation options in the MDLSR include the direct costs of implementing the mitigation activities, potential damages to environmental assets that may occur as a result of the mitigation activities, as well as any reclamation costs associated with demolishing and reclaiming residential and municipal properties.

## 7.1 Direct Costs of Mitigation Activities

The flood mitigation options evaluated in this work include three primary categories of direct mitigation costs:

- Construction costs of necessary infrastructure. We note that construction costs were provide by AE (AE 2022b) and are Class D engineering estimates that should be considered within a margin of error of ±50%.
- Ongoing operation and maintenance costs of necessary infrastructure.
- Residential buyouts for displaced residents.

For each CBA, the Study Team makes the following assumptions regarding direct costs of mitigation:

- Construction of necessary infrastructure takes place over two years, with 50% of the costs occurring in 2023 and 50% occurring in 2024.
- Annual operation and maintenance of necessary infrastructure costs 0.5% of total capital costs (AE 2022b) for each mitigation option and begins the year following construction (i.e., 2025).
- Residential buyouts associated with a given mitigation option occur in 2023.
- Demolition and reclamation costs of residential and/or municipal properties occur in 2024.

## 7.2 Environmental Impacts

The implementation of a given flood mitigation option may result in negative impacts to environmental assets in the Hamlet. The installation of sheet pile walls and berms, or diversion of the oxbow river, may result in erosion of riverbanks and riparian areas, potentially contributing to long-term loss of various ecosystem services such as wildlife habitat provision, climate regulation, water quality/quantity regulation, recreation, etc.

In the RTOA conducted by AE, the authors identified and scored a variety of environmental consequences associated with each flood mitigation option. A summary of these consequences is outlined in Table 7-1 below.

Table 7-1 Risk Treatment Summary for Flood Mitigation Options – Environmental Consequences

| Mitigation Option | Environmental Consequences | Score (1 to 5) |
|---|---|---|
| Option 2 – North Side Dikes | Groundwater impacts were scored to account for impacts around sheet pile walls. This could result in increased groundwater risks to residents in close proximity. Sheet pile walls would also impact wildlife passage and would be a higher risk for regulatory approval. | 2.6 |
| Option 3 – North and South Side Dikes | Groundwater impacts would be similar to Option 2 for the north side dike. There would be a greater impact to overall environmental health compared to Option 2 since the floodplain is constrained on both sides, especially in the downstream portion. Wildlife would be able to pass over the earthen berms but would be constrained by the sheet pile walls. Regulatory approvals would likely be easier to obtain. | 2.3 |
| Option 4 – Diversion to Oxbow with Dikes | Removing the existing river channel would have substantial environmental impacts including removal of aquatic habitat and fish passage. In time, aquatic and fish habitat will re-establish in the new channel, but construction will be very damaging. Due to the large amount of instream construction and significant impacts to habitat, this option would be difficult for regulatory approvals. | 4 |
| Option 5 – Room for the River with Dikes | This option has better groundwater and surface water flow than Options 1-4. Part of the natural floodplain is reclaimed. Regulatory approvals will be challenging as a portion of the natural path of the river is changed. | 2.8 |
| Option 6 – Managed Retreat | The natural environment in the 100-year floodplain would be entirely reclaimed. Further work would be needed to fully reclaim this land to its natural state. | 1.0 |

Source: AE 2022a.

Based on the RTOA, the most prominent potential ecosystem service impacts of the various flood mitigation options are:

- impacts to water quality and flow (including both surface water and groundwater), and
- impacts to wildlife habitat.

The use of dikes in various flood mitigation options has the potentially to alter natural surface water and groundwater flow through the project area. Construction activities associated with flood mitigation may also result in unintentional contamination of surface water and groundwater in the area.

The extent to which impacts to surface water and groundwater quality and flow from flood mitigation activities would impact residents in the Hamlet is unclear. Surface water and groundwater are often important sources of drinking and non-drinking water for rural properties. Contamination of groundwater as a result of flood mitigation activities could therefore impose costs on local residents who rely on that water for various uses. The value of drinking water supply is difficult to estimate. Work by Appiah et al. (2019) attempted to estimate the economic value of drinking water reliability in Alberta using SP techniques. The study specifically oversampled rural Albertans as these residents deal with water reliability issues more regularly. The authors found that households expecting water outages would be willing to pay about $71 per year on top of their water bills for a 10-year period to reduce their risk of short-term outages by 50%. The value of non-drinking water uses from groundwater sources (e.g., irrigation, garden watering, or livestock watering) is also difficult to estimate. Residents have noted that local family gardens are an important source of recreation and socialization for the community; however, the value associated with these activities is likely small relative to the other flood mitigation costs.

Rivers and riparian ecosystems are often important providers of habitat for a variety of aquatic and non-aquatic flora and fauna. The installation of dikes or alterations to the existing river channel could have substantial impacts on the habitat and movement of various fish and aquatic species. Furthermore, any contamination of surface and groundwaters because of flood mitigation activities could harm wildlife in the area. The valuation of wildlife is complex. Not all species are considered to provide a benefit to stakeholders. Indeed, some species such as coyote or mice are considered a nuisance to many, and an individual’s WTP to conserve these species might be zero. In a populated area, the value of habitat provision is often highest for iconic or charismatic species, as well as for species that are considered to be sensitive, threatened, or at risk.

As noted earlier, given that the geographical scope of this work is provincial, should flood mitigation activities in the Hamlet result in the loss or deterioration of ecosystem services, the stakeholders accruing those losses may include those living outside the Hamlet.

Estimating the value of water and wildlife habitat impacts of flood mitigation in the Hamlet would require the following data and information:

- The extent of groundwater damage or contamination as well as the use of groundwater in the region, the number of affected residents, and the timing of impacts.
- An inventory of key wildlife species with habitat in the area and the extent to which that habitat is damaged or lost.

This data and information were unavailable at the time of writing, therefore a quantitative value for the costs associated with environmental impacts of flood mitigation activities was not estimated. We would also note that the reclamation of land to a naturalized state may also yield some benefits in the form of increased ecosystem services (e.g., carbon storage and sequestration, increased provision of wildlife habitat, etc.). However, these benefits would likely be relatively small compared to the baseline scenario given the small geographic area of the potential reclamation.

## 7.3 Demolition and Reclamation Costs

For dwellings that are bought out, demolition and reclamation will be necessary to return the area to a natural or naturalized state. Similarly, reclamation activities may be required for vacant properties and campground properties as well. For Option 6 in particular (Managed Retreat), larger-scale reclamation will likely be needed to reclaim not only properties but also municipal infrastructure such as roads and bridges.

Residential demolition in larger metropolitan areas of Alberta have been quoted to be between $12,000 - $40,000 (Demolition Calgary 2020). This estimate includes the cancellation and removal of utilities connected to the dwelling. The demolition and reclamation of additional utilities and municipal infrastructure such as roads and bridges in the Hamlet would be at the discretion of the MDLSR and may not be demolished/reclaimed in short order depending on the desire to maintain access to the area.

For this category of costs, the Study Team assumes an average cost of demolition of $40,000 per displaced dwelling that occurs in 2024. We assume the higher end of the cited range to account for the fact that septic systems will likely need to be removed and reclaimed for demolished dwellings. Additional costs associated with land reclamation of properties and reclamation of municipal infrastructure are not known at this time and therefore not included in this analysis. We would note that costs and/or benefits may also occur under various flood mitigation options as a result of several factors, including:

- Foregone spending by the MDLSR for future infrastructure maintenance (particularly under Option 6 where municipal infrastructure would likely be reclaimed).
- Resettlement of residents within the MDLSR or to other areas of the province.

The nature of these factors is not known at this time and these potential costs and/or benefits are therefore not considered in this analysis.

# 8. Cost-Benefit Analysis

## 8.1 Baseline Scenario

A CBA requires the definition of a baseline scenario (i.e., business as usual activities expected without flood mitigation in the Hamlet) to which the impacts of the flood mitigation options will be compared. This requires:

- Forecasting the conditions of the Hamlet over the forecast period in the absence of flood mitigation.
- Identifying the key parameters and expected impacts of the flood mitigation options.
- Identifying the pathways through which the flood mitigation activities will affect people.
- Identifying the incremental changes stemming from the flood mitigation activities above the baseline scenario.

To develop the baseline scenario, the Study Team assumes the following:

- The total number and categorization (i.e., permanent versus secondary) of dwellings and residents in the Hamlet will remain constant over the forecast period.
- In the absence of flood mitigation, the Hamlet will bear annual costs of flooding equivalent to the estimated AAD.

## 8.2 Option 2: North Side Flood Protection Dike

As per the assumptions highlighted in Section 6.4, the quantified social benefits of Option 2 are equal to the Hamlet's estimated AAD of flooding ($762,467 per year) and begin in 2024.

The quantified social costs of Option 2 are described in Table 8-1 below. These costs include construction costs and annual operating costs related to the installation of a dike on the north side of Marten Creek, the buyout of 12 properties (3 permanent, 1 secondary, and 8 vacant/campgrounds), as well as the demolition of dwellings.

### Table 8-1 Estimated Social Costs of Flood Mitigation Option 2

| Mitigation Option | Construction Costs | Operating Costs | Buyout Costs | Demolition Costs |
|---|---|---|---|---|
| Option 2 – North Side Dike | $9,800,000 | $49,000 | $4,000,000 | $160,000 |

Given the above-described social costs and benefits of Option 2, as well as the assumed timing of social costs as described in Section 7, the NPVs of this flood mitigation option under 8%, 4%, and 3% discount rates are provided in Table 8-2 below.

## Table 8-2 Estimated Net Present Value for Flood Mitigation Option 2 ($ millions)

| Mitigation Option | 8% Discount Rate | | | 4% Discount Rate | | | 3% Discount Rate | | |
|---|---|---|---|---|---|---|---|---|---|
| | PV Benefits | PV Costs | NPV | PV Benefits | PV Costs | NPV | PV Benefits | PV Costs | NPV |
| Option 2 – North Side Dike | $8.6 | $13.1 | **-$4.5** | $15.5 | $14.2 | **$1.3** | $18.7 | $14.6 | **$4.1** |

The CBA results indicate that Option 2 yields a positive NPV of $1.3 million and $4.1 million under 4% and 3% discount rates, respectively.

## 8.3 Option 3: North and South Side Dikes

As per the assumptions highlighted in Section 6.4, the quantified social benefits of Option 3 are equal to the Hamlet's estimated AAD of flooding ($762,467 per year) and begin in 2024.

The quantified social costs of Option 3 are described in Table 8-3 below. These costs include construction costs and annual operating costs related to the installation of dikes on both the north and south sides of the river, the buyout of 6 properties (1 secondary, 5 vacant/campgrounds), as well as the demolition of the secondary dwelling.

## Table 8-3 Estimated Social Costs of Flood Mitigation Option 3

| Mitigation Option | Construction Costs | Operating Costs | Buyout Costs | Demolition Costs |
|---|---|---|---|---|
| Option 3 – North and South Side Dikes | $18,100,000 | $90,500 | $900,000 | $40,000 |

Given the above-described social costs and benefits of Option 3, as well as the assumed timing of social costs as described in Section 7, the NPVs of this flood mitigation option under 8%, 4%, and 3% discount rates are provided in Table 8-4 below.

## Table 8-4 Estimated Net Present Value for Flood Mitigation Option 3 ($ millions)

| Mitigation Option | 8% Discount Rate | | | 4% Discount Rate | | | 3% Discount Rate | | |
|---|---|---|---|---|---|---|---|---|---|
| | PV Benefits | PV Costs | NPV | PV Benefits | PV Costs | NPV | PV Benefits | PV Costs | NPV |
| Option 3 – North and South Side Dikes | $8.6 | $17.9 | **-$9.3** | $15.5 | $19.7 | **-$4.2** | $18.7 | $20.4 | **-$1.7** |

The CBA results indicate that Option 3 does not yield a positive NPV under any assumed discount rate, with NPVs ranging from -$9.3 million to -$1.7 million.

## 8.4 Option 4: Diversion to Oxbow with Dikes

As per the assumptions highlighted in Section 6.4, the quantified social benefits of Option 4 are equal to the Hamlet's estimated AAD of flooding ($762,467 per year) and begin in 2024.

The quantified social costs of Option 4 are described in Table 8-5 below. These costs include construction costs and annual operating costs related to the diverting the existing river into the Oxbow Channel, and the buyout of half of the campground site immediately south of the river (note that this site does not host dwellings and therefore does not require demolition).

### Table 8-5 Estimated Social Costs of Flood Mitigation Option 4

| Mitigation Option | Construction Costs | Operating Costs | Buyout Costs | Demolition Costs |
| --- | --- | --- | --- | --- |
| Option 4 – Diversion to Oxbow with Dikes | $17,700,000 | $88,500 | $500,000 | $0 |

Given the above-described social costs and benefits of Option 4, as well as the assumed timing of social costs as described in Section 7, the NPVs of this flood mitigation option under 8%, 4%, and 3% discount rates are provided in Table 8-6 below.

### Table 8-6 Estimated Net Present Value for Flood Mitigation Option 4 ($ millions)

| Mitigation Option | 8% Discount Rate | | | 4% Discount Rate | | | 3% Discount Rate | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | PV Benefits | PV Costs | NPV | PV Benefits | PV Costs | NPV | PV Benefits | PV Costs | NPV |
| Option 4 – Diversion to Oxbow with Dikes | $8.6 | $17.2 | **-$8.6** | $15.5 | $18.9 | **-$3.4** | $18.7 | $19.5 | **-$0.8** |

The CBA results indicate that Option 4 does not yield a positive NPV under any assumed discount rate, with NPVs ranging from -$8.6 million to -$0.8 million.

## 8.5 Option 5: Room for the River with Dikes

As per the assumptions highlighted in Section 6.4, the quantified social benefits of Option 5 are equal to the Hamlet's estimated AAD of flooding ($762,467 per year) and begin in 2024.

The quantified social costs of Option 5 are described in Table 8-7 below. These costs include construction costs and annual operating costs related to re-establishing the natural river meander and widening the floodplain, the buyout of 28 properties (5 permanent, 13 secondary, and 10 vacant or campgrounds), as well as the demolition of dwellings.

### Table 8-7 Estimated Social Costs of Flood Mitigation Option 5

| Mitigation Option | Construction Costs | Operating Costs | Buyout Costs | Demolition Costs |
| --- | --- | --- | --- | --- |
| Option 5 – Room for the River with Dikes | $5,700,000 | $28,500 | $5,800,000 | $520,000 |

Given the above-described social costs and benefits of Option 5, as well as the assumed timing of social costs as described in Section 7, the NPVs of this flood mitigation option under 8%, 4%, and 3% discount rates are provided in Table 8-8 below.

### Table 8-8 Estimated Net Present Value for Flood Mitigation Option 5 ($ millions)

| Mitigation Option | 8% Discount Rate | | | 4% Discount Rate | | | 3% Discount Rate | | |
|---|---|---|---|---|---|---|---|---|---|
| | PV Benefits | PV Costs | NPV | PV Benefits | PV Costs | NPV | PV Benefits | PV Costs | NPV |
| Option 5 – Room for the River with Dikes | $8.6 | $11.2 | **-$2.6** | $15.5 | $12.0 | **$3.5** | $18.7 | $12.2 | **$6.5** |

The CBA results indicate that Option 5 yields a positive NPV of $3.5 million and $6.5 million under 4% and 3% discount rates, respectively.

## 8.6 Option 6: Managed Retreat

As per the assumptions highlighted in Section 6.4, the quantified social benefits of Option 6 are equal to the Hamlet's estimated AAD of flooding ($762,467 per year) and begin in 2024.

The quantified social costs of Option 6 are described in Table 8-9 below. These costs include the buyout of all 82 properties (30 permanent, 26 secondary, and 26 vacant or campgrounds) as well as the demolition of dwellings.

### Table 8-9 Estimated Social Costs of Flood Mitigation Option 6

| Mitigation Option | Construction Costs | Operating Costs | Buyout Costs | Demolition Costs |
|---|---|---|---|---|
| Option 6 – Managed Retreat | $- | $- | $20,800,000 | $1,920,000 |

Given the above-described social costs and benefits of Option 6, as well as the assumed timing of social costs as described in Section 7, the NPVs of this flood mitigation option under 8%, 4%, and 3% discount rates are provided in Table 8-10 below.

### Table 8-10 Estimated Net Present Value for Flood Mitigation Option 6 ($ millions)

| Mitigation Option | 8% Discount Rate | | | 4% Discount Rate | | | 3% Discount Rate | | |
|---|---|---|---|---|---|---|---|---|---|
| | PV Benefits | PV Costs | NPV | PV Benefits | PV Costs | NPV | PV Benefits | PV Costs | NPV |
| Option 6 – Managed Retreat | $8.6 | $20.9 | **-$12.3** | $15.5 | $21.8 | **-$6.3** | $18.7 | $22.0 | **-$3.3** |

The CBA results indicate that Option 6 does not yield a positive NPV under any assumed discount rate, with NPVs ranging from -$12.3 million to -$3.3 million.

# 9. Sensitivity and Breakeven Analyses

## 9.1 Sensitivity Analysis

As discussed in Section 4, it is important to undertake sensitivity analyses in a CBA to determine how robust the study results are to changes in key assumptions or parameters. In particular, we are interested in understanding how changes in key assumptions might impact the resulting NPV of the various flood mitigation options, specifically assumption changes that might change a given NPV from positive to negative (or vice versa). The sensitivity of the CBA scenarios with respect to the assumed discount rate are already presented in the results above (see Section 8). The results suggest that two flood mitigation options result in a positive NPV, specifically Option 2 (North Side Flood Protection Dike) and Option 5 (Room for the River with Dikes) under a 4% or 3% discount rate. To demonstrate the variability of these results to changes in key parameters, the Study Team undertook sensitivity analyses with respect to the social costs of Option 2 and Option 5.

For Option 2, construction costs associated with building flood protection on the north side of the river would need to exceed the current estimate by about 45% for the NPV of this option to no longer be positive under a 3% discount rate. The buyout costs associated with this option would need to exceed the current estimate by over 105% to no longer yield a positive NPV under a 3% discount rate. For Option 5, construction costs associated with re-establishing the natural river meander and widening the floodplain would need to exceed the current estimate by about 60% for the NPV of this option to no longer be positive under a 3% discount rate. The buyout costs associated with this option would need to exceed the current estimate by over 75% for this option to no longer yield a positive NPV under a 3% discount rate. As noted earlier, estimates with respect to construction and operating costs for the various flood mitigation options were provided by AE and are Class D engineering estimates that should be considered within a margin of error of ±50%. Therefore, it should be noted that the sensitivity of Option 2 with respect to construction costs (i.e., 45% increase results in a negative NPV) is within this margin of error.

The flood mitigation option with the next highest NPV compared to Options 2 and 5 is Option 4 (Diversion to Oxbow with Barriers). Under a 3% discount rate, this option yields an NPV of approximately -$0.8 million. To demonstrate the variability of this result to changes in key parameters, the Study Team undertook a sensitivity analysis with respect to the social benefits of Option 4. For this option to yield a positive NPV, the social benefits (i.e., estimated AAD of flooding up to a 100-year event in the Hamlet) would need to increase by about 4.5% (total AAD of about $34,300), in which case the NPV of Option 4 under a 3% discount rate would be greater than zero. Given that flood mitigation Options 3 and 6 yield even lower NPVs than Option 4 under baseline assumptions, these options would require even larger social benefits to yield positive NPVs.

We note that several flood mitigation options have substantial environmental concerns (particularly Option 4, Diversion to Oxbow with Dikes) that were not valued quantitatively in this work. For Options 3 and 4, the inclusion of these values would simply reduce resulting NPVs that are already negative. For Options 2 and 5, should the environmental impacts of mitigation activities prove to be substantial, the NPVs of these options may not be positive under a 3% or 4% discount rate.

## 9.2 Breakeven Analysis

Another valuable piece of information that can be calculated from a CBA is the breakeven discount rate (i.e., the rate at which the NPV of a given CBA equals zero). As described in Table 9-1 below, all flood mitigation options analysed in this work have a breakeven discount rate of less than 6%. For mitigation Options 3, 4, and 6, the breakeven discount rates are relatively small (less than 3%). Both Option 2 and Option 5 have a breakeven rate in close alignment with suggested rates for CBAs in Canada (e.g., Boardman et al. 2010).

### Table 9-1 Breakeven Discount Rates for Flood Mitigation Options

| Mitigation Option | Breakeven Discount Rate |
|---|---|
| Option 2 – North Side Dikes | 4.6% |
| Option 3 – North and South Side Dikes | 2.5% |
| Option 4 – Diversion to Oxbow with Dikes | 2.7% |
| Option 5 – Room for the River with Dikes | 5.8% |
| Option 6 – Managed Retreat | 2.2% |

There is a plethora of assumptions made in this work that drive the results of the CBAs. Indeed, should key assumptions with respect to the estimates of AAD, costs of mitigation, the timing of costs and benefits, or the discount rate be changed, the resulting NPVs of any given mitigation scenario would differ. For mitigation Options 3, 4, or 6, incorrect assumptions or missing quantitative information (particularly regarding environmental impacts of mitigation activities) would need to overcome a relatively large value to generate a positive NPV, even under a low discount rate assumption (3%). For mitigation Options 2 or 5, changes in assumptions or additional quantitative information with respect to environmental impacts of mitigation or the avoided damages of flood events could potentially change the NPV results, potentially changing the positive NPV results under a 3% or 4% discount rate to negative.

# 10. Conclusions and Study Limitations

The results of the CBAs under 8%, 4%, and 3% discount rates (as per Section 5.3) are summarized below in Table 10-1. The results suggest that two flood mitigation options result in a positive NPV, specifically Option 2 (North Side Flood Protection Dike) and Option 5 (Room for the River with Dikes) under a 4% or 3% discount rate. Mitigation Options 3, 4, and 6 all yield negative NPVs under all discount rate assumptions, suggesting that these mitigation options would impose net costs onto provincial stakeholders and are likely not in the public interest. In sum, under the assumptions laid out in the preceding sections of this report:

- Option 2 (North Side Flood Protection Dike) and Option 5 (Room for the River with Dikes) yield positive NPVs under 3% and 4% discount rates and baseline assumptions.
- Options 3, 4, and 6 do not generate a net benefit to society under 3%, 4%, or 8% discount rates and baseline assumptions.

Option 5 is the preferred mitigation when evaluated through the cost-benefit framework assuming a 3% or 4% discount rate, as this Option yields the highest positive NPV.[11]

### Table 10-1 Estimated Net Present Value for Flood Mitigation Options 2-6 ($ millions)

| Mitigation Option | 8% Discount Rate | | | 4% Discount Rate | | | 3% Discount Rate | | |
|---|---|---|---|---|---|---|---|---|---|
| | PV Benefits | PV Costs | NPV | PV Benefits | PV Costs | NPV | PV Benefits | PV Costs | NPV |
| Option 2 – North Side Dikes | $8.6 | $13.1 | **-$4.5** | $15.5 | $14.2 | **$1.3** | $18.7 | $14.6 | **$4.1** |
| Option 3 – North and South Side Dikes | $8.6 | $17.9 | **-$9.3** | $15.5 | $19.7 | **-$4.2** | $18.7 | $20.4 | **-$1.7** |
| Option 4 – Diversion to Oxbow with Dikes | $8.6 | $17.2 | **-$8.6** | $15.5 | $18.9 | **-$3.4** | $18.7 | $19.5 | **-$0.8** |
| Option 5 – Room for the River with Dikes | $8.6 | $11.2 | **-$2.6** | $15.5 | $12.0 | **$3.5** | $18.7 | $12.2 | **$6.5** |
| Option 6 – Managed Retreat | $8.6 | $20.9 | **-$12.3** | $15.5 | $21.8 | **-$6.3** | $18.7 | $22.0 | **-$3.3** |

We acknowledge several limitations associated with this work. First, the complete quantification of all social benefit and costs could not be undertaken due to a lack of certain data and information. For example, the potential environmental impacts associated with various flood mitigation options could not be quantified as the extent of environmental damages is not known at this time. Furthermore, there is inherent uncertainty with respect to assumptions made in the estimation of avoided flood damages. Indeed, the mental health impacts of recent

[11] We note that the forecast period assumed for this work is 50 years (2022 – 2071) as flood mitigation infrastructure typically requires replacement or major capital investments after 50 – 75 years. Excluding the additional replacement/maintenance costs that would be required after 50 – 75 years, under a longer forecast period of 100 years (i.e., 2022 – 2121), Options 2 and 5 maintain positive NPVs (under both 3% and 4% discount rates) while Options 3, 4, and 6 also have positive NPVs under a 3% discount rate.

flood events in the Hamlet have been identified as being substantial; while the Study Team relied on the highest quality of published information available regarding the value of intangible mental health impacts of flooding, these values may differ in the context of the Hamlet.

Given the NPV estimates calculated under the methods and assumptions laid out in this study, we believe the results presented are relatively robust. As noted above, changes in any of the baseline assumptions or missing quantitative information may result in different NPVs for any given mitigation option.

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