6.0 COST COMPARISONS OF FLOOD MITIGATION OPTIONS

The cost estimates developed for this study are considered very approximate and are intended to be used to compare options on a magnitude basis. A cost range has therefore been reported for the options to reflect the high level of uncertainty associated with the estimates. Detailed cost estimates would be necessary should any of the options be selected to proceed forward to a subsequent stage of analysis.

Various types of costs were considered depending of the flood mitigation options and included direct costs, indirect costs and a contingency. These capital cost items and pertinent assumptions for each of the individual flood mitigation options are discussed in Sections 6.1.

In addition, operation and maintenance costs as well as the cost to mitigate the rising Quill Lakes water levels were also considered. These are discussed in Sections 6.2 and 6.3 respectively. The summary of costs is provided in Section 6.4.

6.1 PROJECT COSTS

6.1.1 Direct Costs

The direct costs that were considered in the cost estimates included those associated with the construction of the various permanent and temporary components of the development, as well as the supply and installation of equipment. Depending of the options and the source of the data and cost estimate, the direct costs generally consisted of the following items:

- **Embankment Dams** – This included the construction of any required embankment dams and all associated works, including drains.
- **Land Acquisition** – This included the cost related to purchasing any land that would be required to construct the mitigation option.
- **Hydraulic Structures** – This included any required hydraulic structures for the options, such as control structures required for the diversion options.
- **Channel Construction** – This included all costs related to clearing, grubbing, and stripping land, as well as the channel earthworks.

- **Wetland Restoration** – This included all costs related to the restoration of drained or partially drained wetlands.

Further details and key assumptions for each of the individual flood mitigation options are described in the subsections that follow.

6.1.1.1 Hold Water in the Quill Lakes

For the block the natural outlet option, the estimated cost was based on the Kutawagan Creek diversion project [4]. It was assumed that the type of dike that would be constructed at the natural outlet would be similar in design to the type of dike that was considered along the Quill Lakes for the Kutawagan creek diversion project. A dike height of approximately El. 525 m (1722.5 ft) was assumed for the option although modeling results showed that water levels could exceed this elevation under some scenarios. This elevation is higher than the elevation of the dike for the Kutawagan Creek project, however since the existing ground condition at the natural outlet is higher, the dike volume would be less by approximately 4 to 6 times.

For the option to hold water in Little Quill Lakes, the cost estimate was based on an average rate per kilometre to raise Grid Rd. 640 similar to what was used by Golder [2]. The required elevation of the dike was assumed to be El. 530 m, although modeling results showed that water levels could exceed this elevation under some scenarios. Based on the existing road elevation that was taken from LiDAR data, approximately 28 km (17 mi) of road would have to be raised. However, since the cost estimates developed by Golder were to raise the road by 1 m to 3 m (3 ft to 10 ft), compared to approximately 4 m to 10 m (13 ft to 33 ft) for the current study, it was assumed that the rate per kilometre would be 2 to 4 times larger than estimated by Golder.

It should be noted that only flood mitigation costs (discussed in Section 6.3) are considered for the Do Nothing option (base case), and as such there are no project costs for this option.

6.1.1.2 Inflow Diversion Options

The cost assumptions and estimates for the inflow diversion options were generally based on the Golder study, and increased as deemed necessary based on experience and engineering judgment. In general, it was assumed that the actual project costs of the diversion options would be in the range of 2 to 4 times the original estimates developed by Golder.

For the Jansen Lake and Jansen Lake with Romance Creek diversion options, a cost estimate was not available from the Golder report. However, a cost estimate was included in the Golder report for the Lanigan Creek diversion option which incorporated the Jansen Lake and Jansen Lake with Romance Creek diversion options. As a result, these costs were estimated based the ratio of diversion channel lengths to the other Lanigan Creek diversion option.

6.1.1.3 Upland Storage Options

The direct costs for the upland storage options were estimated using a relationship of direct cost per unit of available storage. The relationship was initially developed and used in the 2014 Assiniboine River and Lake Manitoba Basins Flood Mitigation study completed by KGS Group [10]. It was developed based on the estimated direct costs of 28 dam sites, which had reservoir storage volumes of 41,000 dam^3 (33,200 ac-ft) or less, and were previously studied for increasing water supply in the Assiniboine River Basin. The relationship is considered to provide an approximation of the total cost of numerous storage sites when added together, but not necessarily for a single storage site. It is possible that the actual costs of storage would be less in the Quill Lakes basin since most of the proposed storage sites consist of converting already low lying flood prone lands or other existing water bodies into storage, whereas the water supply reservoirs in the Assiniboine River Basin were typically located within a deep valley and required high embankments and larger spillways. On this basis, it was assumed that the estimated cost for the Quill Lakes basin could range from 0.75 to the total cost calculated from the relationship.

6.1.1.4 Inflow Reduction Options

For the wetland restoration option described in Section 4.5.1, the average cost to restore one hectare of wetlands was assumed to be $1500 and includes administration, licensing, surveys and construction. This value was adopted from the Assiniboine River and Lake Manitoba Basins Flood Mitigation Study [10].

For the closure of drainage works described in Section 4.5.2, , the closure cost was assumed to equal the restoration cost of $1500/ha up to three times more due to the very large number of closures that would affect small wetland areas. The small areas could significantly increase the cost per hectare. WSA has indicated that the landowner would be responsible for the construction cost of closure works.

6.1.1.5 Remove Water from Quill Lakes

The cost of the Landowner Proposal (Plan B) option was assumed to be similar to the cost of the Kutawagan Creek project investigated by KGS Group in 2015 [4], but without the Quill Lakes Dike. However, since the Landowner Proposal would also have to accommodate winter flows, it was assumed that the excavation cost could be 50% more than the cost of the Kutawagan Creek Project.

For the deep well injection options, the costs were taken from the SNC report [5] but excluded the pump power consumption and maintenance costs. As well, the costs to treat water and construction of a pipeline if needed were not included in the SNC estimate and could significantly increase the overall cost of the options.

For the option to pump and discharge water to another watershed, a preliminary cost estimate was initially prepared by Golder to construct a pipeline and pump water towards Saline Creek. This cost estimate was adopted for the current study. However considering that this cost was only developed as draft by Golder, and based on the experience and engineering judgement, it was assumed that actual project costs would be in the range of 2 to 4 times the original estimates developed by Golder.

The cost of the options to withdraw water for either the BHP Jansen Lake mine or Karnalyte Potash Mine were estimated assuming that the project would be cost neutral for owner (BHP or Karnalyte). The project components for these options are similar to those for pump and discharge water to another watershed option, and thus it was used as the basis for the cost estimate. However, the costs were prorated based on the approximate length of pipeline that would be required to discharge water to the mines relative to the length of pipeline required to move water from Big Quill Lake to Saline Creek. As noted in Section 4.4.4, treatment of water would likely be required for the BHP Jansen Lake mine option, however this was not considered in the cost at this time.

6.1.1.6 Legislative Policy Options

It was assumed that legislative policy options would not include any project costs but rather would consist of operating costs only as discussed in Section 6.2. These costs would be associated with hiring additional staff or allocating other resources to implement the legislative policies.

6.1.2 Indirect Costs

The indirect project costs that were considered in this study were adopted from the cost estimates produced by Golder in their Quill Lakes Flood Mitigation Study [1] and included the following items:

- **Detailed Engineering** – This includes the costs related to the detailed design and construction specifications, equivalent to 18% of the direct project costs.
- **Permitting/Environmental/Consultation** – This includes an allowance for the permitting process, the environmental approvals and any necessary consultations. It is equivalent to 6% of the direct project costs.

6.1.3 Project Contingency

In order to be consistent with all cost estimates produced by Golder [1], a project contingency of 30% of the total direct and indirect project costs has been applied to each of the flood mitigation options that were evaluated in this study.

6.2 OPERATION COSTS

Operation costs, such as the cost to treat water, to operate pump stations, or to operate control structures were considered for this study. Costs were compared qualitatively based on the following scale:

- **Low operating costs** – for project that have minimal operating requirements such as holding water in the lakes, inflow diversion and reduction options, and upland storage options.

- **Moderate operating costs** – for projects that have regular operation requirements that are seasonal dependant or for parts of the year only, such as the Landowner Proposal.

- **High operating costs** – for projects that have daily operational requirements on an annual basis, to treat and or pump water, such as the Deep Well injection option, the option to Pump and discharge water to another watershed, and the option to withdraw water for BHP Jansen Lake Mine.

6.3 FLOOD MITIGATION COSTS

As discussed in Section 3.0 of the report, increasing water levels on the Quill Lakes could result in the flooding of several roads and cause damages to other property in the vicinity of the lakes. To mitigate against the high water levels, significant investments would be necessary, such as raising roads and buying-out land. These mitigation costs, or alternatively flood damages, would increase as the lake rises and would be independent of whether or not any of the flood mitigation options described in this report would have been implemented. Rather, the flood mitigation options reduce the likelihood of incurring damages around the lake by reducing the probability of exceeding higher water levels (albeit by very small amounts for several of the options as discussed in Section 7.0).

To estimate the cost of mitigating rising water levels on the Quill Lakes a stage-damage curve was developed. The following types of damages were incorporated into the analysis:

- **Infrastructure** – Includes the costs of raising roads, railways and dikes. Quantities and costs were taken from Golder [1] where available and assumed a 1.1 m (3.6 ft) of freeboard for wind and wave effects.

- **Flooded Farmyards** - Includes the costs to purchase flooded farmyards. Quantities and costs were taken from Golder [1].

The quantities of infrastructure and farmyards that would be flooded at various lake levels are summarized in Table 9 and the estimated cost of these damages is summarized in Table 10. The resulting stage-damage relationship is shown in the Figure 20. To be consistent with Golder [1], all damages included a 30% contingency allowance.

TABLE 9
SUMMARY OF QUANTITIES FOR STAGE DAMAGE RELATIONSHIP

Water Level (m)	Infrastructure (Roads, Railway and Dikes) (km)	Flooded Farmyards (each)
518.0	0.0	0
519.0	2.8	0
520.0	10.3	0
520.5	16.0	1
520.6	16.2	1
520.7	16.2	2
520.9	19.0	4
521.0	19.0	5
521.2	21.6	7
522.2	31.1	18
522.3	31.1	19

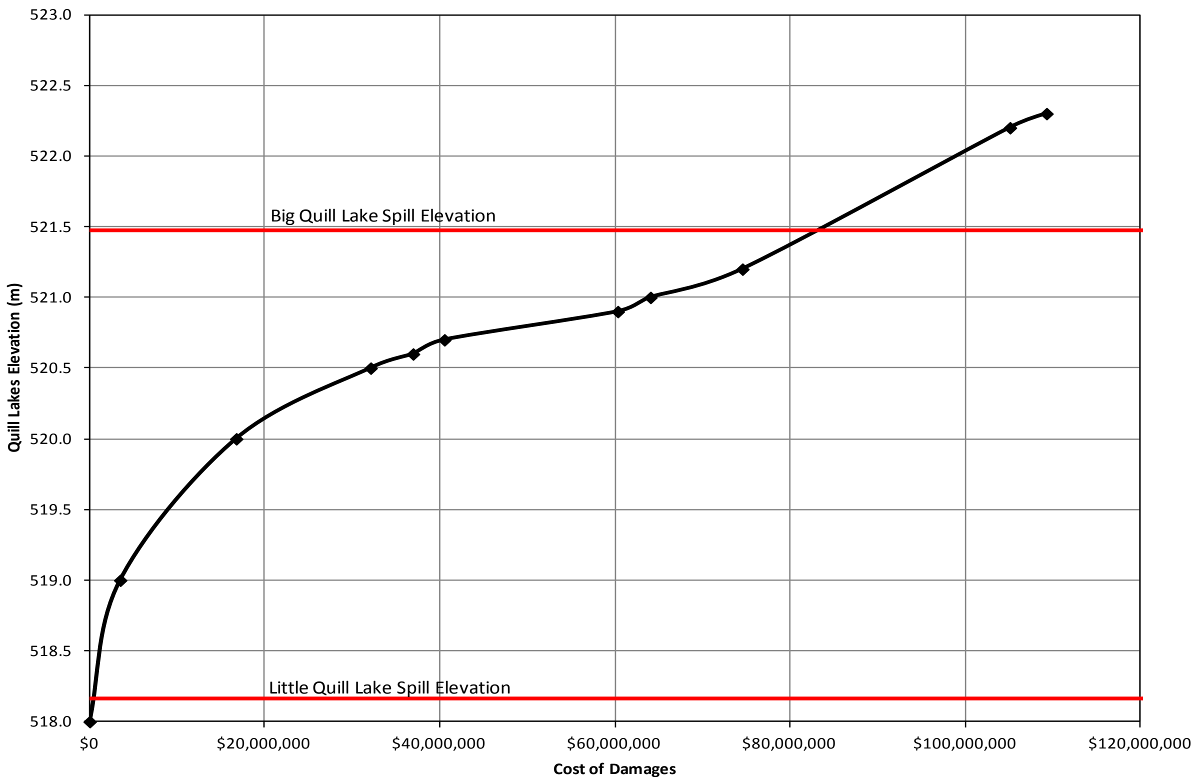
Note: 1 m = 3.28 ft
1 km = 0.62 mi

TABLE 10
SUMMARY OF COSTS FOR STAGE DAMAGE RELATIONSHIP

Water Level (m)	Infrastructure (Roads, Railway and Dikes) (million) (1)	Farmyards (million) (1)	Total (million)(1)
518.0	$0	$0	$0.0
519.0	$3.5	$0	$3.5
520.0	$16.7	$0	$16.7
520.5	$31.4	$0.7	$32.1
520.6	$36.3	$0.7	$37.0
520.7	$39.2	$1.3	$40.5
520.9	$57.7	$2.6	$60.3
521.0	$60.8	$3.3	$64.1
521.2	$70.0	$4.6	$74.6
522.2	$93.4	$11.7	$105.1
522.3	$96.9	$12.4	$109.3

Note: (1) Damage costs are estimated values and therefore may differ from the total costs incurred on flood mitigation measures or actual damages incurred to date given that the lake is already at El. 520.7 m.
1 m = 3.28 ft

FIGURE 20
STAGE-DAMAGE RELATIONSHIP



Note: 1 m = 3.28 ft

The stage-damage relationship shown above indicates that the costs to mitigate rising water levels on the Quill Lakes increases gradually up to approximately El. 520.0 m (1706.0 ft) with damages estimated at about $17 million. Above El. 520.0 m (1706.0 ft) the costs start to increase more rapidly and reach $110 million at approximately El. 522.3 m (1713.6 ft). Damages occurring above El. 522.3 m (1713.6 ft) have not yet been quantified since data was not available from the Golder Report. Further data collection, including identification of at risk properties, would therefore be required to extend the stage-damage curve beyond El. 522.3 m (1713.6 ft).

Estimation of damages for each individual flood mitigation options has not been quantified for this report as it requires combining damages with probabilities and must consider the entire range of water levels presented in the results discussed in Section 5.0. This would require extending the stage-damage curve beyond El. 522.3 m (1713.6 ft).

6.4 SUMMARY OF PROJECT COSTS

Table 11 summarizes the estimated costs of the flood mitigation options. The estimated costs are based on the assumptions and cost items discussed in Sections 6.1.1 to 6.1.3. As previously noted, a range of costs has been reported for the options to reflect the very high level of uncertainty associated with the estimates.

In addition, Table 11 shows the average percent reduction inflows to the lake and average flood mitigation costs that would be saved should any of the flood mitigation options be implemented. The average flood mitigation cost savings was estimated to be approximately $40 M per metre of change in water level. This value was calculated using the average slope of the stage-damage relationship shown in Figure 20 between lake levels of El. 520 m to 523 m (1706 ft to 1715.9 ft). As mentioned previously, these mitigation costs only include damages to infrastructure (roads, railways, dikes) and farmyards.

The flood mitigation cost savings were calculated using the average water level over the next five years, quantifying the short term savings. The same method was not applied to estimate the average long term (over the next 50 years) flood mitigation cost savings since water levels are often outside of the range of El. 520 m to 523 m (1706 ft to 1715.9 ft). The flood mitigation cost savings per metre would be significantly less or more than the estimated rate of $40 M per metre when water levels are above or below this range. To accurately determine the long term flood mitigation cost savings, a detailed economic analysis would be required.

TABLE 11
SUMMARY OF ESTIMATED PROJECT COSTS

Category	Mitigation Option	Range In Project Costs[1] (million)	Average[2] Flood Mitigation Cost Savings (million)	Average[3] Percent Reduction of Inflows to Lake
Hold Water in Quill Lakes	Block Natural Outlet	$10 - $20	-$0.2	0%
	Hold Water in Little Quill Lakes	$130 - $260	$5.1	0%
Inflow Diversion	Ponass Lakes	$30 - $60	$0.7	1.8%
	Kutawagan Creek	$60 - $120	$40 - $80[5]	12.6%
	Kutawagan Creek with Hwy 16	$85 - $170	$40 - $80[5]	14.6%
	Jansen Lake	$45 - $90	$1.0	3.0%
	Jansen Lake and Romance Creek	$200 - $400	$1.7	4.8%
	Jansen Lake, Romance Creek, and Ironspring Creek	$290 - $580	$4.5	9.7%
	Jansen Lake, Romance Creek, Ironspring Creek, and Wimmer Brook	$330 - $660	$5.2	11.9%
Upland Storage	Ponass Lakes Storage	$10 - $30	$1.4	4.0%
	Other Storage	$260 - $350	$5.3	12.6%
Remove Water from Quill Lakes	Landowner Proposal (Plan B)	$65 - $100	$6.6	21.9%
	Deep Well Injection - Mannville Aquifer - 0.47 m^3/s	$100 - $130	$1.7	6.4%
	Deep Well Injection - Mannville Aquifer - 4.4 m^3/s	$920 - $1200	$17.0	51.8%
	Deep Well Injection - Basal Deadwood Aquifer - 0.47 m^3/s	$25 - $35	$1.7	6.4%
	Deep Well Injection - Basal Deadwood Aquifer - 4.4 m^3/s	$240 - $310	$17.0	51.8%
	Pump and Discharge Water to another Watershed - 0.47 m^3/s	$210 - $420	$1.7	6.4%
	Pump and Discharge Water to another Watershed – 4.4 m^3/s	$210 - $420	$17.0	51.8%
	Withdraw Water for BHP Jansen Lake Mine	$100 - $210	$0.8	3.0%
	Withdraw Water for Karnalyte Potash Mine	$40 - $80	$1.0	3.8%
Inflow Reduction	Restoration of Partially Drained and Drained Wetlands - 5000 dam^3	$5 - $15	$0.7	2.3%
	Restoration of Partially Drained and Drained Wetlands - 15000 dam^3	$15 - $40	$2.2	6.8%
	Closure of Drainage Works	$100 - $300[4]	$1.4	38.6%

Notes:
1. Project costs do not include operational costs or costs associated with treating water.
2. Averages calculated over the next 5 years.
3. Averages calculated over the next 50 years.
4. Cost includes administration, licensing, surveys and construction. A portion of the cost would be covered by the landowner. Actual cost would be dependent on the total number of closures across the basin, as well as the relative size of the drainage works and area affected by the closure.
5. Estimated based on the savings of not having to raise Highway 6 and 16 due to the construction of a dike between the Highway and the Quill Lakes.

As evident on Table 11, the range in project costs significantly exceed the average flood mitigation cost savings, by a factor of at least 10 for most options, with the exception of the two Kutawagan Creek inflow diversion options, which have an estimated project cost of approximately twice the average flood mitigation cost savings. Although mitigation costs only include damages to infrastructure (roads, railways, dikes) and farmyards, as previously discussed, it is anticipated that a detailed economic analysis of the options would most likely conclude that none of the flood mitigation options should proceed based on economic factors alone. Rather, the selection of the preferred alternative should be based on other factors, such as environmental considerations and social acceptance. A comparison of these factors for all of the options is provided in Section 7.0.