REPORT

MERIDIAN DAM PRELIMINARY FEASIBILITY STUDY

Submitted to:

Alberta Environment
and
Saskatchewan Water Corporation

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Attention: Mr. Garnet Gobert

RE: **REPORT ON MERIDIAN DAM PRELIMINARY FEASIBILITY STUDY**

Dear Mr. Gobert:

We are pleased to present two copies of the above named report, which is a revision of our draft report dated December 2001. This report incorporates the comments discussed at the review meeting held in January 2002.

The Golder study team conducted this study with the valuable input from a number of other specialists. We would like to acknowledge the contributions of the following companies and consultants:

Mr. Al McPhail	Public Consultation
Mr. Doug Cameron	Irrigation Suitability
J.D. Mollard and Associates Ltd.	Reservoir Geology and Physiography
Mack, Slack, and Associates Inc.	Diversion Tunnels and Outlet Works
Canadian Projects Ltd.	Hydropower Development
Dr. N. Morgenstern	Geotechnical Review
Mr. C.D. Smith	Hydraulic Structures Review
IBI Group	Flood Control Benefits
Lombard North	Recreation Benefits
Dr. Marvin Anderson	Economic Analysis

Thank you for selecting Golder to complete this interesting and challenging project. We trust this document meets your expectations. If you have any questions or comments please do not hesitate to contact me.

Yours very truly,

GOLDER ASSOCIATES LTD.

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Principal, Director of Water Resources

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Attention: Mr. Terry Sly

RE: **REPORT ON MERIDIAN DAM PRELIMINARY FEASIBILITY STUDY**

Dear Mr. Sly:

We are pleased to present two copies of the above named report, which is a revision of our draft report dated December 2001. This report incorporates the comments discussed at the review meeting held in January 2002.

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Executive Summary

Golder Associates Ltd. was commissioned by the Governments of Alberta and Saskatchewan to assess the concept of a dam on the South Saskatchewan River just upstream from the Alberta-Saskatchewan border. The concept of a dam at the Meridian site has been considered for many years, but no previous studies have assessed the economic, environmental, and social benefits and costs. The purpose of this study is to provide a preliminary estimate of benefits and costs, as well as a broad assessment of the potential environmental and social issues associated with construction and operation of a dam and reservoir. This reservoir would supply water for irrigation, generate hydroelectric power and perhaps offer opportunities for water-based recreation. Findings of this study are expected to assist the Governments of Alberta and Saskatchewan in determining whether further investigation of the Meridian Dam is warranted.

Project Scope

The scope of work for this study included the following components: an assessment of water supply in the South Saskatchewan River Basin; conceptual design of dam and reservoir to current CDA Dam Safety Guidelines; conceptual design of irrigation delivery systems and hydroelectric infrastructure; an assessment of environmental issues associated with the potential development; an analysis of benefits and costs; and an evaluation of project implementation issues.

The scope of work involved a pre-feasibility level of assessment and was limited to available information. The work did not include data collection, detailed analysis, or comprehensive evaluations and there was no optimization or refinement of design. The scope of work was limited to the scenario of irrigation water supply for Southeast Alberta and Southwest Saskatchewan with water supply provided by the Meridian Dam. The scope excluded other water supply options and potential use of the Meridian Dam for upstream irrigation intensification.

The water management strategy used in the analysis gives priority to irrigation and, as a result, hydropower and recreation are treated as opportunistic benefits. Competing priorities for water resource utilization and allocation were not optimized in this study. The environmental assessment components of this report are based on available biophysical information of the area,

conceptual engineering design and reservoir operations based on maximizing irrigation, and experience gained from similar large projects and irrigation developments. Environmental mitigation requirements can only be estimated accurately at more advanced stages of development and are provided here as order-of-magnitude estimates. Other benefits and costs are also estimated on the basis of available information.

Scenarios Considered

Three reservoir sizes were considered in this study. Table 1 provides general characteristics of each scenario. The reservoir would be confined to the narrow South Saskatchewan River valley by steep valley walls that average about 100 m in height. The reservoir would extend to the southern part of CFB Suffield for Scenario 1, and to an area near Medicine Hat for Scenario 3. Reservoir widths range from 600 to 900 m at full supply level for the three scenarios.

Table 1 Characteristics of the Three Reservoir Scenarios

Scenario	Reservoir Storage Volume		Full Supply Level		Approximate Reservoir Length		Approximate Reservoir Area	
	(dam^3 x 10^6)	(ac-ft x 10^6)	(m)	(ft)	(km)	(mile)	(ha)	(ac)
1	1.2	1	621.8	2040	112	70	6,900	17,000
2	2.5	2	635.5	2085	153	95	10,900	27,000
3	3.7	3	646.2	2120	168	104	15,000	37,000

The Water Resources Management Model (WRMM) was used to evaluate the effects of a Meridian Dam on the South Saskatchewan River system and to determine the amount of irrigation diversion possible. Maximum irrigation areas in Alberta are summarized in Table 2 and were based on apportionment obligations to Saskatchewan, irrigation deficit criteria, and minimum instream flow objectives. Reservoir inflows, outflows, and water levels from the water supply modelling were used to assess hydropower potential.

Table 2 Irrigation Areas

Scenario	Reservoir Storage Volume		Maximum Irrigation Area	
	(dam^3 x 10^6)	(ac-ft x 10^6)	(ha)	(ac)
1	1.2	1	162,000	400,000
2	2.5	2	202,000	500,000
3	3.7	3	243,000	600,000

Conceptual Design

The general arrangement of the potential Meridian Dam is essentially the same as that considered in the 1970 Prairie Farm Rehabilitation Administration (PFRA) report commissioned by the Saskatchewan-Nelson Basin Board. The site is in Alberta, roughly 5 km upstream of the Saskatchewan border. The dam would be an earth-filled embankment with dam heights ranging from 50 to 75 m depending on the scenario. Secondary Highway 41 would be re-routed over the dam. Four diversion tunnels are planned at the south abutment to divert river flows and permit construction of the dam. Two of the tunnels would operate as the permanent outlet facility and the other two would be designed to accommodate hydropower development. The spillway, on the north bank of the valley, has been sized to pass the 1:500 year peak inflow with the reservoir at full supply level, and the Probable Maximum Flood with surcharging.

A preliminary evaluation of hydropower feasibility at the potential Meridian Dam was undertaken using the reservoir releases estimated from the water management modelling. An installed capacity of 80 MW appears appropriate for all three scenarios. This translates to annual hydropower production of 284, 323, and 359 GWh for Scenarios 1, 2, and 3, respectively.

The suitability of land for irrigation was assessed as part of this preliminary feasibility study. Ten potential irrigation blocks were identified in Southeast Alberta and Southwest Saskatchewan. Although the irrigation volumes determined through water supply modelling are considered part of Alberta's allotment, in this analysis irrigation to new areas was allocated on the basis of proximity and minimum cost of water supply, irrespective of the provincial boundary. For the purposes of this study, the resulting distribution of potential irrigation development in the two provinces is roughly equal for each scenario.

The conceptual delivery system consists of two main pump stations at the reservoir, one on the east bank and one on the west bank. The pumping system consists of large diameter steel pipelines from the pump stations to a main distribution point in each block. From there, the irrigation water would be distributed via a series of gravity canals and booster pump stations.

Infrastructure & Other Costs

There are significant costs associated with other aspects of the potential Meridian development. These include land acquisition, relocation of roads and utilities, and reclamation and loss of revenue associated with oil and gas infrastructure (wells, pipelines, and associated facilities). The development would also reduce the hydropower that could be generated in Saskatchewan.

There are approximately 250 oil and gas wells within the area flooded in Scenario 3 and an additional 1,000 wells alongside the reservoir in areas that might become unstable as a result of reservoir development. The cost of abandoning oil and gas resources is highly dependent on the number of affected wells and on the volatile value of oil and gas resources. As a result, it is difficult to quantify costs of impacts on oil and gas resources with confidence.

Diversions for irrigation would reduce the flow passed to Saskatchewan. The annual flow reduction would be roughly 30 m^3/s (16%) and would represent a reduction of 250 GWh of hydroelectric production in Saskatchewan. Effects on hydropower production in Manitoba were not evaluated as part of this study.

Environmental Considerations

There are many environmental issues associated with construction and operation of the dam. These include the effects of the project on river morphology, fisheries, water quality, native grasslands, wildlife, groundwater, erosion and sedimentation, and heritage resources. The study report provides a preliminary assessment and overview of each, as well as requirements for more study and possible mitigation measures.

Project Implementation

Development of the Meridian Dam would be subject to legislation and regulations at both the federal and provincial levels. Relevant statutes include, among others: the federal Fisheries Act and Navigable Waters Protection Act; Alberta's Environmental Protection and Enhancement Act, Water Act, and Hydro and Electric Act; and Saskatchewan's Environmental Assessment Act, Water Corporation Act, and Irrigation Act. A significant project review and approval process would be expected.

Summary of Estimated Project Benefits & Costs

Tables 3 through 5 provide summaries of estimated overall project capital costs, annual operation and maintenance costs, and annual benefits.

Table 3. Summary of Meridian Project Capital Costs ($ million in 2001 dollars)

Component	Scenario 1	Scenario 2	Scenario 3
Dam Total	812	850	926
Hydropower	101	101	101
Irrigation	2,130	2,780	3,410
Other Infrastructure[1]	497	766	1,027
EIA	6.5	6.5	6.5
Mitigation	46	46	46
Total Cost of Project	*3,592*	*4,550*	*5,517*

[1] Includes land acquisition, roads and utilities relocation, and costs associated with oil and gas developments.

Table 4. Summary of Meridian Project Annual Costs ($ million in 2001 dollars)

Component	Scenario 1	Scenario 2	Scenario 3
Dam Total	3.4	3.5	3.8
Hydropower	1.8	1.8	1.8
Irrigation	23.4	26.6	31.3
Total Cost of Project	*28.6*	*31.9*	*36.9*

Table 5. Summary of Meridian Project Annual Benefits ($ million in 2001 dollars)

Component	Scenario 1	Scenario 2	Scenario 3
Irrigation	40	50	60
Hydropower[1]	14.2	16.1	17.9
Recreation	2.0	2.0	2.0
Flood Control	0.02	0.02	0.02
Environmental Benefit[2]	5.7	6.5	7.2
Total Benefits of Project	*61.9*	*74.6*	*87.1*

[1] Hydropower economic benefits are estimated to be $50/MWh.
[2] Environmental benefits assuming "green" hydropower valued at $20/MWh.

Economic Analysis

A discounted cash flow analysis was conducted for each of the three potential development scenarios. This analysis compares quantifiable projected benefits with quantifiable projected costs into the foreseeable future.

In this analysis the benefit-cost (B/C) ratio is less than 1.0 and the net present value (NPV) is negative. The internal rate-of-return cannot be calculated because there are no positive numbers

in the annual incremental net B/C stream. Similarly, no re-payment period can be calculated. This implies that it is unlikely any of these development options would be economical. Table 6 summarizes this analysis.

Table 6. Summary of Base Case Benefit-Costs Ratios and Net Present Values

Scenario	Benefit-Cost Ratio	Net Present Value
1	.35	-$2.1 billion
2	.34	-$2.4 billion
3	.33	-$2.7 billion

A sensitivity analysis was conducted by developing a "worst case" and "best case" scenario where: Best Case: costs = -20% and benefits = +20%, and Worst Case: costs = +20% and benefits = -20%. Results from the sensitivity simulations for Scenario 3 suggest that under a worst-case scenario, real costs could exceed real benefits by a factor of five. Even under the best-case scenario, real costs would probably exceed real benefits by a factor of two.

Summary

This study indicates that the potential Meridian Dam development for irrigation water supply to Southeast Alberta and Southwest Saskatchewan involves high costs that exceed projected benefits. The high costs are driven by a costly pumped irrigation water supply system that involves mainly pipelines for primary water conveyance. Pumping is required because reservoir water levels are significantly lower than the potential irrigated areas, and pipelines are required since more conveyance routes have adverse gradients. This type of system is unlike the major irrigation delivery systems in Alberta which rely on gravity irrigation canals for conveyance. The high costs for the Meridian development are also affected by the potentially high cost of oil and gas resource abandonment that would be associated with development of the reservoir.

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1 INTRODUCTION

1.1 Background

Many residents of Southeast Alberta and Southwest Saskatchewan believe that a chronic shortage of water in the region is a barrier to economic growth. Some have asked the Governments of Alberta and Saskatchewan to consider a dam and water supply project on the South Saskatchewan River at the border as one possible solution to the chronic water shortages. In the spring of 2001 Alberta Environment and Sask Water agreed to commission a preliminary investigation of the feasibility of a dam immediately upstream from the Alberta-Saskatchewan border, a location known as the Meridian Site, as shown in Figure 1.1-1.

Proposals for a Meridian Dam have been around for many years. A number of investigations have been undertaken, including a study commissioned by the Saskatchewan – Nelson Basin Board and documented in a 1970 engineering report by Prairie Farm Rehabilitation Administration. While none of the various earlier studies have taken a comprehensive look at all the economic, environmental and social benefits and costs, the SNBB study has provided valuable information about the dam site and reservoir characteristics and served as a useful starting point in this investigation.

Golder Associates Ltd. was commissioned to assess the concept of a dam that could store water to supply expanded irrigation development, generate electricity and perhaps provide some opportunities for recreation. The results of this study, presented herein, include an estimate of benefits and costs as well as a broad assessment of the potential environmental and social issues associated with the construction and operation of a dam and reservoir. Findings of this study are expected to assist the Alberta and Saskatchewan Governments to determine if further investigation of the Meridian Dam is warranted.

Figure 1.1-1
General Location Plan

1.2 Scope of Work

The scope of work of the Meridian Dam Preliminary Feasibility Study includes a broad range of components from conceptual design, environmental assessment, analysis of benefits and costs, and issues related to implementation. The scope of work includes the following items for three reservoir sizes, as specified in the project terms of reference:

- Hydrology and water supply
- Conceptual design of dam and reservoir based on current CDA Dam Safety Guidelines; includes design, operation, and maintenance
- Conceptual design of outlet systems: diversion tunnels and spillway
- Conceptual design of delivery systems: delivery in Alberta, delivery in Saskatchewan, and hydropower development
- Environmental issues
- Analysis of benefits and costs
- Other issues including legislative requirements, environmental impact assessment, and aboriginal issues, etc.

1.3 Scope Limitations

The scope of work for this study was necessarily limited due to its nature as a pre-feasibility assessment and due to limited available information. The goal was to provide the Governments of Alberta and Saskatchewan with a better understanding of technical feasibility, environmental impacts, economic benefits and costs, regulatory considerations, and other issues which might affect a decision to consider project feasibility in more detail. The work did not include data collection, detailed analysis or comprehensive evaluations since these inputs could be covered by expert judgement for this level of assessment.

The scope of the engineering components covers all costs of infrastructure including capital works and operations. However, in accordance with the direction given by the Governments of Alberta and Saskatchewan, the scope of work does not comprehensively cover all risks and design variations. Engineering issues and site conditions are addressed based on available site information and some deviation can be expected in the future if more detailed design

investigations are conducted. Equally, the design specifications considered in this study may not be based on an optimum design.

The water management strategy gives priority to irrigation since this was the main driver for the study. As a result, recreation and hydropower are treated as opportunistic benefits. This strategy may not result in optimum economic benefits, as the scope of work does not include the optimization of competing priorities for water resource utilization and allocation. The scope of work was limited to the scenario of irrigation water supply for Southeast Alberta and Southwest Saskatchewan with water supply provided by the Meridian Dam. The scope excluded other water supply options and potential use of the Meridian Dam for upstream irrigation intensification.

There are numerous variations that should be considered in a comprehensive feasibility study and which may result in lower costs and higher benefits. For example, a large reservoir and smaller irrigation allocation would increase power production benefits, allow for hydropower peaking at higher hydraulic heads, and reduce irrigation delivery costs. A higher priority on hydropower generation would also be compatible with maintaining larger instream flows and with regulating Lake Diefenbaker levels. A maximum hydropower scenario is discussed briefly in Section 3.3. Similarly, a reduced size of irrigation area might allow for greater utilization of gravity canals to service those areas, and hence significant cost savings for the delivery system. Changing instream flow criteria and designating Meridian Dam reservoir storage specifically for apportionment obligations might allow for irrigation intensification at existing irrigation blocks in the basin, thereby improving overall project economics at a reduced cost. These and other variations in water management were not addressed in the current study.

The environmental assessment components of this report are based on available biophysical information of the area, the conceptual engineering design and likely reservoir operations, as well as on previous experience from similar large irrigation projects. Environmental mitigation requirements can only be estimated accurately at more advanced stages of development and are provided here as order-of-magnitude estimates only.

1.4 Issues Identification

The governments of Alberta and Saskatchewan undertook a public consultation process to help identify stakeholder issues related to the potential Meridian Dam. Information packages regarding the project were made available to the public to provide a basis for public comment. The package included a facts sheet, pertinent background information, a comment form, and the times and locations of scheduled public meetings. Five public workshops were held at the end of July and the beginning of August 2001: three in Alberta (Medicine Hat, Lethbridge and Calgary), and two in Saskatchewan (Leader and Saskatoon). Summaries of the public meetings were posted on the Alberta Environment and Sask Water websites, and are provided as Appendix I of this report. Written comments were also solicited from stakeholders and other interested parties. The public meeting notes and all written comments were reviewed by Golder Associates for consideration in this study.

Three main questions were put forward to the public for input as follows:

- What are the engineering and agricultural factors of this project that should be included in this feasibility study?
- What environmental issues and operational considerations should be raised for assessment?
- What factors should be included in the cost benefit analysis?

Correspondence and comments in support of the potential Meridian Dam project highlighted economic benefits associated with crop irrigation, as well as benefits from hydropower and recreation. Submissions from the public and other organizations also highlighted a number of concerns including the following:

- Development: cost of the development, who would pay and who would benefit, need for a dam.
- Water availability: accounting for increased evaporation, reliability of water management modeling, and effects of climate change, etc.
- Flooding of unique river valley and native grasslands; important wildlife habitat.
- Fisheries concerns with alteration of habitat and fish passage.

- Impacts on oil and gas wells, pipelines, and abandonment of resources.
- Flooding of palaeontological resources.
- Soil salinity issues, and potential flooding of other low-lying areas.
- Impacts on downstream water quality.

The identified issues were addressed within the scope of the current study. Complete discussion of highlighted concerns could not be provided in all cases due to limitations in available information and the level of analysis involved. Future consideration of outstanding issues is recommended, should the project proceed to further levels of feasibility assessment.

1.5 Acknowledgements

Golder Associates conducted this study with valuable input from other specialists. The Golder study team would like to acknowledge the contribution of the following companies and consultants:

• Mr. Al McPhail	Public Consultation
• Mr. Doug Cameron	Irrigation Suitability
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2 IRRIGATION POTENTIAL

The feasibility of irrigation development enabled by the Meridian Dam depends on a number of factors. Two key aspects governing the maximum potential irrigation development involve the suitability of nearby land for irrigation, and the quantity of available water. Either one of these factors could present a limiting factor in terms of the size and viability of the potential project. The following sections describe land suitability for irrigation and water management issues in further detail.

2.1 Land Suitability for Irrigation

2.1.1 Previous Studies

A Level V broad-based irrigation suitability study of the Alberta side of the South Saskatchewan River Basin was conducted by the Alberta Department of Environment (1972) (this report is also referred to as Schuler, 1972). The study identified about 5,060 ha (12,500 acres) of land suitable for gravity irrigation and 262,630 ha (648,700 acres) suitable for sprinkler irrigation near the potential Meridian dam site and on lands surrounding the Suffield Military Base. A Level V irrigation classification is based on secondary-source information (maps, aerial photos) with some visual inspections, if possible. A Level III irrigation classification requires all the above, plus an on the ground inspection and soil sampling (at least 2 sampling locations per quarter section).

Berry (1985) and Abrahamson and Ireland (1985) conducted a preliminary evaluation of the overall irrigation potential in Saskatchewan[1]. The evaluation was based on textural interpretations from Soil Survey Report #12 (Mitchell, Moss and Clayton, 1944) and estimated that there were about 211,000 ha (522,000 acres) of soils suitable for irrigation on the western edge of Saskatchewan between Maple Creek and Leader.

In Alberta, recent Level III irrigation suitability studies were conducted by Monenco Consultants Ltd. (1986) in the Cavendish and Bindloss blocks north of the Suffield base and south of the Red Deer River, by Monenco (1987) for the Suffield block south of Suffield and north of the South

[1] Information on previous irrigation studies in Saskatchewan was provided by Garnet Gobert, Watershed and Environmental Planning, Saskatchewan Water Corporation, Moose Jaw, Saskatchewan.

Saskatchewan River, and by Leskiw and Rodvang (1987) for the Redcliff Block bounded in the north by Suffield Military Base and in the south and east by the South Saskatchewan River[2]. Recently, the Irrigation Branch of Alberta Agriculture, Food and Rural Development (2001) prepared an irrigation land classification map for the Meridian Dam Project combining the results from the above Level III studies and some of the earlier Schuler (1972) Level V results (i.e. land areas east of the South Saskatchewan River to the Saskatchewan border). The irrigation map categorized 228,370 ha (564,310 acres) as irrigable (Alberta Land Classes 1 to 4) which represents 54% out of the 421,400 ha (1,041,270 acres) investigated.

In the western townships of Saskatchewan, east of the potential Meridian Reservoir, recent irrigation suitability studies, at an equivalent Level III intensity, have not yet been completed.

2.1.2 Irrigation Classes (Alberta, Saskatchewan, and Meridian Dam Study)

The Alberta and Saskatchewan irrigation land classification systems are similar in that both use four soil category ratings and four topography/landscape ratings (Alberta Agriculture, Food and Rural Development, 2000 a, b and Agriculture Canada, 1987).

In Alberta the soil categories (1-excellent, 2-good, 3-fair and 4-non-irrigable) are determined from a basic soil rating system based on standard indices for soil profile, geological deposit and soil texture, with modifications for salinity and drainage. In Saskatchewan, similar soil categories are determined based on the degree of soil limitations for irrigation as evaluated from such soil characteristics as structure, hydraulic conductivity, available water holding capacity, geological uniformity, depth to bedrock, intake rate, drainage and salinity.

In Alberta, the topographic categories include: 1-gravity, 2-conventional sprinkler, 3-rougher lands requiring specialized sprinklers, and 4-non-irrigable due to complex or steep topography or other barriers. In Saskatchewan, the landscape categories include: A-non-limiting, B-slightly limiting, C-moderately limiting and D-severely limiting. These categories are evaluated based on slope (simple vs. complex), stones, inundation, impact on non-target areas and horizontal variability that might affect surface ponding.

[2] Information on irrigation studies in Alberta was provided by Frank Hecker, Irrigation Branch, Alberta Agriculture, Food and Rural Development, Lethbridge, Alberta.

Using the soil and topography/landscape ratings, Alberta has developed seven irrigation land classes while Saskatchewan has four. For purposes of the Meridian Dam study, irrigable areas in Alberta and Saskatchewan have been identified and are grouped into three main classes: Good, Fair and Poor. A comparison of the Alberta, Saskatchewan and Meridian Dam study classification systems is given in Table 2.1-1. For planning irrigation pumping and delivery systems from the reservoir, priority irrigation soils would be Good and Fair, while areas with large pockets of Poor should be circumvented if possible.

Table 2.1-1 Comparison of Irrigation Classes

Alberta Classes		Saskatchewan Classes			Meridian Dam Study Classes	
Irrig. Class	**Irrigation Rating**	**Soil Class**	**Land-scape Class**	**Irrigation Rating**	**Irrigation Rating**	**Comments**
1	Excellent	1	A	Excellent	**Good**	Includes both Alberta and Saskatchewan Good and Excellent Classes
2	Good	1 2 2	A A B	Good		
3	Fair	1 2 3 3 3	C C A B C	Fair	**Fair**	Includes Alberta Fair and Restricted Classes and Saskatchewan Fair Class
4	Restricted					
5R	Temporarily irrigable for reclamation	1 2 3 4 4 4 4	D D D D A B C	Poor	**Poor**	Includes Alberta Classes 5, 5R and 6 (non-irrigable) and Saskatchewan Class Poor
5	Non-irrigable pending detailed investigation					
6	Non-irrigable					

2.1.3 Irrigation Suitability Map and Estimated Areas

An irrigation suitability map shown in Figure 2.1-1 was prepared in two stages. First, the three irrigation categories were mapped using the available soils maps and Level III land class maps as base maps. Second, the irrigation suitability map was then prepared for the current study by transposing the new irrigation categories from other maps (of various scales) onto 1:250,000 base maps (Energy, Mines and Resources Canada, 1986 and 1994).

Figure 2.1-1 Irrigation Land Suitability Map for Meridian Dam.

In Alberta, the Suffield Military Base was excluded from the study area. The land area west of the Base was also excluded because of its long distance from the potential reservoir. The land area south of the Military Base, north of the South Saskatchewan River and west to Range 10 was mapped at a Level III by Monenco Consultants Ltd. (1987) and Leskiw and Rodvang (1987). The Level III irrigation map units were then grouped into three irrigation classes (Good, Fair and Poor). The land areas east of the South Saskatchewan River (north and east of Medicine Hat) were mapped using the irrigation ratings for the soils of Medicine Hat area (Kjearsgaard and Pettapiece, 1986a, b). These ratings were derived using an older version of the irrigation classification for Alberta (Alberta Agriculture, 1983). The resulting map provided a more detailed irrigation land classification than originally mapped by Schuler (1972).

Part of the land area north of the Military Base and south of the Red Deer River was previously mapped by Monenco Consultants Ltd. (1986) based on a Level III irrigation mapping intensity. The Monenco mapping was extended west of the Monenco map (Range 4) up to the east edge of Range 8 using the Kjearsgaard and Pettapiece (1986b) soil map to determine the irrigation classes.

In Saskatchewan, the irrigation mapping area was limited to lands north and west of the Great Sand Hills and southward to the north edges of Many Island Lake and Bitter Lake. All of the irrigation mapping was based on soils maps (1:100,000) prepared by the Saskatchewan Institute of Pedology (1990a, b, c, d, e) for western Saskatchewan rural municipalities. The soils were mapped based on the ACECSS (1987) Canadian soil classification and the irrigation ratings were determined based on the Agriculture Canada (1987) guidelines for irrigation classification of Prairie soils. The irrigation ratings were modified in two respects: 1) the Sceptre clay and heavy clay soils (except those in poorly drained areas) were moved from the Poor to Fair irrigation category, and 2), some of the complex (t2) soil groups were moved from the Fair to Poor irrigation category based on air photo examination. Regina heavy clay soils (the Dark Brown soil equivalent of Sceptre clays) are presently being irrigated in Birsay-Lucky Lake-Riverhurst large-scale irrigation schemes. Smaller areas of these heavy clay soils are also being irrigated by individual farmers in Saskatchewan. On the Saskatchewan side, air photo coverage was provided by SaskWater (1:60,000 stereo coverage flown in 1991).

For the most part, the Alberta irrigation categories matched those for Saskatchewan at the border. No attempt was made to adjust the map unit boundaries for the few locations where the map lines did not match.

Irrigation land area calculations were made from the original base maps by overlaying grids on Township quadrants (9 sections) and proportioning the irrigation categories within each quadrant. The Alberta Level III reports documented irrigation land classes in tabular form. For convenience, portions of townships occupied by urban development, lakes, large wet areas or wide rivers were placed into the Poor irrigation category. All the information was summarized by Township and these results are compiled in Appendix II.

An overall summary of the extent of the various categories of irrigation land classes is compiled in Table 2.1-2 (hectares) and Table 2.1-3 (acres). Of the 522,605 ha (1,291,360 acres) evaluated in Alberta, 60% were rated as suitable for irrigation. In Saskatchewan, 529,923 ha (1,309,440 acres) of land were evaluated and 72% were considered suitable for irrigation. Overall, 30% of the land area evaluated was rated as Good for irrigation, 36% as Fair and 34% as Poor. Approximately, 2/3 of the land evaluated is irrigable and 1/3 is not irrigable.

Table 2.1-2 Summary of Irrigation Land Class Areas for the Meridian Dam (hectares)

	Irrigation Suitability Land Classes				
Location	**Good**	**Fair**	**Good plus Fair**	**Poor**	**Total**
ALBERTA					
South of Military Base	48,439	29,338	77,777	14,559	92,336
East of South Sask. R.	64,719	88,676	153,395	126,498	279,894
North of Military Base	31,713	49,687	81,400	68,975	150,375
Alberta Total	**144,871**	**167,702**	**312,573**	**210,032**	**522,605**
SASKATCHEWAN	**173,425**	**205,915**	**379,341**	**150,582**	**529,923**
TOTAL	**318,296**	**373,617**	**691,914**	**360,614**	**1,052,528**

Table 2.1-3 Summary of Irrigation Land Class Areas for the Meridian Dam (acres)

	Irrigation Suitability Land Classes				
Location	**Good**	**Fair**	**Irrigable**	**Poor**	**Total**
ALBERTA					
South of Military Base	119,690	72,500	192,190	35,980	228,160
East of South Sask. R.	159,920	219,120	379,040	170,440	691,620
North of Military Base	78,360	122,780	201,140	170,440	371,580
Alberta Total	**357,980 (28%)**	**414,390 (32%)**	**772,370 (60%)**	**518,990 (40%)**	**1,291,360**
SASKATCHEWAN	**428,530 (33%)**	**508,820 (39%)**	**937,350 (72%)**	**372,090 (28%)**	**1,309,440**
TOTAL	**786,510 (30%)**	**923,210 (36%)**	**1,709,720 (66%)**	**891,080 (34%)**	**2,600,800**

The best consolidated land tract for irrigation is west of Medicine Hat in the Suffield and Red Cliff areas. Another smaller consolidated area is just east of Medicine Hat. There is also a large area of acceptable land for irrigation around Schuler, Alberta (northwest of Medicine Hat), however, the area is dissected with strips and patches of non-irrigable land. The tract of land from around Hilda, Alberta, through Richmound, Saskatchewan to Fox Valley, Saskatchewan contains large areas of Good to Fair irrigation land classes, but with pockets of poorer lands. A similar situation exists in the tract of land from McNeil, Alberta, through Burstall, Saskatchewan to Liebenthall, Saskatchewan.

The land area directly southwest of Empress, Alberta contains several townships of Good and Fair irrigation lands, but further west around Calvendish the irrigable soils are surrounded by pockets of Poor soils. Further west yet, near Buffalo, there is a diagonal strip of land area (closer to the Red Deer River) that is irrigable.

East of Empress, on the Saskatchewan side going towards Leader, Prelate and Portreeve, there is a large tract of irrigable land between the South Saskatchewan River and the Great Sand Hills. The northeast portion of this tract contains a large area of Sceptre clay and heavy clay soils, which have been rated as Fair for irrigation in this study, but are rated Poor for irrigation by Agriculture Canada (1987) standards. As mentioned previously, heavy clay soils are currently being irrigated in large-scale irrigation schemes, as well as in smaller area by individual farmers.

2.2 Water Availability

An analysis of water management issues was conducted to determine the water availability within the South Saskatchewan River basin. The purpose of this was to assess the potential for irrigation expansion in southeast Alberta using water supply from the Meridian dam. The water management analysis covers existing practices, water use priorities, and water supply modelling as discussed below.

2.2.1 Existing Water Management in Southern Alberta

The South Saskatchewan River Basin (SSRB) comprises four sub-basins: the Red Deer River basin in the north, the Bow River basin, the Oldman River basin in the south, and the South Saskatchewan sub-basin in the east. The basin covers an area of 121,000 km^2, which is approximately one fifth of the total area of the Province of Alberta. On average, 75% of basin runoff originates from snow-melt, and 60% of annual runoff occurs from early May to mid-July. The availability of runoff varies both seasonally and spatially, which poses difficulties to basin management.

Current water use in the basin can be classified as consumptive and in-stream. Consumptive water use refers to withdrawals from the river which are not fully returned to the stream. Examples include irrigation, municipal, and industrial water use. Development of irrigation in Southern Alberta started in the late 19th century and today, irrigation in the SSRB accounts for about half of all irrigated land in Canada. Thirteen large irrigation districts in the Bow and the Oldman river sub-basins are listed in Table 2.2-1, with the estimated irrigated acreage based on 2001 data available from Alberta Environment. Their locations are shown on Figure 2.2-1.

Figure 2.2-1 Existing Irrigation Districts in the South Saskatchewan River Basin

Table 2.2-1 Irrigation Districts in SSRB

Location	Name of Irrigation District	Irrigated Area (acres)
Bow Basin	Western	87,236
	Bow River	210,353
	Eastern	281,720
Oldman Basin	Lethbridge Northern	157,825
	United	34,329
	Mountain View	3,722
	Leavitt	4,763
	Aetna	3,609
	St. Mary	369,771
	Magrath	18,300
	Taber	82,257
	Raymond	45,888
	Ross Creek	1,210
Total		1,300,983
Private Irrigators		250,000

The total consumptive water use in the SSRB is roughly 2.78 million acre-feet based on current licenses. This is approximately 36% of the annual runoff from the basin of about 7.7 million acre-feet. In addition to consumptive use, there are non-consumptive (or in-stream) water uses in the basin that include hydropower generation, recreation and fisheries. There are conflicting and often competing interests among various water users in the basin, arising from the fact that water is not available to meet all demands for some locations at certain critical periods. To remedy this, a number of reservoirs have been built to store water during the short period of high runoff and to release it later when natural runoff is insufficient to meet all demands. The main storage reservoirs on the major rivers are the Gleniffer reservoir created by the Dickson Dam on the Red Deer River, the Oldman reservoir on the Oldman river, the Waterton reservoir, and the St. Mary reservoir. There are a number of reservoirs on the tributaries to these rivers, including the McGregor and Travers reservoirs, as well as numerous smaller reservoirs within the irrigation districts.

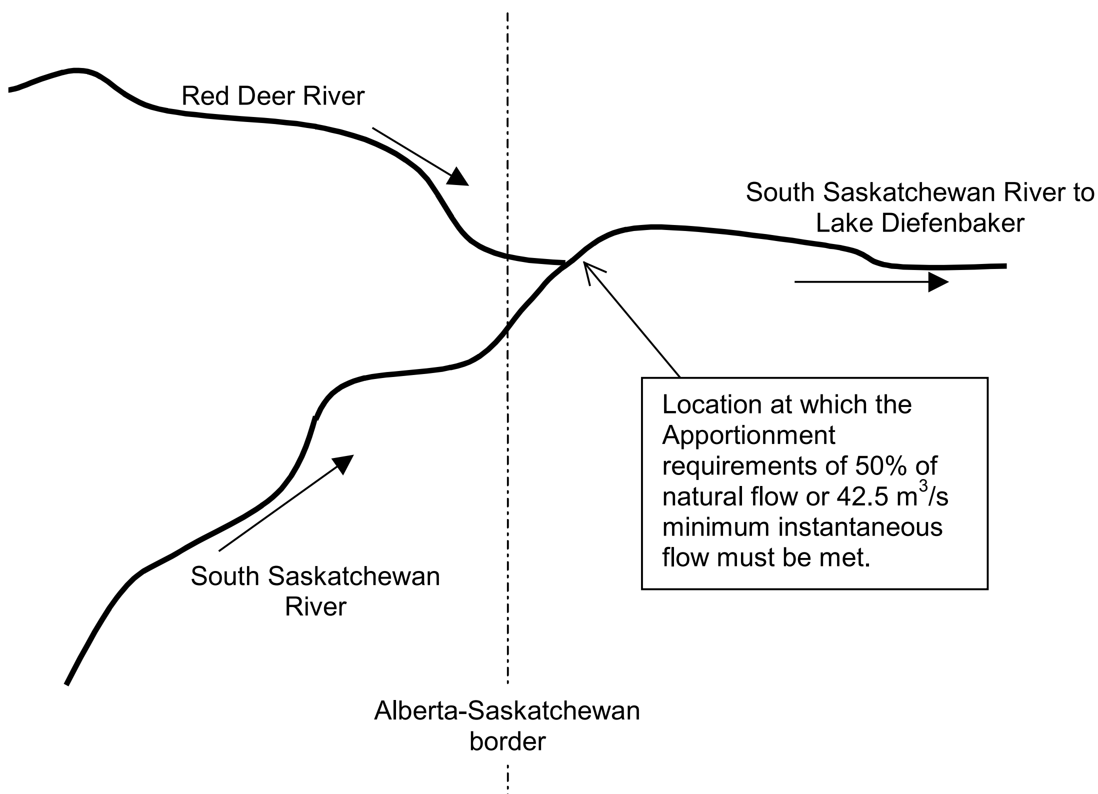
2.2.2 Water Use Needs and Priorities

The South Saskatchewan River Basin (SSRB) in Southern Alberta is widely known for complex issues associated with water management. In addition to irrigation, the largest water use component in the basin, there are industrial and municipal off-stream water users, and a number of designated river reaches with in-stream flow objectives that should be maintained for aquatic

habitat during critical low flow periods. The instream objectives are usually governed by a combination of water quality and environmental concerns related to aquatic habitat.

There is also a legal agreement (known as the apportionment agreement) between the provinces of Alberta and Saskatchewan regarding flow in the South Saskatchewan River. This agreement requires that the minimum flow near the border (below the confluence of the Red Deer River and the South Saskatchewan River) be maintained at 42.47 m^3/s at all times. It also includes a provision that Alberta must pass a minimum of 50% of natural flow of the South Saskatchewan River that originates in Alberta. Refer to Figure 2.2-2 which illustrates the river system and the location of meeting apportionment requirements. Historically, Alberta has passed well above 50% of its natural flow hence the apportionment has not yet become a critical issue in daily water management on either side of the border. However, given the steady increase in the number of water license applications in Alberta, this is likely to change in the future.

Figure 2.2-2 Schematic of River System and Apportionment



The Provincial Government of Alberta has invested significant funds in water management of the South Saskatchewan River Basin since the late 1970's. An initiative known as the South Saskatchewan River Basin Planning Program (SSRBPP) was undertaken in the late 1970s and early 1980s. It included numerous studies and participation of various stakeholders to ascertain the water supply/demand situation in the forthcoming decades and to investigate various management alternatives. On the technical side, this effort included updating and extending the natural flow and water demands database for the entire basin, development of computer modeling tools such as the Water Resources Management Model (WRMM), and various studies conducted by both the public and the private sector. The current modeling schematic of the entire South Saskatchewan river basin is the result of the continued efforts to maintain and update the database and tools developed initially within the SSRBPP. There are currently about 430 components (irrigation blocks, reservoirs, river reaches, diversion canals, etc.) in the SSRB modeling schematic. The impact of the Meridian Dam on this system was assessed by simulating the entire system with three additional components representing: i) the Meridian reservoir, ii) future irrigation off the Meridian reservoir, and iii) the diversion system to divert water from Meridian reservoir for future irrigation.

2.2.3 Water Supply Modeling

Water supply modelling is a process of matching the water available as runoff or storage, with water requirements in the system based on a legal set of priorities of allocation. In Alberta, as in most of North America, the priority of water allocation is determined by the existing system of water licenses, where priorities are given according to the age of license. Therefore, any tool used to study the issues of water supply should be able to mimic the existing water licensing system.

The estimates of available runoff are supplied as a database of weekly naturalized flow series (1928-1995) for many locations in the basin. This database has been created and maintained over the years by Alberta Environment, and it allows a breakdown of the large basin into smaller sub-basins such that the spatial variation of available supply can be represented within the model. The use of naturalized flow series is predicated on the assumption that future runoff in the forthcoming decades will not significantly change in comparison to the runoff recorded in recent decades. However, the level of demand used in the model reflects the anticipated level of water

licenses issued by the year 2010. Hence the historic hydrologic data, which are assumed to adequately represent the available runoff volumes and variations in the near future, are matched with the future level of demands within the model. The WRMM output file contains a sequence of water levels for reservoirs and flows for streams and channels. These are either equal to or less than the future target requirements as represented in a "target" or "ideal" comparison file. The success or failure of various alternative scenarios is evaluated based on the magnitude and frequency of deficits in supply.

Three alternative reservoir sizes were considered, representing total storage volumes of 1.2, 2.4, and 3.7 billion cubic metres (1, 2 and 3 million acre-feet). Results of the water supply modeling (see section 2.2.5) indicated that these storage sizes would be able to supply additional irrigable areas of roughly 162,000, 202,000 and 243,000 hectares (400,000, 500,000, and 600,000 acres), respectively. Table 2.2-2 describes the scenarios of interest.

Table 2.2-2 Modeling Scenarios

Modelling Scenario	Storage Volume		Irrigable Area	
	(10^6 m^3)	(10^6 ac-ft)	(hectare)	(acre)
Scenario 1	1.2	1.0	162,000	400,000
Scenario 2	2.4	2.0	202,000	500,000
Scenario 3	3.7	3.0	243,000	600,000

For each choice of storage and irrigated area the type of adjustment period selected for the apportionment agreement can vary between annual, semi-annual, tri-annual, or weekly. This defined 12 initial modelling scenarios, from which three scenarios were selected for detailed analyses based on the comparison of initial results.

2.2.4 Analysis of Results

Alberta Environment performed all of the WRMM simulation runs related to the current Meridian Dam study. Results were provided to Golder for further evaluation and analysis. Table 2.2-3 shows the annual water balance for a dry and a wet year, as well as the average for all years for Scenario 3. Years 1944 and 1951 were selected to represent dry and wet years, respectively. Net evaporation is a function of precipitation, evaporation and the available reservoir water surface area. In 1944 the evaporation losses were high, but the storage is low most of the year, which

reduces total evaporation losses due to a reduced water surface area. In 1951, larger than average precipitation cancels out much of the expected annual evaporation, which does not vary from year to year as much as precipitation. For Scenario 3, irrigation water supply requirements from Meridian dam range from 51% to 4% of the total annual inflow into the reservoir. The average irrigation water supply proportion of total inflow is 19%.

Table 2.2-3 Water Balance for Meridian Dam

Hydrologic Conditions	Inflow	Net Evaporatio n	Irrigation	Riparian Outflow and Spills	Storage Change	Apportionment Contribution
	(10^6 m^3)	(10^6 m^3)	(10^6 m^3)	(10^6 m^3)	(10^6 m^3)	(%)
Dry year (1944)	1908	32	966	1446	-537	52.4
Average year	4331	46	819	3465	0	57.4
Wet year (1951)	11410	18	487	8990	1915	73.1

Modeling results are often assessed in terms of deficit criteria. In this study the failure criteria were based on the following:

- no more than 10% of simulated years with annual irrigation deficits of more than 100 mm, and
- no more than 20% of years with annual irrigation deficits of more than 50 mm.

In the model, the most recent irrigation license is associated with possible future irrigation from the Meridian reservoir hence this irrigation has the lowest priority. However, it may happen that annual irrigation deficits are higher for some blocks in the Bow River basin as there is no storage for irrigation supply within this basin. Table 2.2-4 shows the number of years of irrigation deficit at the Meridian reservoir for each scenario that was evaluated in this study. There are a total of 68 simulated years. Hence, 7 years of failure (i.e. 7 years with more than 100 mm of annual irrigation deficits) would approximately correspond to the first deficit criteria. Table 2.2-4 shows that annual and semi-annual choices of adjustment periods for apportionment result in the best performance. The worst performance occurs when apportionment is modeled with a weekly adjustment period. This is not surprising, since the weekly adjustment period offers little flexibility for carrying over surplus apportionment flows from the wet season into the dry season by adjusting the targets accordingly.

Based on the results of the initial simulations, three scenarios were selected for further consideration: Scenario 1 with an annual adjustment period, Scenario 2 with a semi-annual adjustment period, and Scenario 3 with an annual adjustment period. The selected scenarios represent all three potential storage levels. Table 2.2-4 also shows the potential irrigation expansion for each scenario. It should be noted that the selected Scenario 1 has a slightly higher deficit than the given failure criteria of 10%, however, these results were provided by Alberta Environment as the best modeling scenario for the respective storage size and irrigated area, and is considered to be acceptable for this pre-feasibility stage of analysis.

Table 2.2-4 Description of Initial Modelling Scenarios and Results

Scenario	Meridian Reservoir Capacity (10^6 Acre-Feet)	Meridian Block Irrigated Area (Acres)	Apportionment Period	Number of Years With Irrigation Failure (Out Of 68)	Frequency of Years With Irrigation Failure (%)
A (no dam or irrigation)	n/a	n/a	Annual	-	-
1	1	400,000	Annual	8	11.8
	1	400,000	Semi annual	9	13.2
	1	400,000	Tri annual	10	14.7
	1	400,000	Weekly	15	
2	2	500,000	Annual	8	11.8
	2	500,000	Semi annual	7	10.3
	2	500,000	Tri annual	10	14.7
	2	500,000	Weekly	11	16.2
3	3	600,000	Annual	7	10.3
	3	600,000	Semi annual	8	11.8
	3	600,000	Tri annual	9	13.2
	3	600,000	Weekly	10	14.7

The following sections provide a brief description of the WRMM results related to reservoir water levels, evaporation losses, irrigation diversions, and reservoir inflows and outflows.

2.2.4.1 Reservoir Water Levels

A storage vs. elevation relationship for the Meridian site was developed using available topographic information as described in Section 3.1.2. Based on this relationship, full supply levels for the three reservoir sizes were determined for storage objectives of 1.2, 2.4, and 3.7 million dam^3 (1, 2, and 3 million ac-ft). The full supply levels are 621.8 m, 635.5 m, and 646.2 m for Scenarios 1, 2, and 3, respectively. The flood routing analysis and discussion on required dam crest elevations is provided in Section 3.1.2 of this report.

Annual maximum, average, and minimum reservoir levels over the simulation period are plotted in Figures 2.2-3 to 2.2-4. Reservoir levels reach full supply in the majority of years, however low water levels are experienced in relatively dry periods such as in the 1930's and 1980's. The same information is plotted as annual reservoir drawdown to illustrate the minimum water level below full supply that occurs each year. Figures 2.2-6 to 2.2-8 provide a time series of drawdown, the average magnitude of which is around 9.5 m annually for each scenario.

2.2.4.2 Evaporation Losses

Mean weekly evaporation losses from the Meridian Reservoir are illustrated in Figure 2.2-9. The evaporation from the potential reservoir would be considered part of Alberta's allotment of water when determining required apportionment flows to Saskatchewan. The figure indicates high gross evaporation during the summer months compared to net evaporation, and much smaller amounts over the winter period. The evaporation estimates appear to be slightly overestimated, however the difference represents an insignificant amount (<0.5%) in the overall water balance.

2.2.4.3 Irrigation Season

The irrigation season typically runs from May through October, and is represented in the WRMM as Weeks 19 through 41. Diversion requirements are based on demand volumes that are influenced by meteorologic variables. Historic rainfall and evaporation records were used in conjunction with irrigation deficit criteria to determine irrigation demands for the simulations. Mean weekly irrigation diversions from the Meridian Reservoir are illustrated in Figure 2.2-10 for all three scenarios. There is a steady increase in irrigation demand toward the middle of the irrigation season which corresponds to July and August. The drop in irrigation diversion at Week 28 is likely due to historic rainy periods at the end of June and in early July. Increased precipitation results in a lower demand in the model, regardless of actual irrigation practices.

Figure 2.2-3 Annual Maximum, Average, and Minimum Reservoir Levels - Scenario 1

Figure 2.2-4 Annual Maximum, Average, and Minimum Reservoir Levels - Scenario 2

Figure 2.2-5 Annual Maximum, Average, and Minimum Reservoir Levels - Scenario 3

Figure 2.2-6 Annual Reservoir Drawdown - Scenario 1

Figure 2.2-7 Annual Reservoir Drawdown - Scenario 2

Figure 2.2-8 Annual Reservoir Drawdown - Scenario 3

Figure 2.2-9 Evaporation Losses at Meridian Reservoir - Scenario 3

Figure 2.2-10 Mean Weekly Irrigation Diversions from the Meridian Reservoir

Figure 2.2-11 Reservoir Elevation-Duration Curve for the Irrigation Season

Figure 2.2-12 Riparian Releases and Spills During the Irrigation Season

Figure 2.2-13 Mean Monthly Reservoir Inflows and Outflows – Scenario 1

Figure 2.2-14 Mean Monthly Reservoir Inflows and Outflows – Scenario 2

Figure 2.2-15 Mean Monthly Reservoir Inflows and Outflows – Scenario 3

Based on the WRMM results for the 1928-1995 simulation period, water levels during the irrigation season (Weeks 19-41) would be at or close to full supply levels approximately 50% of the time for Scenario 1, and 40% of the time for Scenarios 2 and 3. This is illustrated in the water level exceedence curve shown in Figure 2.2-11. As expected, there is a higher variation in water levels for the larger reservoir size due to greater water volumes associated with increased irrigation diversion. The figure also indicates that the reservoir dead storage elevation is approximately 588 m.

Reservoir outflows over the irrigation season were compared to South Saskatchewan river flows from Scenario A (representative of the SSRB with no Meridian reservoir or associated increased irrigation). The comparison for all three scenarios is depicted in Figure 2.2-12. It shows a reduction in reservoir outflows with increased storage size, as expected due to the attenuating effects and evaporation losses from storage.

2.2.4.4 Reservoir Inflows and Outflows

The weekly WRMM results were analyzed to determine the effect of the Meridian Dam on downstream flows in the South Saskatchewan River. Figures 2.2-13 to 2.2-15 illustrate the monthly variation of inflows and outflows for the three scenarios. For nearly all months, outflow is less than inflow due to evaporative losses and irrigation diversion. The largest differences are in the summer months when irrigation demands and evaporation are highest.

2.2.5 Discussion of Modeling Issues and Uncertainties

Several modeling issues were identified and are summarized below. These issues could be improved in future applications, but would not have a significant impact on the results obtained for this preliminary study.

- **Instream Objectives:** The minimum outflow for all three scenarios was set at 42.47 m^3/s. This corresponds to downstream instream objectives and license requirements, as well as the minimum apportionment flow that should be made up of flow from both the South Saskatchewan and Red Deer Rivers. If instream objectives or existing

licenses are altered in the future, restriction in the water management modelling should be modified accordingly.

- **Reservoir Dead Storage:** In the model, a small portion of the reservoir below 620.0 m, but above the dead storage level of 608 m, is not available for irrigation allocation.
- **Reservoir Evaporation:** Reservoir evaporation calculations could be refined. Currently, evaporation is slightly overestimated when compared to hand calculations, however this represents less than 1% of the overall water balance.
- **Irrigation Intensification:** The water management analysis undertaken for this study is based on new irrigation development in the Meridian area. The terms of reference exclude the expansion of existing irrigation districts, however, this affects project economics as it would be less costly to expand existing systems than to develop new ones.
- **Impacts on Lake Diefenbaker:** The water supply modeling undertaken was conducted without taking into account downstream water levels in Lake Diefenbaker. As such, impacts on the lake were not a factor in determining or limiting upstream withdrawals. Downstream impacts are considered in detail in Section 6.4 of this report.
- **Long Term Climate Change:** Long term climate change adds uncertainty to the model results. The assumption that historic natural flows can be used to represent runoff anticipated in forthcoming decades is uncertain. Estimates of natural flows do not appear to exhibit visible trend over the last decades, however, this may only be so due to relatively short records and the inherent random variation which is part of natural runoff processes. Global warming has the potential to introduce systemic changes to future runoff patterns. In general, higher temperatures would result in more evaporation and possibly a larger amount of water in the hydrologic cycle by increasing evaporation and melting of snowpacks, glaciers, and icepacks. This would imply more precipitation and more runoff from snow melt in late spring and early summer. However, this may also result in longer and hotter dry spells later in the summer due to increased energy input. A high variability in runoff patterns would likely occur, with increased risk of both floods of higher magnitude and prolonged droughts. It does not appear that the potential Meridian Dam would present any disbenefit under flood or drought conditions.

3 PRE-FEASIBILITY DESIGN

The conceptual design of the dam, reservoir, and delivery system is presented in the following sections. Reservoir conditions that govern design, such as flood conditions, reservoir storage, geology, and physiography, are also presented.

3.1 Reservoir Conditions

3.1.1 Flood Hydrology

Estimates of the inflow flood hydrographs for various return periods and for the PMF are provided by the Water Sciences Branch of Alberta Environment (Alberta Environment, 2001). This study contains an acknowledgement that the results obtained so far are preliminary and that they can only be used for preparing a conceptual design at this phase. More detailed analyses may be required if the Meridian project is considered further.

There are two flow monitoring stations that were considered as a basis for the flood analysis. Station 05AJ001 (South Saskatchewan River at Medicine Hat) was the primary source of data for this study as it has a lengthy flow record starting in 1911. Flows upstream of Medicine Hat are regulated by the Oldman Dam, TransAlta reservoirs on the Bow, and numerous diversions from the river (WID, EIC, LNID, etc.). A previous study on the Oldman River (Alberta Environment, 1999) suggested that the maximum flow reduction that can be expected due to upstream flow regulation is about 300 m^3/s during a 100 year flood event, and that reductions at PMF values would be minimal.

A number of statistical functions were fitted to the observed series of annual peak discharges at Station 05AJ001. It was found that Log-Pearson III distribution gives the most probable fit for the high flood events that are on record. Table 3.1-1 lists the peak flow estimates for floods with return periods between 2 and 500 years estimated using the Log-Pearson III distribution. Table 3.1-1 also lists the Probably Maximum Flood (PMF) estimate.

Table 3.1-1 Flood Peak Estimates, Station 05AJ001

Return Period (yrs)	Peak Flow (m^3/s)	Time to peak (days)
2	1030	-
5	1770	-
10	2350	3.95
20	2970	3.61
50	3880	3.20
100	4630	2.92
200	5460	2.67
500	6660	2.36
1000	8308	2.16
PMF	20844	1.40

Analyses were also conducted on 10-day flow volumes, as well as on the shape of the flood hydrograph at this site used to derive the dimensionless hydrograph. The Probable Maximum Flood was estimated using an approximative technique. The results were compared to other PMF studies in terms of specific yield and in terms of the Creager's Plot (Neill, 1986) which confirmed that the estimates were realistic. The dimensionless hydrograph is depicted in Figure 3.1-1.

3.1.2 Reservoir Storage and Dam Crest Elevation

A storage vs. elevation curve was developed for the Meridian reservoir using the most recent NTS topographic mapping available at a 1:50,000 scale. Except for one map sheet, this mapping dates from around 1979 and may therefore be out of date. Surface areas at various elevations were delineated and measured using a digital planimeter. The flooded areas are confined to the existing river valley in all scenarios except for Scenario 3 where the Drowningford area is also flooded. Approximate reservoir extents are shown in Figure 3.1-2. The resulting storage-elevation relationship is also shown in Figure 3.1-3 (metric units) and Figure 3.1-4 (imperial units).

Full supply levels (FSL) for the three reservoir scenarios were determined using the storage vs. elevation relationship described above. These levels are summarized shown in Table 3.1-2 and are illustrated in Figure 3.1-5.

Figure 3.1-1 Dimensionless Flood Hydrograph for S. Saskatchewan River at Medicine Hat

Figure 3.1-2 Approximate Extents of the Potential Reservoirs

Figure 3.1-3 Storage-Elevation Curve for Meridian Dam Reservoir (Metric)

Figure 3.1-4 Storage-Elevation Curve for Meridian Dam Reservoir (Imperial)

Figure 3.1-5 Reservoir Profile and Full Supply Levels

Table 3.1-2 Full Supply Levels for the Three Reservoir Sizes

Scenario	Reservoir Storage	Full Supply Level	Surface Area
	(billion m^3)	(m)	(ha)
1	1.2	621.8	6,900
2	2.5	635.5	11,000
3	3.7	646.2	15,000

Flood routing analysis was performed to determine the reservoir surcharge resulting from the 1:1000 year flood and from the Probable Maximum Flood (PMF). A summary of the results is provided in Table 3.1-3 and a detailed discussion is given in Section 3.3.

Table 3.1-3 Reservoir Surcharges Resulting from Flood Events

Scenario	Reservoir Storage	Full Supply Level	1:1000 Year Flood Surcharge	PMF Surcharge
	(billion m^3)	(m)	(m)	(m)
1	1.2	621.8	0.49	5.81
2	2.5	635.5	0.35	4.74
3	3.7	646.2	0.27	4.02

In order to determine wind and wave effects, a freeboard analysis was conducted for the three reservoir sizes. Results are shown in Table 3.1-4 and Table 3.1-5 for the 1:1000 year hourly wind and the mean maximum annual wind, respectively. The results are noted for the “5% wave” which represents the smallest of the largest 5% of waves generated in a wave train. Setup calculations are based on estimated total fetch with wind from the SW rather that from the SE as per the runup calculations. As a result, the estimate of setup is conservative since the critical directions for both runup and setup have been applied at the same time.

Table 3.1-4 Estimated Wind Generated Runup and Setup (1:1000 Year Hourly Wind)

Description	Hourly Overland Wind Direction and Speed	Runup	Effective Fetch (km)	Setup	Runup plus Setup
	(km/h)	(m)	(km)	(m)	(m)
Scenario 1	SE – 99.7	1.69	1.38	0.30	1.99
Scenario 2	SE – 99.7	1.98	1.86	0.28	2.26
Scenario 3	SE – 99.7	2.13	1.16	0.26	2.39

Table 3.1-5 Estimated Wind Generated Runup and Setup (Mean Maximum Annual Wind)

Description	Hourly Overland Wind Direction and Speed	Runup	Effective Fetch (km)	Setup	Runup plus Setup
	(km/h)	(m)	(km)	(m)	(m)
Scenario 1	SE – 44.4	0.70	1.38	0.10	0.80
Scenario 2	SE – 44.4	0.82	1.86	0.09	0.91
Scenario 3	SE – 44.4	0.88	1.16	0.09	0.97

The crest elevation for the main embankment associated with the three reservoir scenarios was determined based on the requirements of the Canadian Dam Safety Guidelines, where the following conditions should be satisfied.

- FSL plus wave conditions and set-up due to wind with a 1/1000 annual exceedance probability;
- Reservoir level due to the PMF, plus wave conditions and set-up due to the mean maximum annual wind;
- For embankment dams, the reservoir level due to the PMF should be at or below the top of the low permeability core.

At this site, the reservoir level due to the PMF, plus wave conditions and wind wet-up govern the minimum dam crest elevation as shown in Table 3.1-6 below. Minimum dam crest elevations are 628.4 m, 641.2 m, and 651.2 m for Scenarios 1, 2, and 3, respectively. The required flood storage and crest levels are also shown in Figure 3.1-5.

Table 3.1-6 Design Conditions for Dam Crest Elevation

Scenario	Full Supply Level	Maximum PMF Reservoir Surcharge	Minimum Freeboard Requirement	Minimum Dam Crest Elevation
	(m)	(m)	(m)	(m)
Scenario 1	621.79	5.81	0.80	628.4
Scenario 2	635.51	4.74	0.91	641.2
Scenario 3	646.18	4.02	0.97	651.2

The above minimum freeboard provisions may be insufficient to protect the upper part of the core from frost action. Measures to protect the long-term integrity of the core should be considered as part of subsequent phases of design.

3.1.3 Geology and Physiography

A geological overview of the dam and reservoir site was undertaken by J.D. Mollard and Associates (2001) and is presented in Appendix [illegible] of this report. This section provides a summary of the geological setting, bedrock geology, and surficial geology of the area.

3.1.3.1 Geological Setting

The bedrock geology map for the Medicine Hat area (Borneuf and Stevenson (1970) Figure 6 in Appendix III) identifies three bedrock units occurring in the area of the potential Meridian Dam and the associated reservoir. These bedrock units are, in descending order, the Bearpaw Formation, the Oldman Formation, and the Foremost Formation. The Lea Park Formation underlies the Foremost Formation across the wider regional area. These formations vary in lithology, thickness, and visual exposure in the sides of the South Saskatchewan River valley. The regional dip of the bedrock is to the northeast at low angle, so upstream of the dam site the Foremost Formation becomes progressively more exposed in the sides of the river valley.

The regional surficial geology map (Shetson (1987) Figure 2 in Appendix III) indicates the presence of eolian deposits comprising fine and medium grained sand and silt up to 7 m (23 ft.) thick, overlying lacustrine sand and silt that has locally been modified by wind erosion. Stream and slope wash deposits, exposed till, and bedrock are identified as occurring along the South Saskatchewan River valley. Till is exposed in the valley sides, and underlies much of the general

area. A localized area of coarse fluvial sediments is identified on the west side of the South Saskatchewan River on the inside of a large meander at the upstream end of the reservoir area.

Based on the drift thickness map (Carlson (1970) Figure 7 in Appendix III), the thickness of the surficial materials in the upper part of the reservoir area ranges from 15 to 46 m (50 to 150 ft). Toward the lower part of the reservoir area, and in the vicinity of the dam site, the thickness of the surficial deposits is indicated to range between 76 and 137 m (250 and 450 ft).

Based on the bedrock topography map for the Medicine Hat area (Carlson (1970) Figure 8 in Appendix III), the thalweg of a major buried valley is situated approximately 10 km (6 miles) to the west of the South Saskatchewan River. This buried valley is called the "Oldman Valley" and parallels the South Saskatchewan River valley. Two subsidiary buried valleys that trend in a northwest direction across the South Saskatchewan River valley are also indicated on the regional hydrogeological map (Borneuf and Stevenson (1970) Figure 9 in Appendix III). The base of the Oldman buried valley is at an elevation of approximately 579 m (1900 ft). There is a bedrock "high" which rises to an elevation of up to 701 m (2300 ft) between the South Saskatchewan River valley and the Oldman buried valley. The bedrock high decreases in elevation downstream, such that at the potential dam site the elevation of bedrock is indicated to be approximately 594 m (1950 ft). This would suggest that the thickness of the surficial deposits increases downstream through the potential reservoir area towards the axis of the dam.

3.1.3.2 Bedrock Geology

A geological section through the potential dam site is presented in Figure 11 of Appendix II. The lithology and thickness of the main bedrock formations in the area are described in the following sections, and Unit designations are as detailed on Figure 11 of Appendix II.

<u>Bearpaw Formation</u>

The Bearpaw Formation is a grey marine claystone, shale and siltstone unit, with minor grey sandstone layers and concretionary beds and thin bentonite layers. The Formation is less than 200 m thick in the area. The published geological maps (Figure 6 in Appendix III) would indicate that the Bearpaw Formation is not exposed at the dam site, and the Formation is not indicated on the geological section presented on Figure 11 of Appendix III.

Oldman Formation

The Oldman Formation (Unit 2) is a continental (non-marine) interbedded weakly cemented fine to medium grained friable weathered sandstone with hard sandstone layers, and medium to high plastic silty shale layers and lenses. The Formation is of Upper Cretaceous age. The sandstone and shale interbeds lack continuity, and pinch out laterally over short distances. Permeability values for the Formation range between $5x10^{-11}$ up to $5x10^{-8}$ m/s. Given these relatively low permeability values, coupled with the lack of continuity of the sandstone layers, reservoir seepage through the Oldman Formation is expected to be negligible. However, in the vicinity of the dam structure, seepage through this Formation may be expected through weathered and stress relief open joint fractures, bedding planes and thin more permeable sandstone layers in the dam abutments.

Mollard (2001) suggests that the Oldman Formation is thought to be the main source of springs along the valley walls, especially in the downstream reaches of the potential reservoir area. It was also noted that many water wells in southern Saskatchewan and Alberta tap into groundwater resources in the Oldman Formation.

Foremost Formation

The Foremost Formation (Unit 1) is a continental (non-marine) waxy shale and silty shale of Upper Cretaceous age. The Formation is located below the infilled river channel at an elevation of 555 m (1820 ft) at the dam site, and does not appear in the sideslopes of the reservoir area until approximately the east side of T18-R3-W4M.

3.1.3.3 Surficial Geology

A section through the dam site detailing the disposition of the surficial geological units is presented on Figure 11 in Appendix III.

The surficial geologic materials comprise in descending order:

- post glacial alluvial fine sand and silty clay, with locally sand dunes on the surface (Unit 6);
- post glacial alluvial terrace sand and gravel (Unit 5);

- Pleistocene icelaid clay rich till (Unit 4); and
- late Tertiary/Lower Pleistocene Empress Formation comprising gravels and cobbles in a silty fine sand matrix (Unit 3).

The valley of the South Saskatchewan River is infilled with alluvial poorly graded fine sand and silty sand (Unit 7), which is locally overlain by alluvial complexly interbedded gravelly sand, silty sand, clayey gravel and slope wash materials (Unit 8). Locally there are alluvial poorly graded gravel, fine sand and silty sand materials (Unit 10) and interbedded slope wash and colluvial sediment overlying Units 7 and 8.

The till unit is a low to medium plastic silty clay. It is absent in the left abutment, and is approximately 17 m thick in the right abutment. In the area of the Alberta-Saskatchewan border to the east of the site, this till unit averages around 90 m (295 ft) in thickness. Typically in southern Saskatchewan, the unfractured till has a permeability in the range of $1x10^{-11}$ up to $1 \times 10^{\ 9}$ m/s.

The Empress Formation is preglacial in age, or alternatively, partly preglacial and partly early Pleistocene in age. The post-Oldman pre-Empress erosional unconformity in the dam site area is rolling, with its elevations varying between 518 m and 549 m (1,700 and 1,800 ft) along the Alberta-Saskatchewan border. The bottom elevation of the Empress Formation in the reservoir near the dam site is about 625 m (2,050 ft. This is some 21 m (70 ft) below the highest potential Full Supply Level (FSL) of 646 m. (2119 ft). Accordingly, the Empress Formation could daylight downstream of the dam site, and could extend below the highest FSL. In the left abutment the Empress Formation is about 6 m thick, whereas on the right abutment it is approximately 12 m thick.

Approximately 1.6 km (1 mile) southeast of the dam site the Empress Formation is 33 m (108 ft.) thick in the reservoir valley sides. The approximate base of the Empress Formation is located at about the 549 m (1,800 ft) elevation in the South Saskatchewan River downstream of the dam site. Gravelly layers have also been identified at elevation 625 m (2,050 ft) in the formation some 21 m (70 ft) below the highest FSL elevation in the reservoir area. Mollard (2001) reports that previous studies indicate an average permeability for the Empress Formation at the dam site of 1.5×10^{-6} m/s. It is also pertinent to note that the formation is permeable enough to yield several

hundred gallons a minute from water wells installed in it in southern Saskatchewan. Based on the results of water well drilling and testing in southern Saskatchewan in the Estevan aquifer permeability values in the Empress Formation may be as high as $1x10^{-4}$ to $1x10^{-2}$ m/s.

The main valley infill deposit (Unit 7), is approximately 25 m (82 ft) thick. Based on the gradation of similar sand deposits downstream and west of Burstall village (Mollard 2001), the permeability of this valley bottom sand is estimated using Hazen's formula to be in the range $4x10^{-4}$ up to $1x10^{-3}$ m/s.

3.2 Dam Design

This section addresses the preliminary design of the main embankment for the Meridian Dam along with measures for seepage control below the dam and within the abutments. Preliminary geotechnical aspects of the cofferdam design are also included. Appurtenant structures (spillway, diversion tunnels, hydropower facilities etc.) are discussed in Sections 3.3 and 3.4. The geotechnical analysis and design is at a conceptual or pre-feasibility level and no attempt has been made to optimize the embankment design. This study considers the dam location that was identified in 1970 studies by PFRA; no other locations have been reviewed.

3.2.1 General Arrangement

The Meridian Dam site considered by this study is located in Section 13 and 24, Tp 22, Range 1 as shown on Figure 3.2-1. The conditions and general geology at the site are described in Section 3.1.3 of this report.

Costs for all three scenarios have been estimated (Section 3.2.5), however, only the reservoir scenario resulting in the highest dam (Scenario 3) is specifically discussed below. Many of the issues discussed below are common to all scenarios. The lower dam heights result in significantly greater excavation volumes for the spillway cut, the spillway approach channel cut and the highway approach cuts. The cofferdam, the diversion tunnels and the upstream and downstream cuts associated with the diversion tunnels are the same size and configuration for all three scenarios.

The dam considered by this study is a zoned, earth fill embankment. The planned crest elevation for the highest configuration (Scenario 3) is 651.2 m and is approximately 71 metres above the current stream channel. At that elevation, the embankment crest length is estimated to be about 1500 metres.

The general arrangement of the embankment and appurtenant structures are shown on Figure 3.2-2. Available digital elevation models at a scale of 1:20,000 have been used as the base plan. The general arrangement considered in this analysis, is essentially the same as that considered in 1970 by the PFRA, with some adjustments to reflect the results of current analysis and opinion. The elevation data used by the PFRA studies, at a scale of 1" = 400' were not used for the current work. Adjustments to the centreline configuration and location may be required during future design stages to optimize fill usage and to improve the embankment/abutment arrangement.

The general arrangement includes a spillway located on the right (north) bank of the valley and 4 low level diversion tunnels set within the left (south) bank. These structures are discussed in more detail in Section 3.3. A powerhouse would be installed in the south bank at the planned outlet of the permanent low level outlet tunnels.

It is anticipated that the materials required to construct the dam (with the exception of rip-rap) will be available in the immediate vicinity of the dam. The spillway cuts are anticipated to be a source area for the low permeability material required in the construction of the dam core. The alluvial terrace gravels in the planned excavation are intended to provide the materials needed for the external shell as well as select materials required for the filter zones, toe drainage zones and base gravel for rip-rap. A gravel terrace deposit (north of the dam site) that has been identified on Figure 3, Appendix II, may also be required as a borrow source for select granular materials.

Figure 3.2-1 General Location Plan

Figure 3.2-2 General Arrangement Plan Scenario 3

Figure 3.2-3 Spillway Structure General Arrangement Scenario 3

3.2.2 Geotechnical Design Basis of Dam and Appurtenant Facilities

The following discussion is intended to address the geotechnical aspects of the dam and appurtenant facilities. Other design details of the appurtenant facilities are addressed in Sections 3.3 and 3.4.

Cofferdam

The cofferdam is expected to be a zoned earth fill embankment dam with a crest elevation of 611.0 metres. This elevation is approximately 31 metres above the valley floor and was selected to retain the maximum water levels during a 1 in 50-year return period flow event. The normal service water elevation for the cofferdam would be approximately 585 metres and peak flow events above the normal operating levels would be of relatively short duration. Based on available hydrological information the 1:50 year event is expected to return to normal levels within about 1 month.

The cofferdam design concept was developed assuming side slopes of 2H:1V. The cofferdam would be founded on up to 25 metres of alluvial deposits underlain by sandstone and shale bedrock. Overall stability of the cofferdam would be satisfactory at the valley centre, assuming a depth of 25 metres to the bedrock surface. However, the stability of the embankment nearer the valley walls should be checked once the bedrock in those areas has been investigated. More detailed analyses may identify the need for flatter sideslopes for the cofferdam embankment. Results of the stability analyses are provided in Appendix IV-1.

Seepage below the cofferdam should be carefully assessed. A seepage cut-off trench below the dam has been included in the conceptual design however, detailed analysis may show that other seepage control measures are more cost effective. Further, analysis of the time dependant aspects of the pore pressure response within and below the cofferdam may show that the anticipated retained water levels are not in place long enough to cause concern. It is also possible that some other cross section can be developed so that the seepage cut-off below the cofferdam can be incorporated into the overall seepage control system for the main embankment.

Filter zones within the cofferdam embankment should be placed on both the upstream and downstream sides of the low permeability core. Considering the relatively short service life of

the cofferdam, consideration could be given to the use of filter fabric for the upstream filter zone and for the downstream filter zone above approximate elevation of 585 metres.

It is intended that the cofferdam be incorporated, as much as is practical, within the volume of the main embankment. As can be seen from the cross-section shown on Figure 3.2-2 most of the cofferdam volume can be incorporated in the upstream shell of the main dam for the highest dam scenario being considered. Lower dam elevations would incorporate less of the cofferdam, leading to an increased incremental cost premium for cofferdam construction for those scenarios.

The approximate footprint of the cofferdam is shown in the General Arrangement Plan on Figure 3.2-2. A conceptual cross section for the cofferdam is also shown on Figure 3.2-2. The cross section details should be re-assessed in subsequent phases of design to take advantage of the materials available during the initial stages of construction.

The cofferdam considered for this study is a significant structure in itself and will present construction challenges. The construction sequencing details should be developed during subsequent phases of the design, however, it is assumed at this time that the cofferdam would be constructed during winter low-flow conditions. It is also assumed that temporary river training works (or a secondary cofferdam) will be required to confine river flows to a small portion of the valley width to facilitate construction of the cofferdam foundation and seepage cut-off elsewhere across the valley. The location of the confined river flows will likely have to be changed (and temporary river training works reconstructed) at least once during cofferdam construction.

Diversion Tunnels and Outlet Works

The diversion tunnel centrelines considered by this study are shown on the general arrangement plan, Figure 3.2-1. The plan shows specific entry and exit portal locations, however, the actual locations will be depend on further investigation and analysis. The portal locations should be selected to optimize tunnelling and open cut excavation costs. Further discussion on the number and configuration of the diversion tunnels is provided in Section 3.3.

The diversion tunnels are located within the left (south) abutment to avoid having both the low level outlet and the spillway located on the same side of the valley. Available geological

information indicates that the bedrock conditions within the left bank are also more appropriate for tunnelling. Tunnelling techniques appropriate for the anticipated conditions have not been closely examined. No specific premium associated with tunnelling difficulties has been included in the cost estimates.

A more detailed assessment may show that the outlet portals can be located somewhat further downstream than is shown on the plan, thereby reducing the excavation associated with the planned outlet portals. A detailed understanding of the geology in this area will be required to provide a reliable decision on the ultimate location of the outlet portals.

The upstream cut around the entrance to the diversion tunnels is a significant excavation into the valley wall. The stability of the planned cut has been briefly assessed and it was found that the planned 4 horizontal to 1 vertical cut slope will be adequately stable under the anticipated conditions of service. However, a rapid, full reservoir drawdown event could cause local instability in this cut, resulting in the need for remedial works on the slope. The stability of this cut is governed by the presence (or absence) of continuous weak layers within the Oldman Formation. Careful characterization of the geology will be required to optimize excavation slopes.

The downstream cut around the outlet for the diversion tunnels, as currently configured, involves a significant excavation into the valley wall. The stability of this cut was reviewed and it was found that a slope angle of 4 horizontal to 1 vertical would provide adequate stability. The Oldman Formation is also expected to be exposed in this cut and the stability is expected to be substantially governed by the presence (or absence) of continuous weak layers within this formation. Additionally, stability will be affected by the long-term pore pressure regime within the Oldman Formation. If the bedrock transmits excess pore pressures into the vicinity of the cut slope, some reduction in stability will occur. This transmission could occur through both relatively steep fracture zones oriented roughly parallel to the valley wall and/or through higher permeability zones oriented roughly parallel to bedding. The Empress Formation sediments that overlie the bedrock of the Oldman Formation may also act as a relatively permeable zone that could bring reservoir seepage onto the cut slope. Additional discussion regarding the Empress Formation and seepage control in general is provided in Section 3.2.3.

The preliminary stability analyses carried out as part of this study are included in Appendix IV-2.

Spillway and Approach Channel Excavations

The spillway approach channel and the spillway will require significant cuts for all three dam configuration scenarios. The cut slopes have been selected to be no steeper than 4 horizontal to 1 vertical. The stability of these slopes has been checked at a preliminary level and found to be stable under most operating conditions. The stability of both these slopes is governed by the possibility of weak layers within the Oldman Formation, which is expected to be exposed by these excavations.

It is anticipated that seepage within the Oldman Formation and the overlying pre-glacial Empress Formation may affect the stability of the spillway cut, if allowed to discharge onto the cut slope. Seepage control measures, therefore, are recommended and are discussed in more detail in Section 3.2.3.

The stability assessments carried out for this study are included in Appendix IV-3.

Embankment Foundation

Based on available information, it is understood that the potential embankment will be founded on up to 25 metres of alluvial material within the valley bottom. This material is expected to consist of stratified fine to medium grained sand, containing occasional silt and gravel layers along with some lenses of clay-silt mixtures. The consolidation characteristics of these soils are currently unclear, however, it is anticipated that consolidation would occur primarily during the construction period. Differential settlement at the abutments may be of concern and additional characterization of the foundation conditions should be carried out during the feasibility assessment stage of the project. For the purposes of the present study, it is assumed that some amount of foundation improvement and/or drainage will be required.

A number of stability analyses of the foundation of the main dam have been carried out. These analyses were carried out using assumed strength values for the various materials and did not consider the potential effects of earthquakes. Earthquake effects are expected to be relatively minor. The analyses were undertaken using 2-D techniques and a geological model developed

based on the information provided in the PFRA reports of 1969 and 1970 as well as the geological assessment by J.D. Mollard and Associates, included in Appendix II. Table 3.2-1 provides a summary of the material properties used in the stability analyses for the main embankment.

Table 3.2-1 Modeled Embankment Material Properties

Material	Unit Weight (kN/m^3)	Cohesion (kPa)	Friction Angle (degrees)
Foremost Formation (bedrock)	20	0 – parallel to bedding 7 – cross bedding	13 – parallel to bedding 33 – cross bedding
Alluvial	20	0	33
Low Permeability Core	20	10	24
Filter zones	20	0	35
Shell	20	0	33

The analyses show that the stability of this embankment is substantially governed by the strengths assumed within the clay rich bedrock of the Foremost Formation that exists below the valley alluvium. The borehole logs report sheared and slickensided zones within the drill core recovered, raising the concern that continuous weak layers could exist within this formation. Further, construction induced pore pressure increases in the valley alluvium and the underlying Foremost Formation may take place, adversely affecting the stability of the embankment during and after construction. The suggested cross sectional configuration shown on Figure 3.2-2 assumes 3 horizontal to 1 vertical slopes for the normal working range of the reservoir and 6 horizontal to 1 vertical side slopes below approximately elevation 626.8 metres. Further geotechnical investigation and analysis may identify a need for flatter slopes than are presently considered. The current general arrangement can accommodate significantly flatter slopes without affecting the spillway or diversion tunnel arrangement.

The analyses undertaken and the strengths assumed are provided in Appendix IV-4.

3.2.3 Dam Design Components

The anticipated typical embankment cross section is presented on Figure 3.2-2. This cross section is similar to that potential by the PFRA in 1970. The cross section is conceptual and it is

recommended that the design details be established during subsequent stages of assessment and design. In general the cross section includes the following elements:

Core Trench

The core trench is intended to expose reasonably uniform foundation conditions for the low permeability core of the dam. It does not appear practical to excavate sufficiently deep to extend the core trench to the bedrock at depth within the valley bottom area, though this possibility cannot be ruled out. Further investigation may identify conditions that render a seepage cut-off wall, as discussed below, uneconomic.

At the base of the abutments, wedge shaped deposits of slope debris are expected, overlying (and perhaps interlayered with) the alluvial sediments. The core trench excavation is intended to remove this material as far as is practical. The core trench is also intended to remove loose and weathered bedrock from the abutments and to provide a minimum depth key into the abutment materials. Local stability of the valley walls exposed in the core trench excavation should be reviewed carefully in subsequent stages of the assessment and design of this project.

Seepage Cut-off Wall

A seepage cut-off wall below the main embankment has been included in the typical cross section shown on Figure 3.2-2. The section shows the wall extending fully to the bedrock at depth, however, no specific seepage analysis has been carried out. It is anticipated that the wall would consist of a plastic concrete mix so that it would retain a plastic characteristic over time.

The purpose of the seepage cutoff wall is primarily to control piezometric pressures (under general reservoir service conditions) within the alluvial sediments below the downstream shell of the dam. Piezometric pressure relief using a series of relief wells, was included in the PFRA study reported in 1970. Considering that a positive seepage cut-off below the core of the dam is now being considered, the need for these relief wells is not certain. For costing purposes, the relief wells have been included however, it is recommended that this component of the embankment design be re-assessed at later stages of the design process.

Low Permeability Core

A low permeability core is to be constructed using the glacial clay materials that exist in the vicinity of the north abutment. It is anticipated that the spillway cut and the spillway approach channel cut will be primary source areas for this material. The anticipated core configuration is

shown in Figure 3.2-2. It is assumed that sufficient suitable medium plastic clay is available for use in core. Additional characterization of the source area is recommended for use in subsequent design and analysis. The size and shape of the core is similar to that recommended by the PFRA in 1970, however, a marginally wider core crest and a substantially narrower core base width could also be considered if supported by dam performance considerations, economics and availability of suitable material. Consideration could also be given to another type of embankment cross section that optimizes the seepage cut-off needs of both the cofferdam and the main embankment. The crest of the core has been chosen at an elevation of 650.2 metres, which is equal to the anticipated water level of the PMF and is 1.0 m below the design top of dam. A core crest width of 3 m has been used in the analysis. The core crest will be exposed to frost and measures to protect the long term integrity of the core should be developed in subsequent stages of the design.

Filter Zones

Filter zones have been included both on the upstream and downstream sides of the low permeability core. The current concept is shown on Figure 3.2-2, however, the actual configuration and composition of the filter zones should be determined during subsequent stages of the design. While the current cross section shows a filter zone only between the core material and the shell material, care should be taken during design to ensure an adequate filter relationship between the core and the alluvial foundation as well as between the shell material and the alluvial foundation. It is anticipated that filter materials can be manufactured from the terrace gravel that exists within the planned cuts or a potential borrow area located to the north of the dam site.

Shell Materials

The external slopes of the dam are currently planned at 6H:1V. The final configuration should be confirmed following further characterization of the foundation conditions. The shell materials are intended to consist of relatively clean sand and gravel sourced from within the planned cuts or a potential borrow area located to the north of the dam site. Other miscellaneous materials (rock, excess fine-grained soils, etc.) could be placed within the upstream shell, provided they are suitably prepared. The crest width should be 15 metres to accommodate the requirements of Secondary Highway 41, which could be routed across the crest of the dam.

Toe Drain

A toe drain is planned below the shell materials on the downstream side of the dam. It is anticipated that this material can be developed from the terrace gravel within the potential cuts or a potential borrow area located to the north of the dam site.

Erosion Protection

Rip-rap erosion protection is required as shown on Figure 3.2-2. It is understood that no source of rip-rap has been identified at this site, therefore, the costing has assumed that rip-rap will be transported from the Rocky Mountains. Considering the high relative cost for this source, it is recommended that additional investigation in the vicinity of the dam site be undertaken to identify a possible source of coarse boulders that could serve as rip-rap.

Abutment Seepage Control

As discussed in Sections 3.2.2, seepage through the Oldman Formation and the overlying Empress Formation may adversely affect the stability of the downstream cuts for the low level outlet and for the spillway. Further, available grain size analyses for materials sampled from the Empress Formation show a gap graded character for (at least some of) this deposit. The gap graded nature of this deposit creates a greater susceptibility to the development of piping failures due to reservoir seepage through this material.

It may be necessary to provide a partial grout curtain within the Oldman Formation bedrock that will be exposed in the core trench at the abutments. The purpose of this grout curtain would primarily be to address the potential for seepage through fractured zones oriented roughly parallel to the valley wall along with zones oriented roughly parallel to bedding.

Seepage control measures within the overlying Empress Formation are also likely to include a grout curtain, though the installation techniques may differ from those used within the bedrock of the Oldman Formation. Pressure grouting is not expected to be effective within the Empress Formation due to the fine-grained matrix that exists within much of this deposit. Jet grouting techniques may be required, or, alternatively, slurry trench techniques where practical. Additionally, full exposure of all outcrops of the Empress Formation encountered during construction and installation of filter zones at those locations may be required.

Depending on the effectiveness of the seepage cut-off efforts, it may also be necessary to install drainage tunnels below the spillway structure and within the left abutment upstream of the low level outlet excavation. An estimate of the cost of these tunnels has been included in the overall estimates developed for this study however, the actual location and configuration of these tunnels should be determined during subsequent stages of the design.

Careful characterization of the Oldman Formation as well as determination of the composition and distribution of the Empress Formation should be undertaken for both abutments during subsequent stages of the design.

3.2.4 Major Issues and Uncertainties

The major issues and uncertainties from a preliminary dam design and costing perspective relate to unknown or incompletely defined geological conditions. These can be categorized as follows:

North (Right) Abutment Borrow Source

The north abutment is expected to serve as the major source of materials for the low permeability core and for the shell. These are major assumptions in the design and costing of the dam. These source areas should therefore be thoroughly investigated to confirm the volumes and characteristics of the various materials. Haul road concepts should also be considered at this stage to confirm that exploitation is practical. Development of an additional borrow source (north of the dam site) for select granular material may be required.

One borehole in the north abutment (Borehole C3) carried out by PFRA in 1970, encountered granular material below a significant thickness of bedrock from the Oldman Formation. This finding raises the concern that old valley wall instabilities and/or large sections of glacially rafted or thrusted bedrock may exist in this area. The presence of this condition may affect stability conditions during construction, may affect seepage conditions within the abutment and/or may reduce the effectiveness of seepage cut-off walls.

Foremost and Oldman Formations

The physical properties of the Foremost and Oldman Formations will fundamentally affect the design and layout of the dam and appurtenant structures. In particular, the presence and

continuity of weak layers within these bedrock formations would affect the cost of the dam and the design cut slope for the major excavations.

Embankment Foundation Performance

The characteristics of the alluvium within the valley below the base of the main embankment may require foundation improvement to reduce settlements caused by embankment loading. Further, installation of foundation pressure relief wells may also be required. These issues may affect the cost as well as the schedule of the dam construction.

Tunnelling

Tunnelling conditions within the south abutment will be critical. Currently, it is assumed that the probable conditions are acceptable from a tunnelling perspective, however, this circumstance has not been thoroughly investigated. Bedrock conditions can have a significant effect on construction schedule and cost.

Foundation Seepage

Seepage conditions within the foundations of the embankment are uncertain and will need to be thoroughly examined during subsequent stages of design. At this time it is assumed that seepage can be controlled using a positive cut-off below the dam and, possibly, a system of relief wells at the toe of the dam. These seepage control elements, however, are costly and their design and configuration should be thoroughly examined.

Abutment Seepage

Control of seepage within the Oldman Formation and, in particular, the Empress Formation may prove to be very difficult to reliably achieve. It is possible that this issue could critically affect the technical viability of the dam at this location. Current information indicates that a significant challenge may exist. Additional investigation would be expected to determine whether or not this challenge can be practically addressed.

Reservoir Stability

Over 50 slides have been identified from the air-photo interpretation carried out by J.D. Mollard and Associates Ltd. as part of this study, including a slide within 1 km of the dam site. No assessment has been carried out regarding the nature of these failures, or the potential for new failures to form as a consequence of the creation of the reservoir. From a dam safety perspective, a concern exists with respect to slide induced waves that may overtop the dam. No specific allowance has been made in the current embankment concept to account for the freeboard required for such an event. It seems probable that significant landslide activity along the reservoir could take place in response to flooding. This possibility has been considered in the discussion on the effects on other infrastructure within and adjacent to the reservoir, provided in Section 6.1.1.

Regional Seepage

Regional seepage conditions are uncertain, and are expected to be closely related to the composition and configuration of materials deposited within large, pre-glacial valleys known to exist in the vicinity of the dam and reservoir. A good understanding of this surficial geology is needed so that a reliable regional groundwater model can be developed. The purpose of this model would be to identify possible significant effects of the dam and reservoir on the regional groundwater regime and the existing discharge zones within (for example) the Red Deer River valley. Refer to Section 5.7 for a discussion on groundwater issues in the Meridian area.

3.2.5 Estimated Costs

The estimated costs included in this section are related to embankment preparation and construction, associated earthworks, foundation drainage, and abutment drainage. Separate costs for cofferdam construction have also been included and are expected to be essentially the same for all three scenarios. The volume of the cofferdam that is within the upstream shell has been removed from the volumes used for estimation of the embankment construction costs. The costs associated with the highway approach cuts have been assumed to be part of the overall borrow costs for the embankment construction. Costs for the spillway and associated excavations, as well as costs for the diversion tunnels and associated excavations have been included in Sections 3.3 and 3.4.

The volumes used in this cost estimate are based on the available 1:20,000 digital elevation model and are approximate only. Unit costs are based on historical data as well as published heavy construction cost data. It should be noted that no royalty payment for exploitation of the borrow resource has been included in the costs. Components of estimated costs for Scenario 3 are provided in Table 3.2-2. The estimated costs for Scenarios 1, 2 and 3 are summarized in Table 3.2-3.

Table 3.2-2 Detailed Cost Estimate of the Dam for Scenario 3

Description	Estimated Quantity	Unit Cost	Estimated Construction Cost
Secondary Cofferdam Construction & Movement	50,000m^3	$6.00	$300,000
Cofferdam Foundation Preparation	35,000 m^3	$6.00	$210,000
Cofferdam Foundation Seepage Cut-Off Wall	4,000 m^2	$550.00	$2,200,000
Cofferdam Embankment Construction	1,025,000 m^3	$5.00	$5,100,000
Foundation Preparation & Core Trench Excavation	804,000 m^3	$10.00	$8,000,000
Seepage Cutoff Wall Below Base of Dam	4,000 m^2	$550.00	$2,200,000
Seepage Control Within North and South Abutments	35,000 m^2	$600.00	$21,000,000
Foundation Improvement	65,000 m^2	$10.00	$650,000
Embankment Placement and Compaction	12,900,000 m^3	$5.00	$64,000,000
Drainage Tunnels	750 m	$5,000.00	$3,800,000
Relief Wells	850 m	$160.00	$140,000
Filter Material & Toe Drain Material - Supply & Placement	1,100,000 m^3	$30.00	$32,600,000
Riprap Bedding Gravel - Supply & Placement	45,000 m^3	$20.00	$900,000
Rock Riprap - Supply & Placement	72,000 m^3	$75.00	$5,400,000
Subtotal			$147,000,000
Contingencies – 35%			$51,000,000
Construction Capital Cost for Embankment Scenario 3			**$198,000,000**
Engineering Costs – 20%			$39,600,000
Total Construction Cost for Embankment Scenario 3			**$237,600,000**

Costs for planning, engineering and project management have been included and are estimated at 20% of the capital cost. Estimates of annual operation and maintenance costs for the embankment are approximately 0.2% of capital costs (Agra Earth & Environmental 1997). These are included in the overall dam structure (embankment, spillway, and tunnels) operation and maintenance costs at 0.5% of the overall capital cost (pers. comm John Morrison, AENV). A brief explanation of each cost item is provided below.

- **Secondary Cofferdam & Move**. This item is intended to be an allowance for required for river training water needed to allow construction of a portion of the main cofferdam foundation and cut-off wall. It is assumed that these works would be moved at least once.
- **Cofferdam Foundation Preparation.** This item includes excavation, primarily with an excavator and truck operation, and removal to selected disposal areas within about 500 metres. It has been assumed that disposal of this material will be outside of the volumes required for the main embankment.
- **Cofferdam Foundation Seepage Cut-Off Wall.** This item includes all activities required for the construction of the cut-off wall within the alluvium. This includes shifting the works at least once during the construction of the cut-off wall and construction of a new temporary stream channel.
- **Cofferdam Embankment Construction.** This item includes all materials that would be part of the actual embankment for the cofferdam. No attempt has been made to separate the costs for the various select materials within the embankment. Cost only includes placement, spreading and compaction. Excavation and hauling is included. The unit is either spillway or tunnel excavation estimates.
- **Foundation Preparation and Core Trench Excavation for Main Embankment.** This item includes excavation primarily with an excavator and truck operation, and removal to disposal areas within 500 metres. Conditions at the abutments may require special treatment or double handling of materials. It has been assumed that disposal of this material will be outside of the volumes required for the main embankment.
- **Seepage Cutoff Wall Below Base of Dam.** The design of this seepage control element has been developed to a conceptual stage only. For the purposes of this estimate it is assumed that the cut-off wall will be installed using slurry trenching techniques and that it will consist of a plastic concrete mixture. This item includes supply of all material required for the work, installation of the cut-off wall and disposal of waste materials.
- **Seepage Control Within North and South Abutments.** A general concept only for this seepage control element has been developed. Pressure grouting may be used within the Oldman Formation, if the conditions prove to be amenable to this technique. A jet grouting process may be used within the Empress Formation if

location and character of this deposit allows this to be a practical tool. For the purposes of this cost estimate, the grout curtain has been assumed to extend about 25 metres below the underside of the core trench

- **Foundation Improvement.** Ground improvement may (or may not) be required at this site. The concept has been developed only to a preliminary stage and is intended to be applied to the foundation of the core only. A number of methods could be used, however, for the purpose of this study, dynamic consolidation techniques have been assumed.
- **Embankment Placement and Compaction.** This item includes spreading and conditioning fill as well compaction of that fill. The cost of water for compaction is included. The overall volumes exclude the volume within the upstream shell occupied by the cofferdam. The cost to excavate and haul this volume is included in the costs identified for the spillway and diversion tunnels. For Scenario 3, the planned excavation generates approximately 9,000,000m^3 greater volume than is required for dam construction. For Scenarios 1 and 2, this excess excavation volume significantly increases to 20,000,000m^3 and 33,000,000m^3, respectively. The cost to haul this extra material to waste has been included in Section 3.3.
- **Drainage Tunnels.** This item includes excavation and lining two tunnels, approximately 6 m in diameter. One tunnel will be in the right abutment and extend below the spillway structure. One will be within the left abutment and will be intended to drain both the Oldman and the Empress formations behind the low level outlet excavation.
- **Relief Wells.** Relief wells are assumed to be drilled and screened and approximately 200 mm in diameter.
- **Filter Material Supply and Placement.** It is anticipated that this material will be manufactured from the alluvial terraces that exist within the planned cuts or a terrace gravel deposit north of the dam site. This item includes excavation, processing, hauling with trucks, spreading and compaction.
- **Toe Drain Material.** It is anticipated that this material will be manufactured from the terrace gravel within the planned cuts or a terrace gravel deposit north of the dam site. This item includes excavation, processing, truck haulage and placement.
- **Rip-Rap Bedding Gravel.** It is anticipated that this material will be manufactured from the terrace gravel within the planned cuts or a terrace gravel deposit north of the

dam site. Similar to the other processed materials, this item includes excavation, processing, truck haulage and placement.

- **Rip-Rap Supply and Placement.** No source of rip-rap has been identified in the vicinity of the potential dam site. It has been assumed, therefore, that rip-rap will have to be brought in from the Rocky Mountains. The costs are difficult to estimate at this stage since they are highly dependent on the source and the transportation methods actually used. This item includes production at the quarry, transportation and placement.

Table 3.2-3 summarizes the costs for all three reservoir storage scenarios being considered in this study.

Table 3.2-3 Estimated Embankment Costs for Scenarios 1, 2 and 3

Description	Estimated Construction Capital Costs	Estimated Engineering Costs[1]	Estimated Total Construction Costs
Scenario 1	$77,000,000	$15,400,000	$92,400,000
Scenario 2	$126,000,000	$25,200,000	$151,200,000
Scenario 3	$198,000,000	$39,600,000	$237,600,000

[1] Engineering Costs were estimated at 20% of the capital costs

The costs shown in Table 3.2-3 have been developed by pro-rating the costs of the embankment by the relative volumes. For each scenario, however, the cost of seepage cut-off below the dam, drainage tunnels within abutments, as well as the overall cofferdam costs, have been kept constant.

3.3 Diversion, Outlet Works and Spillway Design

This section describes the diversion tunnels, outlet works, and spillway structure potential for the Meridian Dam development. The general arrangement, design basis, issues and uncertainties, and estimated costs are described in the following sections.

3.3.1 General Arrangement

The diversion works, low level outlet works, and spillway structure are located in the same general arrangement as previously potential in the "South Saskatchewan River Drowningford Project, Meridian Site, Preliminary Design Report, PFRA, July 1970."

The diversion tunnels are at the south abutment, and the spillway on the north abutment as shown on Figure 3.2-2. The diversion tunnels would be maintained as permanent facilities to provide for downstream riparian water requirements and hydropower production

PFRA indicated in their report that the spillway was located on the higher north abutment primarily because more suitable materials needed for construction of the dam (impervious and granular materials) could be derived from this location through excavations for the spillway and approach channel. The tunnels were located on the south abutment primarily because of a substantial thickness of slopewash at the base of the north valley slope which could result in slope stability issues, particularly at the inlet structure.

A review of the available geotechnical data and stratigraphic information indicates that locating the spillway on the north abutment would be advantageous as increased fill materials could be obtained from structure related excavations rather than from borrow sources. With the spillway at the north abutment, the low level outlet works should be located at the south abutment to avoid all of the outlet facilities at the same side of the river.

3.3.2 Design Basis

The design basis for the various outlet facilities are discussed below.

<u>Diversion Tunnels, Cofferdam, and Outlet Works</u>

Four 6.7 m diameter concrete lined diversion tunnels with an average length of approximately 1,220 m would be constructed at the south abutment in order to divert river flows and permit construction of the dam. A discharge rating curve for the tunnels was developed as shown on Figure 3.3-1.

Figure 3.3-1 Diversion Tunnel Discharge Rating Curve

Figure 3.3-2 Diversion Tunnels 1:25 Year Flood Routing

Figure 3.3-3 Diversion Tunnels 1:50 Year Flood Routing

Flood routing simulations were conducted to assess the height of the cofferdam that would be required. Simulations were conducted for the 1:25 and 1:50 year flood events with peak inflows of 3,117 and 3,877 m^3/s, respectively, as discussed in Section 3.1-2. The results are shown graphically on Figures 3.3-2 and 3.3-3, and are summarized in Table 3.3-1.

Table 3.3-1 Diversion Tunnels and Cofferdam Requirements

Flood Event	Peak Inflow (m^3/s)	Peak Routed Outflow (m^3/s)	Maximum Routed Water Level (m)	Minimum Cofferdam Height (m)
1:25 Year	3,117	1,326	606.7	26.7
1:50 Year	3,877	1,434	610.5	30.5

The results indicate that a minimum cofferdam height of 26.7 m would be required for the 1:25 year flood, and 30.5 m for the 1:50 year flood. A cofferdam height designed for the 50 year flood is assumed since this criterion is generally consistent with that for other large dam projects.

Two of the diversion tunnels would be designed to operate as the permanent low level outlet facility and the other two would be designed to accommodate hydropower development. The tunnels would include a vertical control shaft structure, and gates or valves to control releases from the reservoir.

Spillway

Based on the Canadian Dam Association, Dam Safety Guidelines (January 1999), the Meridian Dam would be considered as a "Very High Consequence" dam. Consequently, the inflow design flood for the project would be the probable maximum flood (PMF). As a result, the spillway structure is sized to safely pass the PMF.

The 1:500 year, 1:1000 year and PMF events have peak inflows of 6,660 m^3/s, 8,308 m^3/s, and 20,844 m^3/s, respectively, as discussed in Section 3.1.2. The conceptual design of the spillway structure is based on these events.

The hydraulic capacity of the spillway was sized to enable the 1:500 year peak inflow to be passed with the reservoir at FSL (i.e. no surcharge in flood storage). With the crest of the ogee

weir set 8.6 m below the FSL, a crest length of approximately 144 m would be needed as shown on Figure 3.2-3. Piers would be incorporated to divide the crest section into twelve 12 m wide bays, and to accommodate the radial gates that would be required for flow control. It was estimated that with the addition of piers, the overall width of the crest section would be approximately 200 m.

Flood routing simulations were conducted to determine the surcharge in reservoir level that would occur during the 1:1000 year and PMF events. The simulations were based on an initial reservoir level at FSL, with no releases through the low level outlet works. The resulting flood levels, inflows and outflows are summarized in Table 3.3-2 and 3.3-3, and shown graphically on Figures 3.3-4 and 3.3-5 for Scenario 3.

Table 3.3-2 Flood Routing Simulations for the 1:1000 Year Flood

Description	**1:1000 Year Peak Inflow** (m^3/s)	**1:1000 Year Peak Routed Outflow** (m^3/s)	**Maximum Reservoir Surcharge** (m)
Scenario 1: FSL 621.8 m	8,308	7,505	0.49
Scenario 2: FSL 635.5 m	8,308	7,332	0.35
Scenario 3: FSL 646.2 m	8,308	7,232	0.27

Table 3.3-3 Flood Routing Simulations for the PMF

Description	**PMF Peak Inflow** (m^3/s)	**PMF Peak Routed Outflow** (m^3/s)	**Maximum Reservoir Surcharge** (m)
Scenario 1: FSL 621.8 m	20,844	14,970	5.81
Scenario 2: FSL 635.5 m	20,844	13,328	4.74
Scenario 3: FSL 646.2 m	20,844	12,261	4.02

The crest section is located approximately in line with the centreline extension of the dam. A bridge deck would be provided so that the secondary highway can be relocated across the spillway and dam. A drainage gallery would be constructed within the base slab of the spillway crest section to collect seepage water that is intercepted by the pressure relief drains that extend into the underlying rock foundation. To reduce seepage, a grout curtain would also be installed beneath the spillway crest, as discussed in Section 3.2.3.

Figure 3.3-4 Spillway Structure 1:1000 Year Flood Routing (Scenario 3)

Figure 3.3-5 Spillway Structure PMF Flood Routing (Scenario 3)

Figure 3.3-6 Meridian Dam Tailwater Rating Curve

A transition chute section would be provided downstream of the spillway crest to accommodate a reduction in chute width from 200 m to between 150 m and 165 m, depending on the scenario being considered. The profile of the chute would consist of a upstream slope of 14H:1V and a downstream slope of 4H:1V. The overall length of the chute would be dictated by the change in elevation between the invert of the approach channel and the outlet channel. Beneath the chute slab, an underslab drainage system would be provided consisting of: a drainage gravel and filter sand blanket; transverse slotted collector drain pipes; and, collector manholes with longitudinal conveyance pipes.

A hydraulic jump stilling basin is provided for energy dissipation. The basin is conceptually designed to provide optimum hydraulic performance during the 1:1000 year event, and less than optimum during the PMF. The floor of the basin is set below the existing riverbed elevation so that a suitable sequent depth for jump formation is provided during both the 1:1000 year and PMF events. In the absence of detailed survey data and channel information, corresponding tailwater levels were estimated using a simplified flow analysis. The rating curve developed was extrapolated for high flows, associated with flood conditions, and is illustrated in Figure 3.3-6. Provisions for preventing displacement of the basin due to uplift pressures during jump formation could include: using a thick concrete slab; extending the slab beyond the sidewalls to mobilize the weight of backfill; installing anchors; and, providing a underslab drainage system including pumping equipment.

Approach and Outlet Channels

An approach channel would be provided to connect the reservoir to the spillway. The channel invert elevation would be set at the same elevation as the spillway crest slab, and the channel bed width would be equal to the total crest width. It is expected that riprap erosion protection would be provided on the sides of the approach channel, and along the bed immediately upstream of the spillway.

Downstream of the hydraulic jump stilling basin, an outlet channel would be provided to permit spillway releases into the river. The bed width of the channel would be the same as the basin width. A transition slope would be provided to accommodate the difference in elevation between the proposed basin and the existing river bed. Riprap erosion protection would be provided on the invert and sides of the outlet channel.

3.3.3 Major Issues and Uncertainties

Major issues and uncertainties related to diversion tunnels, outlet works and the spillway pertain to: hydrology; hydraulics; geological; and, geotechnical conditions including seepage and drainage concerns, and availability and suitability of local materials for use in construction. These issues are discussed below:

- Any uncertainities in the peak flood inflows and volumes would have an impact on the size and discharge capacity of the diversion and/or spillway facilities.
- Tailwater conditions and flow velocities in the river during the passage of various flows including the PMF, are important factors affecting the design and performance of the spillway, diversion tunnels, and low level outlet works. In the absence of data, these conditions were estimated by rough approximation.
- Erosion needs to be examined as it could affect the stability of the dam, spillway structure, and valley slopes adjacent the dam and spillway.
- Rock quality must be determined as this could have significant impacts on excavation, tunnelling, protection requirements for weathering, and seepage control.
- Stability of slopes and embankments, foundation movements, groundwater conditions, and seepage control and drainage measures need to be assessed.
- The suitability of local materials for use in construction should be determined.

Geological and geotechnical issues pose significant uncertainty. These issues could have significant impact on the design, construction, performance and cost of the diversion tunnels, outlet works, spillway, and channels.

3.3.4 Estimated Costs

General

Cost estimates were derived using historical cost information from other large dam projects in Alberta and Saskatchewan including the Oldman River Dam, St. Mary Dam, Dickson Dam, and the Gardiner Dam. Specific project costs were converted to 2001 dollars using the Canadian non-residential building construction index.

Adjustments were made where necessary to reflect specific site conditions and design requirements for the appurtenant structures that would be required for the Meridian Dam project.

Diversion Tunnels

As noted in Section 3.3.2, four 6.7 m diameter concrete-lined tunnels with a combined total length of about 4,880 m would be required for construction diversion purposes. This arrangement would be required irrespective of the scenario that might be adopted for the project. The construction cost for the diversion tunnels is estimated at $232,000,000 as indicated in Table 3.3-4. The cost includes: excavation, tunnel lining, inlet and outlet structures, vertical control shaft and gates for four tunnels, and riprap erosion protection. The cost components of the gates is approximately $15,000,000. Engineering costs have been estimated at 20% of the total capital cost of the diversion tunnels. Costs for hydropower facilities are discussed separately in Section 3.4.5.

Table 3.3-4 Diversion Tunnels Estimated Costs

Scenario	Estimated Cost
Scenario 1, 2, and 3	$232,000,000
Contingencies – 35%	$81,000,000
Construction Costs	**$313,000,000**
Engineering Cost – 20%	$62,600,000
Total	**$375,600,000**

Spillway

As noted in Section 3.3.2, the proposed reinforced concrete spillway structure is located on the north abutment. Existing ground at the top of the valley is around 670 m. Consequently, as the FSL is lowered from 646.5 m for Scenario 3 to 621.8 m for Scenario 1, differences in spillway capacities configurations would occur and affect construction costs. These differences and impacts would include the following:

- Reduced flood routing effects, which would increase the required spillway capacity.
- Reduced change in elevation between the approach channel and outlet channel, which would reduce the chute length but increase the length of the outlet channel.

- Lower approach channel and spillway elevations, which would increase excavation requirements.

Table 3.3-5 Spillway Construction Cost Estimates

Description	Estimated Quantity	Unit Cost	Estimated Construction Costs
Scenario 1- FSL 621.8 m			
Spillway Structure			$81,000,000
Riprap and Riprap Bedding	205,000 m^3	$54/$m^3$	$11,100,000
Excavation	26,430,000 m^3	$4.50/$m^3$	$118,900,000
Control Building			$ 1,500,000
		Sub-total	$212,500,000
		Contingencies – 35%	$74,000,000
		Construction Cost	**$286,500,000**
		Engineering Cost – 20%	$57,300,000
		Scenario 1 Total Cost	**$343,800,000**
Scenario 2 – FSL 635.5 m			
Spillway Structure			$104,000,000
Riprap and Riprap Bedding	238,000 m^3	$54/$m^3$	$13,000,000
Excavation	17,850,000 m^3	$4.50/$m^3$	$80,300,000
Control Building			$ 1,500,000
		Sub-total	$198,800,000
		Contingencies – 35%	$70,000,000
		Construction Cost	**$268,800,000**
		Engineering Cost – 20%	$53,760,000
		Scenario 2 Total Cost	**$322,560,000**
Scenario 3 – FSL 646.2 m			
Spillway Structure			$123,000,000
Riprap and Riprap Bedding	282,000 m^3	$54/$m^3$	$15,400,000
Excavation	11,750,000 m^3	$4.50/$m^3$	$52,900,000
Control Building			$ 1,500,000
		Sub-total	$192,800,000
		Contingencies – 35%	$67,000,000
		Construction Cost	**$259,800,000**
		Engineering Cost – 20%	$51,960,000
		Scenario 3 Total Cost	**$311,760,000**

Cost estimates for each scenario are provided in Table 3.3-5. The excavation costs include the excavation required for the approach channel, spillway structure, and outlet channel. The spillway structure cost includes: reinforced concrete required for the crest, chute and stilling basin; radial gate systems; underslab drainage systems including pressure relief drains at the crest; structure backfill materials; structure instrumentation; and, secondary highway bridge. Costs associated with the proposed deep drainage adit and for providing a grout curtain at the north abutment are included in the dam costs discussed in Section 3.2.5. Riprap and riprap bedding costs are estimated for the erosion protection works required at the approach and outlet

channels. Costs for providing a control building that is needed to house the control equipment and facilities for conducting operations and maintenance activities for the project are included. Engineering costs are included and estimated at roughly 20% of capital costs.

Annual operation and maintenance costs for the overall dam structure (embankment, diversion tunnels, and spillway) are assumed to be 0.5% of total dam costs as described in section 3.2.5.

3.4 Hydropower

A preliminary evaluation of hydropower feasibility at the potential Meridian Dam was undertaken using the reservoir releases estimated by water management modeling by Alberta Environment. It was assumed that all the flow released downstream of the dam would be available for hydropower generation. The site has sufficient head and flow for hydropower production, and such a development would be attractive if capital costs did not include construction of the dam and diversion tunnels. This scenario represents development of the Meridian Dam for irrigation purposes, with hydropower considered as an opportunistic benefit. The costs provided in this section also assume that reasonable provisions are made at initial design and construction stages to accommodate the necessary hydropower components.

A second scenario was considered representing construction of the Meridian Dam for maximum hydropower production, with zero irrigation off-take. This scenario does not appear to be feasible as dam construction and diversion costs would have to be considered (see Economic Analysis, Section 8.4.4).

3.4.1 Hydropower Analysis

A hydropower generation model was developed with its input being the reservoir level and downstream release results from the water resources management model (WRMM). The WRMM modeling focused on overall water management for the potential irrigation reservoir, and as such did not incorporate any optimization for hydropower potential. The gross head available was calculated as the difference between the simulated reservoir level and an assumed constant tailwater level. It was assumed that all flow released downstream was available for hydropower generation taking into consideration expected limits on tunnel capacity. Model data such as

conveyance headloss, turbine-generator efficiency, operation limits, and transmission availability were estimated from literature and other projects.

A range of hydropower capacities was analyzed for each of the three project scenarios to understand the following characteristics:

- Average annual energy production
- Variation in annual energy production
- Lost production
- Time at capacity (capacity factor)

A summary of the model results is presented in Table 3.4-1 and Figure 3.4-1. These represent the hydropower potential of each of the three scenarios and their associated irrigation areas at full irrigation development. As shown, energy production is proportional to the target irrigation acreage and plant capacity. This is primarily due to the large reservoir storage and corresponding available gross head. Table 3.4-2 also provides a summary of modeling results for the three scenarios (with varying FSL) at Year 0 when irrigation development has not yet begun. WRMM outflows and water levels for Scenario 3 with zero irrigation off-take were used to determine the energy and capacity factors associated with this maximum hydropower scenario. Energy and capacity factors for Scenarios 1 and 2 were estimated using outflows and water levels for Scenario 3, and adjusting the water levels to reflect differences in full supply levels. The same outflows were assumed for all scenarios.

Table 3.4-1 Summary of Power and Energy Model Results (Full Irrigation Development)

Scenario	Scenario 1		Scenario 2		Scenario 3	
	Energy	Capacity Factor	Energy	Capacity Factor	Energy	Capacity Factor
	(GWh)	(%)	(GWh)	(%)	(GWh)	(%)
40	237	68	269	77	272	77
60	265	50	303	58	331	63
80	284	40	323	46	359	51
100	291	33	340	39	372	42
120	292	28	353	34	390	37
140	-	-	-	-	-	-
160	-	-	-	-	-	-
180	-	-	-	-	-	-
200	-	-	-	-	-	-

Note: – indicates scenario was not analysed.

Figure 3.4-1 Power and Energy Model Curves

Table 3.4-2 Summary of Power and Energy Model Results (Year 0 - No Irrigation Development)

Scenario	Scenario 1[1]		Scenario 2[1]		Scenario 3	
	Energy	Capacity Factor	Energy	Capacity Factor	Energy	Capacity Factor
	(GWh)		(GWh)		(GWh)	
40	-	-	-	-	NA	NA
60	-	-	-	-	NA	NA
80	315	45	371	53	494	70
100	323	37	391	45	525	60
120	324	31	406	39	550	52
140	-	-	-	-	566	46
160	-	-	-	-	575	41
180	-	-	-	-	580	37
200	-	-	-	-	583	33

Note: – indicates scenario was not analysed.
[1] Energy and capacity factors for Scenarios 1 and 2 were estimated using outflows and water levels associated with Scenario 3 (no irrigation development), with the water levels adjusted for differences in reservoir full supply levels.

3.4.2 Feasibility & General Arrangement

The optimum hydropower capacity and development strategy is very much a function of the energy markets, valuation of intangible benefits, and risk that are beyond the scope of this study. Nevertheless, the feasible range of hydro development plant sizes and probable arrangement of components can be assessed based on the hydropower analysis, estimated cost, and past experience.

The site has sufficient head and flow for hydropower development and would be economically attractive since the cost for the dam and spillway works would not be included.

The minimum plant capacity that should be considered is based on the minimum instream objective release of 42.47 m^3/s. For the largest project scenario, Scenario 3, this capacity would be about 20 MW. At 20 MW, such a project would operate at capacity near 100% of the time. From experience, a higher plant capacity would be more economically attractive. However, the minimum release will occur nearly 40% of the time, meaning a considerable portion of the

hydropower energy will be produced at this flow. Therefore, consideration should be given to the hydropower plant operating efficiently at this minimum flow.

The head available for power generation fluctuates with reservoir level. For Scenario 3, it ranges from 8 to 66 metres. Since the reservoir will be at or near full supply level for close to 40% of the time, the plant should be designed to operate efficiently at near full head. However, the plant will not be able to operate continuously due to insufficient head when the reservoir is near its lowest level. The minimum operating head will be a function of the turbines selected. Variable blade Kaplan technology can accommodate a wider head variation than Francis machines, but may cost more. Therefore, the value of any additional energy must be properly considered. Whichever turbine is selected, the resulting lost energy will be a small portion of the total expected production and will not affect the feasibility of hydropower development.

There is a practical and economic limit to the development capacity of the site. Tunnel costs and construction constraints may be such that the minimum size for diversion is most economic. Therefore, the hydropower capacity would be limited by either the velocity or headloss restrictions, posed by the selected tunnel configuration. However, a preliminary analysis indicates that the tunnels can support much higher flow rates than will be available. To meet diversion requirements during construction, the tunnels have been preliminarily sized at 6.7 m in diameter. At this size, it is likely that the low-level outlet flow will limit hydro production, not the tunnel conveyance capacity.

Design Basis

From the above power and energy analysis and experience with similar projects, an installed capacity of 80 MW consisting of four units seems most appropriate for all three scenarios. The arrangement of an appropriate plant (for Scenario 3 as an example) would comprise the following:

Plant Capacity	80 MW
Number of Units	4
Maximum Plant Flow	154 m^3/s (77 m^3/s per tunnel)
Minimum Plant Flow	42.47 m^3/s (minimum apportionment release)
Turbines	Francis or Kaplan
Maximum Gross Head	66 m
Headloss at Capacity	1 m (at maximum output)

Net Head at Capacity	65 m
Average Net Head	54 m
Minimum Operating Net Head	20 to 30 m
Capacity Factor	51%
Average Annual Energy	360 GWh/year
Transmission Line	20 km, 138 kV to McNeill substation

The associated power duration curve is presented as Figure 3.4-2.

In other recent larger capacity hydro developments, the selection of multiple units over a single unit has proven to be the better option for several reasons including:

- similar cost
- easier handling of smaller components
- ability to use more easily constructed horizontal-shaft machines versus vertical-shaft arrangements
- system reliability/redundancy
- greater and more efficient range of operation

Two of the four tunnels would be used for hydropower while the other two would remain as bypass tunnels. With two tunnels for hydropower, a two or four unit development is appropriate. Dividing the 80 MW capacity in four gives a unit capacity of 20 MW that would be well suited to operation during times of minimum release. Each unit would consist of a Francis or Kaplan-type turbine coupled to a synchronous generator. It may be possible to install horizontal shaft units, but due to space restrictions vertical shaft units may be more suitable. The key deciding factor here is the offset distance between tunnel outlets and the size of the outlet structure itself.

The velocity and headloss criteria were based on 6.7 metre diameter tunnels, sized to meet the construction diversion requirements. The tunnel outlet elevation and the elevation of the base slab beyond the outlet structure must be set to accommodate the turbines and draft tubes in accordance with the river tailwater levels downstream.

Figure 3.4-2 Power Duration Curve

To construct the hydro facility, a cofferdam will be installed around half the outlet area and the area will be dewatered. The power tunnel outlets will be designed or modified to accept a steel penstock and wye bifurcation. The four turbines will be connected to the ends of the bifurcations and installed on the concrete powerhouse foundation. The generators as well as auxiliary equipment will be in the powerhouse located within the outlet structure. Water will exit the turbines via draft tubes and continue downstream. A wicket gate and governor system will provide turbine flow control during operation. Each unit will be equipped with a butterfly valve upstream of the wicket gates to enable unit isolation.

Transmission infrastructure will consist of a substation near the powerhouse and a 138 kV line to the nearest substation, located approximately 20 km away near McNeill, Alberta. Upgrades to the equipment at the McNeill substation will likely be required. This needs to be investigated with the Transmission Administrator (ESBI). For construction of the works besides the hydro facility it is estimated a 69 kV line for site power will be required. Assuming the hydroplant will be built shortly after the dam completion, it is more economical to install a 138 kV standard line but operate it at 69 kV with a 69 kV substation during construction. The substation should be designed to be readily expanded such that additional transformers can be added to upgrade the system to 138 kV for the later addition of the hydro plant.

3.4.3 Major Issues and Uncertainties

Major issues and uncertainties related to a hydro facility at the Meridian Dam site include:

- Development Strategy
- Water Licensing
- Outlet and Tunnel Design
- Transmission and Interconnection Requirements
- Hydropower Development without Irrigation

These issues are discussed in detail below:

Development Strategy

The construction of the hydropower facility could be a part of the initial project development or completed afterwards. The incremental cost of including hydropower will be less if it is built concurrently and could be significantly higher if built later. However, in the case of building afterwards, there is a range of provisions that could be included in the initial construction that would facilitate hydropower development and significantly reduce the incremental additional cost of construction afterwards. The extent of the provisions would be a function of the project development strategy and the associated parties.

Key development strategy alternatives to consider include:

- Build the Plant and then Sell - Facility constructed by government owner and sold to a private entity
- Lease the Site with Royalties – Long term site lease agreement between government owner and a private entity with a revenue sharing royalty arrangement
- Sell the Site - Hydro provisions included in the development of the reservoir by government then sale of the site to a private entity upon project completion for hydro development

Each of these strategies needs to consider the longterm benefits and risks desired by the proponents and should intrinsically include compensation for the embedded provisions of the project. It is assumed, given electrical market deregulation, that the government would not consider owning the hydroplant on a long-term basis.

Water Licensing

The water licensing process for the project will trigger a review under the Canadian Environmental Assessment Act (CEAA). If the hydroelectric facility is not developed at the same time as the dam, the water licensing process can be undertaken either with or without the hydro plant included. If the water license is obtained for the facility without the hydro facility, then a new license will have to be obtained for the development of the hydro plant. The licensing process for the hydroelectric plant could again trigger a review under CEAA. As the CEAA review process can be rather involved, and therefore costly, the best approach would likely

include the hydro facility in the initial water license even if it is developed at a later stage. A regulatory legal review of this strategy is required to ensure that this approach is acceptable.

Tunnel and Outlet Works

The arrangement and design of the tunnel and outlet must be done with consideration of the hydro facility. Some of the major issues to be considered include:

- Tunnel capacity may be a function of one or more of the following: diversion requirements, minimum release, hydropower capacity, flood flow passage.
- The tunnels may be designed as half pressure conduit and half open flow conduit with the control valves at an intermediate location, or as complete pressure conduits with valves at the outlet ends. The latter is better suited to hydropower development. The benefits and costs of each option should include the effect on the capital cost of hydropower development.
- Control valves for operation of the tunnels as low-level outlets are costly, therefore, consideration should be given to the use of only 2 tunnels for low level operation or gated tunnels with an energy dissipation outlet basin design. Valves or gates that would be suitable for the hydropower works could be used in the other two tunnels.
- The tunnel elevation and channel invert downstream of the outlet structure should be set with consideration of the hydro plant design requirements.
- The outlet structure and area downstream should be able to readily facilitate the cofferdam for a post-constructed hydro plant and consider minimizing instream work and environmental impacts.

Given the site geology and topography, it is likely that only a small premium relative to the overall project cost would be incurred to better accommodate the hydro development than if these components are not provided initially. The potential saving could be several million dollars.

Transmission and Interconnection Requirements and Issues

A 138 kV transmission line is located approximately 10 km away from the site and the closest substation is located approximately 20 km away. Interconnection with the Alberta grid would require interconnection at the nearest substation. However, if the existing substation cannot

handle the required expansion when the project is initiated then the construction of a new substation would be required. The interconnection and transmission agreement for the project should include provisions for future hydro development capacity.

The Alberta and Saskatchewan electricity systems are out of phase, therefore, the site will have to interconnect with either the Alberta or Saskatchewan system. Without expensive phase conversion facilities power cannot flow between Alberta and Saskatchewan. The existing McNeill converter station is located approximately 20 km from the proposed site, however, it is limited to 150 MW of transfer capability. Until future interconnection facilities are developed transmission between Alberta and Saskatchewan may be difficult. SaskPower has historically been legislated as the sole owner of transmission facilities in Saskatchewan but they are currently in the process of implementing an Open Access Transmission Tariff with firm service expected to commence January 1, 2002.

Maximized Hydropower Development (Without Irrigation)

The bypass tunnels, which are sized to meet the diversion requirements, have abundant hydraulic conveyance capacity for increased hydropower development.

The proposed irrigation infrastructure will be relatively costly to construct, and the rate of construction will be dictated by the agricultural economy. As discussed in Section 8, it is expected that full irrigation development would take between 31 and 44 years to complete for the three scenarios. Therefore, it may be prudent to develop a larger hydro facility to generate an increased revenue stream that could significantly offset the capital cost of the dam, reservoir pumping and water delivery systems.

To evaluate this Maximized Hydro Scenario the water resources management model was run without irrigation and with maximum reservoir water levels associated with Scenario 3. Based on the power and energy analysis for this scenario, an installed capacity of 160 MW consisting of four units seems most appropriate. The average annual energy production is expected to be approximately 575 GWh with a capacity factor of approximately 41%. These energy and power modelling results are shown in Table 3.4-3 for each scenario.

Table 3.4-3 Power and Energy Model Results for Maximized Hydropower Development

Maximized Hydropower Scenario	Scenario 1		Scenario 2		Scenario 3	
	Energy	Capacity Factor	Energy	Capacity Factor	Energy	Capacity Factor
	(GWh)	(%)	(GWh)	(%)	(GWh)	(%)
40	-	-	-	-	NA	NA
60	-	-	-	-	NA	NA
80	315	45	371	53	494	70
100	323	37	391	45	525	60
120	324	31	406	39	550	52
140	-	-	-	-	566	46
160	-	-	-	-	575	41
180	-	-	-	-	580	37
200	-	-	-	-	583	33

Note: – indicates scenario was not analysed.

Details including the power and energy model results, power duration curve, plant arrangement and cost estimates for Scenario 3 Maximized Hydropower development are presented in Appendix V.

3.4.4 Estimated Costs

The estimated costs for hydropower development are presented in Table 3.4-4. The costs are based on experience with similar projects and adjusted accordingly. They also assume the following:

- 4 identical Francis Turbines, 80 MW total
- Scenario 3 FSL, 6.7 m diameter penstock
- tunnels are designed as full-length pressure conduits
- the hydro facility is constructed after the dam project is commissioned; and
- reasonable provisions are made during initial construction to readily accept the hydro facility, particularly the tunnel control valves/gates, tunnel outlets and outlet structure.

Entire transmission line/substation cost is included here even though a 69 kV service will be required for the dam project, regardless of the hydro development.

Table 3.4-4 Hydropower Cost Estimates

Description	Estimated Costs
3.4.4.1.1 Capital Works	
• Site preparation including cofferdams, dewatering, and environmental work.	1,000,000
• Bypass control valves/gates and associated works	Not included[1]
• Steel penstocks from outlet to powerhouse and bifurcations	5,000,000
• Turbine-generator equipment supply c/w controls, switchgear, draft tubes and associated operating auxiliaries	37,000,000
• Powerhouse foundation and related concrete encasement of penstocks, turbines, draft tubes, etc.	6,000,000
• Powerhouse building with misc. powerhouse mechanical and electrical equipment	3,000,000
• Meridian 100 MVA substation c/w transformers and civil works	3,000,000
• 20 km - 138 kV Transmission line	5,000,000
• McNeill substation upgrade	2,000,000
Subtotal Capital Works	**$62,000,000**
Contingency (35%)	$22,000,000
Total Construction Capital Cost	**$84,000,000**
Engineering Cost (20%)	$17,000,000
Total Estimated Cost	**$101,000,000**

[1] Included as part of riparian outlet system.

These cost estimates include costs associated with engineering, project and construction management, temporary facilities, and site management. It is estimated that these costs would be on the order of 20% of capital costs, or roughly $17 million. Annual operation and maintenance costs are estimated at 2.2% of capital costs plus inflation. This represents roughly $1.8 million for the first year.

3.5 Irrigation Water Delivery System

An irrigation water supply system consisting of irrigation outlet works at the Meridian Dam reservoir and irrigation delivery facilities to the outlying areas would be required for the Meridian Dam development. These works normally involve large capital costs comparable to the development costs of the reservoir headworks. This section describes the potential water delivery systems and their basic conceptual design. The design was selected to serve as a basis for estimating rough costs for the financial analysis of the project. There are many variations and options that would need to be considered in a complete feasibility study.

3.5.1 General Arrangement

Based on the WRMM results discussed in Section 2.2, the potential Meridian reservoir would enable new irrigation in the range of 162,000, 202,000, and 243,000 hectares for Scenarios 1, 2, and 3, respectively. The irrigation volumes associated with these blocks come out of Alberta's entitlement under the Apportionment agreement, as reservoir outflows would still meet apportionment requirements to Saskatchewan.

Based on the discussion of land suitability for irrigation provided in Section 2.1, irrigation blocks were located on the lands around the potential development. They were designed to include the greatest amount of area with irrigation ratings of good and fair, as illustrated on Figure 3.5-1. In general, it appears that irrigation development in the region would be limited by land suitability rather than water availability. Although the above irrigation allocations (162, 202, and 243 thousand hectares) reflect Alberta's entitlement to water, no priority was given at this stage of preliminary feasibility to providing the available irrigation to blocks in either Alberta or Saskatchewan. If the project proceeds to further levels of assessment, this is one area that would require additional consideration.

Figures 3.5-2 to 3.5-4 present schematics of the irrigation water delivery systems for the three Meridian Dam development scenarios, involving irrigated areas of 162,000 ha, 202,000 ha, and 243,000 ha, and associated with reservoir volumes of 1.2, 2.4, and 3.7 billion m^3, respectively. The water delivery systems include two pump stations, a series of pressure pipelines and some booster pump stations to supply irrigation water to selected irrigation blocks. The systems shown on the figures are main water supply systems and do not include irrigation distribution systems within each irrigation block.

Table 3.5-1 summarizes the irrigation infrastructure associated with each of the three scenarios.

Table 3.5-1 Irrigation Infrastructure Summary Table

Scenario	Number of River Pump Stations	Number of Main Pipelines	Number of Secondary Pipelines	Number of Booster Pumps	Number of Canals
1	2	5	7	7	7
2	2	4	11	9	10
3	2	5	15	13	13

Figure 3.5-1 Irrigation Suitability and Potential Irrigation Blocks

Figure 3.5-2 Potential Irrigation Distribution System for Scenario 1

Figure 3.5-3 Potential Irrigation Distribution System for Scenario 2

Figure 3.5-4 Potential Irrigation Distribution System for Scenario 3

Details of the water supply delivery systems are discussed below.

Pump Stations

Pump stations are needed to raise irrigation water from the reservoir level to a location beyond the river valley, from where water can be supplied by gravity. Most irrigation districts are served by gravity reservoir outlet structures and headworks canals. However, all potential irrigated areas served by the Meridian Dam would need to be supplied by pumps and a combination of pipeline and gravity canals. The reason for this costly difference is that the potential reservoir levels (maximum 646 m) are lower than the ground levels at the potential irrigated areas.

One pump station is required on each side of the South Saskatchewan River Valley, to serve each side separately. The pump stations are located at the upstream end of the dead storage pool to provide effective water delivery to all potential irrigation blocks irrespective of reservoir elevation over the range of live storage levels (i.e., 587 m to FSL).

Water Distribution Systems

Irrigation water supply pipelines and some gravity canals would convey water from the reservoir pump stations directly to a convenient high point distribution location within each irrigation block. Beyond the distribution locations, irrigation water could be distributed by gravity to the irrigated areas (refer to Section 3.6). Because of adverse topography, a combination of pipelines and gravity canals are required between the pump station and the distribution location.

Irrigation Blocks

Despite the preliminary nature of this study, it was necessary to tentatively select irrigation blocks to serve as a basis for cost estimates related to water supply distribution. Potential irrigation blocks were selected to encompass the greatest amount of irrigable area with ratings of good or fair, as illustrated in Figure 3.5-1. Table 3.5-2 lists the 10 main irrigation blocks (a total of 22 sub-blocks) along with the irrigable area in each plot. Irrigation blocks are located in both Alberta and Saskatchewan and could include up to 244,000 hectares. Some of the blocks span the Alberta-Saskatchewan border.

Table 3.5-2 Potential Irrigation Plots

Irrigation Plot	Scenario	Irrigable Area in Plot	
		hectare	acre
1a	1,2,3	15,410	38,080
1b	1,2,3	5,827	14,400
2	1,2,3	8,547	21,120
3a	1,2,3	25,900	64,000
3b	1,2,3	3,108	7,680
4a-1	1,2,3	4,727	11,680
4a-2	1,2,3	8,417	20,800
4b	1,2,3	777	1,920
5	1,2,3	3,885	9,600
6a	1,2,3	11,396	28,160
6b	1,2,3	10,489	25,920
7a	1,2,3	37,037	91,520
7b	3	4,403	10,880
7c	2,3	20,849	51,520
8a	1,2,3	28,490	70,400
8b	2,3	5,439	13,440
8c	2,3	7,381	18,240
8d	2,3	1,554	3,840
9a-1	2	18,130	44,800
9a-2	2	4,921	12,160
9b	2	8,676	21,440
10	2,3	8,547	21,120
Total		243,913	602,720

A summary of the irrigated area and tentative irrigation blocks and plots for each scenario is given in Table 3.5-3. The allotment by province is given in Table 3.5-4.

Table 3.5-3 Irrigation Plot Serviced For Each Scenario

Scenario	Total Irrigation Area		Irrigation Plots Serviced
	hectare	acre	
1	164,011	405,280	1 - 7a, & 8a
2	203,897	503,840	1 - 4b, 6a - 7a, 7c - 8d, & 10
3	243,913	602,720	1 - 10, excluding 7b

Table 3.5-4 Summary of Increased Irrigation Areas in Alberta and Saskatchewan

Scenario	Alberta		Saskatchewan		Total
	ha	%	ha	%	ha
1	103,341	63	60,671	37	164,011
2	99,456	49	104,441	51	203,897
3	126,392	52	117,521	48	243,913

Irrigation for Scenario 3 includes all of the delineated irrigation blocks and was designed to irrigate approximately 240,000 hectares as shown on Figure 3.5-4. The river pump station on the

west bank (P1) would provide water to irrigation Blocks 1 to 3 through a series of booster pumps, canals, and pipelines. There is one main line that runs from P1 to the high point of Block 3a located in the southeast corner. From this location four booster pumps, four secondary pipelines, and three canals distribute water to the irrigation blocks further west. The east bank pump station (P2) services irrigation blocks on the east side of the river. As discussed below, four main lines run from pump station (P2) to irrigation Blocks 4a-1, 5, 6a, and 8a. The main line to Block 4a-1 also supplies water to Blocks 4a-2 and 4b though the use of a booster pump/secondary pipeline combination and required canals. An additional main pipeline connection to one of the river pumping stations is required to sole serve irrigation Block 5. The third main line runs from pump station (P2) to Block 6a. This pipeline transfers sufficient water for irrigation of Blocks 6a, 6b, 7a, 7b, and 7c. The fourth main pipeline from pump station (P2) services irrigation Blocks 8 through 10. Water is distributed through booster pumps and secondary pipelines, with canals being used in areas where gravity drainage is possible.

Scenarios 1 and 2 are like Scenario 3 except that some of the blocks and plots are excluded.

3.5.2 Design Basis

A conceptual design was undertaken to provide a suitable basis for estimating costs. Summary details of the design basis are discussed below.

Conveyance Capacities

Conveyance capacities for sizing pipelines and canals were derived based on the procedure given in "Channel System Design for Southern Alberta" (1987; Table II-A). The resulting peak monthly conveyance capacity is 4.19 m^3/s for an irrigation block area of 10,000 ha and 38.21 m^3/s for an irrigation block area of 100,000 ha.

Annual Water Demand

The annual water demand for each irrigation block was also derived from "Channel System Design for Southern Alberta" (1987; Table II-B). This data was needed to estimate pump energy costs. The resulting annual water demand is 35,500 dam^3 for a 10,000 ha block (i.e., 355 mm unit depth) and 262,000 dam^3 for a 100,000 ha block (i.e., 262 mm unit depth).

Pipelines vs. Gravity Canals

The layout of primary water delivery facilities to each block (distribution location) includes pipelines and lined gravity canals. The location of the conveyance facility to each block involves a straight line direct route to minimize costs. Canals are provided wherever there is a downward slope of the topography along the conveyance route.

The layouts shown on Figures 3.5-2, 3.5-3 and 3.5-4 are not optimized. Little consideration could be given at this stage to topographic irregularities, utilities or dwellings. The layout did not consider on-line turnouts, offstream reservoir storage for balancing delivery, or potential land owner acceptance. Such matters would be considered in any future detailed studies and are not expected to affect the results of this preliminary analysis.

3.5.3 Major Issues and Uncertainties

There are a number of significant issues and uncertainties associated with the design of irrigation water delivery systems. The fundamental issue pertains to the pre-feasibility design level of the current study. Major issues are discussed as follows:

- Proportion of irrigation blocks in Alberta and Saskatchewan. At this stage, no priority has been given to provide a certain portion of the available irrigation to irrigation blocks in either Alberta or Saskatchewan. The distributions as shown on the accompanying schematics indicate allotments as given in Table 3.5-4.
- Location of irrigation blocks are tentative. The potential blocks as outlined on Figures 3.5-2, 3.5-3 and 3.5-4 are believed to serve the purposes of a cost estimate would not serve the purposes of a final development plan. Selection of final irrigation block locations would be based on public input, farmer acceptance, and a detailed optimization study.
- Layouts of pipelines and canals are not optimized. Major issues regarding the irrigation distribution network are the length of pipelines and the general location of the pumps, canals, and distribution points. For some of the irrigation blocks a number of options exist for the location of booster pumps, pipelines, and canals. Although the local topography has been reviewed, exact locations of infrastructure have not been fully optimized from either an economic or construction viewpoint.

- Design details are rudimentary. The potential irrigation water delivery system includes many components and many options. The level of detail for this study necessarily involves qualitative assessment.
- Cost estimate is uncertain. The estimated cost as outlined in the following section, is believed to represent a realistic estimate. However, the uncertainty limits of this cost estimate are higher than those of other capital works. The reason is the many components, options and constraints, which cannot be assessed at this stage of the development.
- Third river pump station for Block 5. Due to the surrounding topography, Block 5 requires its own main pipeline from pump station (P2). It may be more cost effective to locate a third river pump station on the east bank of the South Saskatchewan River near the south-west corner of irrigation Block 5. This would reduce the length of pipeline required to irrigate the area, however the pump intake would be located above the reservoir dead storage elevation. This could result in additional irrigation deficits for the irrigation block (not accounted for in the water supply modelling).
- Fourth river pump station for Block 9. An additional river pump station could also benefit irrigation Blocks 9a-1, 9a-2, and 9b. They are presently serviced through the main pipeline from P2 to Block 8a. This requires a larger pump and pump station to transport sufficient amounts water to service all of the irrigation blocks. If a third river pump station was installed upstream of P2 it would allow for the above irrigation blocks to be serviced independently from irrigation Blocks 8a-d, and 10. As discussed above, there would also be a concern related to an intake above the reservoir's dead storage elevation.

3.5.4 Estimated Costs

Capital costs and operating and maintenance (O & M) costs of irrigation water delivery systems were estimated based on actual costs of previous irrigation construction projects in Southern Alberta and Saskatchewan. Many project costs are documented and analyzed in a report entitled South Saskatchewan River Basin Planning Program – Cost Study Report (Klohn Leonoff 1983). Actual construction costs were factored upward to reflect construction costs in 2001 dollars based on the Canadian non-residential building cost indices. The Canadian non-residential index was used as it has a long period of records and tracks with other relevant indices (e.g. gross domestic

product price index, consumer price index, U.S. Bureau of Reclamation indices). For example, original construction costs in 1982 dollars were factored by 1.45 to represent 2001 dollars.

Details of the cost estimate are given on Table 3.5-5. The basis of the unit costs on Table 3.5-5 is given below:

- The estimated costs that are provided include engineering costs.
- The pump well height affects pump station costs. The elevations of the two Meridian Dam reservoir pump intakes would be equal to FSL minus the dead storage level of 587 m minus 5 m submergence.
- Pump well heights of pump stations along a gravity canal would be about 3 m and the pump well height of booster pumps along a pipeline would be zero.
- The static head is equal to the level of the distribution location minus the dead storage level (587 m).
- Length of pipeline and canals are straight-line distances from origin to destination.
- The dynamic head is equal to the friction head loss, assuming a pipe diameter which provides a peak flow velocity of 4 m/s.
- The irrigable area in each irrigation plot is based on the irrigability study discussed in Section 2.1
- Annual energy consumption of the pumps is based on continuous operation over a 100-day period (translates to 1.35 ac-ft/ac based on average pumping rates).
- Annual pumping costs are based on energy costs of $0.05 /kWh.
- Annual maintenance and operation costs are based on 0.5% of capital costs.
- The costs of pipelines, canals and pump stations are assumed to be as follows:

\$Pump Station (including pumps) = 1,600,000 + 960,000 Q_p + 112,000 PWH + 8,800 HD

Where Q_p = Peak Flow Capacity (m^3/s)
Length = Canal or Pipe Length (km)
PWH = Pump Well Height (m)
HD = Pump Dynamic Head (m)

Table 3.5-5: Estimated Costs for Irrigation Distribution Network

	Irrigation Plot	Irrigable Area		Elevation at Destination		Irrigation Rates: Peak Rate[a]	Average Rate[a]	Annual Volume[a]	Pump Type (main or booster)	Design Criteria: Design Flow[b]	Assumed Height of Pump Well[c]	Estimated Total Maximum Head	Estimated Total Average Head	Pumps and Pump Stations: Cost of Main Pump Stations	Estimated Booster Pump Station Cost	Estimated Booster Pump Cost	Total Cost of Booster Pump and Pump Station	Pipeline: Approximate Length of Pipeline	Cost of Pipeline[d]	Canal: Length of Canal	Unit Cost of Canal[e]	Cost of Canal	Pump Size / Operation & Management: Estimated Total Pump Size	Estimated Energy Consumption[f]	Annual Costs: Estimated Annual Pumping Costs	Est. Annual Operating & Maintenance Costs[g]	Capital Costs: Estimated Total Capital Cost[h]
		acre	hectare	ft	m	m^3/s	m^3/s	dam^3		m^3/s	m	m	m					km		km	$1,000/km		HP	(kW-h)	($0.05/kW-h)		
Scenario 1 FSL 621.79 m (2040')	1a	38,080	15,410	2575	785	15.2	7.6	128,132	Booster	21.0	3	176	176		$ 18,460,514	$ 5,505,838	$ 23,966,352	30	$ 113,600,000	0	0	$ -	21,989	3.935E+07	$ 1,970,000	$ 690,000	$ 138,000,000
	1b	14,400	5,827	2550	777	5.8	2.9	48,453	Booster	5.8	3	72	72		$ 5,881,806	$ 2,313,828	$ 8,195,634	4	$ 5,100,000	10	609	$ 6,090,000	3,392	6.071E+06	$ 300,000	$ 70,000	$ 19,000,000
	2	21,120	8,547	2250	686	8.4	4.2	71,065	Booster	8.4	3	46	46		$ 8,101,578	$ 2,458,243	$ 10,559,821	10	$ 15,800,000	9	711	$ 6,394,500	3,184	5.698E+06	$ 280,000	$ 130,000	$ 33,000,000
	3a	64,000	25,900	2450	747	25.6	12.8	215,347	PS 1	58.1	5	187	126		$ -	$ 10,987,194	$ 10,987,194	6	$ 68,200,000	0	0	$ -	26,450	4.734E+07	$ 2,370,000	$ 400,000	$ 79,000,000
	3b	7,680	3,108	2300	701	3.1	1.5	25,842	Booster	3.1	3	31	31		$ 3,662,034	$ 1,534,568	$ 5,196,602	5	$ 2,400,000	9	435	$ 3,915,000	771	1.380E+06	$ 70,000	$ 40,000	$ 12,000,000
	4a_1	11,680	4,727	2400	732	4.7	2.3	39,301	PS 2	13.8	5	231	111		$ -	$ 4,985,977	$ 4,985,977	19	$ 63,000,000	0	0	$ -	4,242	7.592E+06	$ 380,000	$ 340,000	$ 68,000,000
	4a_2	20,800	8,417	2325	709	8.3	4.2	69,988	Booster	8.3	3	12	12		$ 7,995,875	$ 2,120,489	$ 10,116,364	1	$ 1,600,000	8	689	$ 5,510,000	834	1.493E+06	$ 70,000	$ 60,000	$ 17,000,000
	4b	1,920	777	2350	716	0.8	0.4	6,460	n/a	0.8	0	0	0		$ -	$ -	$ -	0	$ -	6	203	$ 1,218,000	0	0.000E+00	$ -	$ -	$ 1,000,000
	5	9,600	3,885	2525	770	3.8	1.9	32,302	PS 2	3.8	5	288	149		$ -	$ 4,084,830	$ 4,084,830	23	$ 29,000,000	0	0	$ -	4,689	8.391E+06	$ 420,000	$ 170,000	$ 33,000,000
	6a	28,160	11,396	2500	762	11.3	5.6	94,753	PS 2	58.2	5	230	141		$ -	$ 11,411,224	$ 11,411,224	12	$ 136,400,000	0	0	$ -	13,048	2.335E+07	$ 1,170,000	$ 740,000	$ 148,000,000
	6b	25,920	10,489	2500	762	10.4	5.2	87,216	Booster	47.0	3	67	67		$ 39,918,309	$ 8,239,126	$ 48,157,435	8	$ 60,600,000	3	943	$ 2,827,500	5,722	1.024E+07	$ 510,000	$ 540,000	$ 112,000,000
	7a	91,520	37,037	2575	785	36.6	18.3	307,946	Booster	36.6	3	99	99		$ 31,356,331	$ 7,041,602	$ 38,397,933	10	$ 75,800,000	8	1523	$ 12,180,000	29,839	5.340E+07	$ 2,670,000	$ 570,000	$ 126,000,000
	8a	70,400	28,490	2750	838	28.2	14.1	236,882	PS 2	28.2	5	379	217		$ -	$ 8,474,155	$ 8,474,155	28	$ 185,600,000	0	0	$ -	50,250	8.993E+07	$ 4,500,000	$ 970,000	$ 194,000,000
	Pump 1													$ 49,331,274												$ 250,000	$ 49,000,000
	Pump 2													$ 87,225,952												$ 440,000	$ 87,000,000
	Total	*405,280*	*164,011*					*1,363,686*						*$136,557,226*			*$ 184,533,521*	*156*	*$ 757,100,000*	*53*		*$ 38,135,000*		*2.942E+08*	*$ 14,710,000*	*$ 5,410,000*	*$ 1,116,000,000*
Scenario 2 FSL 635.51 m (2085')	1a	38,080	15,410	2575	785	15.2	7.6	128,132	Booster	21.0	3	176	176		$ 18,460,514	$ 5,505,838	$ 23,966,352	30	$ 113,600,000	0	0	$ -	21,989	3.935E+07	$ 1,970,000	$ 690,000	$ 138,000,000
	1b	14,400	5,827	2550	777	5.8	2.9	48,453	Booster	5.8	3	72	72		$ 5,881,806	$ 2,313,828	$ 8,195,634	4	$ 5,100,000	10	609	$ 6,090,000	3,392	6.071E+06	$ 300,000	$ 70,000	$ 19,000,000
	2	21,120	8,547	2250	686	8.4	4.2	71,065	Booster	8.4	3	46	46		$ 8,101,578	$ 2,458,243	$ 10,559,821	10	$ 15,800,000	9	711	$ 6,394,500	3,184	5.698E+06	$ 280,000	$ 130,000	$ 33,000,000
	3a	64,000	25,900	2450	747	25.6	12.8	215,347	PS 1	58.1	5	187	114			$ 10,987,194	$ 10,987,194	6	$ 68,200,000	0	0	$ -	23,926	4.282E+07	$ 2,140,000	$ 400,000	$ 79,000,000
	3b	7,680	3,108	2300	701	3.1	1.5	25,842	Booster	3.1	3	31	31		$ 3,662,034	$ 1,534,568	$ 5,196,602	5	$ 2,400,000	9	435	$ 3,915,000	771	1.380E+06	$ 70,000	$ 40,000	$ 12,000,000
	4a_1	11,680	4,727	2400	732	4.7	2.3	39,301	PS 2	13.8	5	231	99			$ 4,985,977	$ 4,985,977	19	$ 63,000,000	0	0	$ -	3,782	6.768E+06	$ 340,000	$ 340,000	$ 68,000,000
	4a_2	20,800	8,417	2325	709	8.3	4.2	69,988	Booster	8.3	3	12	12		$ 7,995,875	$ 2,120,489	$ 10,116,364	1	$ 1,600,000	8	689	$ 5,510,000	834	1.493E+06	$ 70,000	$ 60,000	$ 17,000,000
	4b	1,920	777	2350	716	0.8	0.4	6,460	n/a	0.8	0	0	0		$ -	$ -	$ -	0	$ -	6	203	$ 1,218,000	0	0.000E+00	$ -	$ -	$ 1,000,000
	6a	28,160	11,396	2500	762	11.3	5.6	94,753	PS 2	78.8	5	230	129			$ 14,395,262	$ 14,395,262	12	$ 181,800,000	0	0	$ -	11,938	2.137E+07	$ 1,070,000	$ 980,000	$ 196,000,000
	6b	25,920	10,489	2500	762	10.4	5.2	87,216	Booster	67.6	3	67	67		$ 56,936,560	$ 11,223,165	$ 68,159,725	8	$ 121,200,000	3	943	$ 2,827,500	5,722	1.024E+07	$ 510,000	$ 950,000	$ 192,000,000
	7a	91,520	37,037	2575	785	36.6	18.3	307,946	Booster	36.6	3	99	99		$ 31,356,331	$ 7,041,602	$ 38,397,933	10	$ 75,800,000	8	1523	$ 12,180,000	29,839	5.340E+07	$ 2,670,000	$ 570,000	$ 126,000,000
	7c	51,520	20,849	2525	770	20.6	10.3	173,354	n/a	20.6	0	0	0		$ -	$ -	$ -	0	$ -	3	1291	$ 3,871,500	0	0.000E+00	$ -	$ -	$ 4,000,000
	8a	70,400	28,490	2750	838	28.2	14.1	236,882	PS 2	50.8	5	379	205			$ 11,754,744	$ 11,754,744	28	$ 318,200,000	0	0	$ -	47,474	8.496E+07	$ 4,250,000	$ 1,650,000	$ 330,000,000
	8b	13,440	5,439	2675	815	5.4	2.7	45,223	Booster	22.7	3	102	102		$ 19,834,658	$ 5,050,111	$ 24,884,769	9	$ 34,100,000	11	580	$ 6,380,000	4,516	8.082E+06	$ 400,000	$ 290,000	$ 65,000,000
	8c	18,240	7,381	2600	792	7.3	3.6	61,374	Booster	17.3	3	59	59		$ 15,395,114	$ 3,866,171	$ 19,261,285	3	$ 11,400,000	7	653	$ 4,567,500	3,565	6.381E+06	$ 320,000	$ 150,000	$ 35,000,000
	8d	3,840	1,554	2475	754	1.5	0.8	12,921	Booster	1.5	3	31	31		$ 2,393,593	$ 1,312,155	$ 3,705,748	5	$ 1,600,000	0	0	$ -	386	6.901E+05	$ 30,000	$ 30,000	$ 5,000,000
	10	21,120	8,547	2575	785	8.4	4.2	71,065	Booster	8.4	3	102	102		$ 8,101,578	$ 2,993,511	$ 11,095,089	14	$ 22,100,000	0	0	$ -	7,102	1.271E+07	$ 640,000	$ 170,000	$ 33,000,000
	Pump 1													$ 49,331,274			$ -									$ 250,000	$ 49,000,000
	Pump 2													$ 119,782,607			$ -									$ 600,000	$ 120,000,000
	Total	*503,840*	*203,897*					*1,695,321*						*$169,113,881*			*$ 265,662,500*	*164*	*$ 1,035,900,000*	*74*		*$ 52,954,000*		*3.014E+08*	*$ 15,060,000*	*$ 7,370,000*	*$ 1,522,000,000*
Scenario 3 FSL (2120')	1a	38,080	15,410	2575	785	15.2	7.6	128,132	Booster	21.0	3	176	176		$ 18,460,514	$ 5,505,838	$ 23,966,352	30	$ 113,600,000	0	0	$ -	21,989	3.935E+07	$ 1,970,000	$ 690,000	$ 138,000,000
	1b	14,400	5,827	2550	777	5.8	2.9	48,453	Booster	5.8	3	72	72		$ 5,881,806	$ 2,313,828	$ 8,195,634	4	$ 5,100,000	10	609	$ 6,090,000	3,392	6.071E+06	$ 300,000	$ 70,000	$ 19,000,000
	2	21,120	8,547	2250	686	8.4	4.2	71,065	Booster	8.4	3	46	46		$ 8,101,578	$ 2,458,243	$ 10,559,821	10	$ 15,800,000	9	711	$ 6,394,500	3,184	5.698E+06	$ 280,000	$ 130,000	$ 33,000,000
	3a	64,000	25,900	2450	747	25.6	12.8	215,347	PS1	58.1	5	187	105			$ 10,987,194	$ 10,987,194	6	$ 68,200,000	0	0	$ -	22,033	3.943E+07	$ 1,970,000	$ 400,000	$ 79,000,000
	3b	7,680	3,108	2300	701	3.1	1.5	25,842	Booster	3.1	3	31	31		$ 3,662,034	$ 1,534,568	$ 5,196,602	5	$ 2,400,000	9	435	$ 3,915,000	771	1.380E+06	$ 70,000	$ 40,000	$ 12,000,000
	4a_1	11,680	4,727	2400	732	4.7	2.3	39,301	PS2	13.8	5	231	90			$ 4,985,977	$ 4,985,977	19	$ 63,000,000	0	0	$ -	3,436	6.150E+06	$ 310,000	$ 340,000	$ 68,000,000
	4a_2	20,800	8,417	2325	709	8.3	4.2	69,988	Booster	8.3	3	12	12		$ 7,995,875	$ 2,120,489	$ 10,116,364	1	$ 1,600,000	8	703	$ 5,626,000	834	1.493E+06	$ 70,000	$ 60,000	$ 17,000,000
	4b	1,920	777	2350	716	0.8	0.4	6,460	n/a	0.8	0	0	0		$ -	$ -	$ -	0	$ -	6	203	$ 1,218,000	0	0.000E+00	$ -	$ -	$ 1,000,000
	5	9,600	3,885	2525	770	3.8	1.9	32,302	PS2	3.8	5	288	128			$ 4,084,830	$ 4,084,830	23	$ 29,000,000	0	0	$ -	4,026	7.206E+06	$ 360,000	$ 170,000	$ 33,000,000
	6a	28,160	11,396	2500	762	11.3	5.6	94,753	PS2	83.2	5	230	120			$ 15,025,432	$ 15,025,432	12	$ 181,800,000	0	0	$ -	11,105	1.987E+07	$ 990,000	$ 980,000	$ 197,000,000
	6b	25,920	10,489	2500	762	10.4	5.2	87,216	Booster	71.9	3	67	67		$ 60,530,476	$ 11,853,334	$ 72,383,811	8	$ 121,200,000	3	943	$ 2,827,500	5,722	1.024E+07	$ 510,000	$ 970,000	$ 196,000,000
	7a	91,520	37,037	2575	785	36.6	18.3	307,946	Booster	41.0	3	99	99		$ 34,950,248	$ 7,671,772	$ 42,622,019	10	$ 75,800,000	8	1523	$ 12,180,000	29,839	5.340E+07	$ 2,670,000	$ 590,000	$ 131,000,000
	7b	10,880	4,403	2375	724	4.4	2.2	36,609	Booster	4.4	3	49	49		$ 4,719,068	$ 1,893,182	$ 6,612,251	4	$ 5,100,000	13	493	$ 6,409,000	1,746	3.125E+06	$ 160,000	$ 60,000	$ 18,000,000
	7c	51,520	20,849	2525	770	20.6	10.3	173,354	n/a	20.6	0	0	0		$ -	$ -	$ -	0	$ -	3	1291	$ 3,871,500	0	0.000E+00	$ -	$ -	$ 4,000,000
	8a	70,400	28,490	2750	838	28.2	14.1	236,882	PS2	82.2	5	379	196			$ 16,295,672	$ 16,295,672	28	$ 424,200,000	0	0	$ -	45,392	8.124E+07	$ 4,060,000	$ 2,200,000	$ 440,000,000
	8b	13,440	5,439	2675	815	5.4	2.7	45,223	Booster	22.7	3	102	102		$ 19,834,658	$ 5,050,111	$ 24,884,769	9	$ 34,100,000	11	580	$ 6,380,000	4,516	8.082E+06	$ 400,000	$ 290,000	$ 65,000,000
	8c	18,240	7,381	2600	792	7.3	3.6	61,374	Booster	17.3	3	59	59		$ 15,395,114	$ 3,866,171	$ 19,261,285	3	$ 11,400,000	7	653	$ 4,567,500	3,565	6.381E+06	$ 320,000	$ 150,000	$ 35,000,000
	8d	3,840	1,554	2475	754	1.5	0.8	12,921	Booster	1.5	3	31	31		$ 2,393,593	$ 1,312,155	$ 3,705,748	5	$ 1,600,000	0	0	$ -	386	6.901E+05	$ 30,000	$ 30,000	$ 5,000,000
	9a_1	44,800	18,130	2750	838	17.9	9.0	150,743	Booster	31.4	3	83	83		$ 27,022,491	$ 6,123,878	$ 33,146,369	18	$ 136,400,000	0	0	$ -	12,156	2.176E+07	$ 1,090,000	$ 850,000	$ 170,000,000
	9a_2	12,160	4,921	2625	800	4.9	2.4	40,916	Booster	4.9	3	180	180		$ 5,141,882	$ 3,210,408	$ 8,352,291	6	$ 7,600,000	15	544	$ 8,156,250	7,190	1.287E+07	$ 640,000	$ 80,000	$ 24,000,000
	9b	21,440	8,676	2650	808	8.6	4.3	72,141	Booster	8.6	3	61	61		$ 8,207,281	$ 2,621,289	$ 10,828,570	10	$ 15,800,000	5	725	$ 3,625,000	4,306	7.706E+06	$ 390,000	$ 130,000	$ 30,000,000
	10	21,120	8,547	2575	785	8.4	4.2	71,065	Booster	8.4	3	102	102		$ 8,101,578	$ 2,993,511	$ 11,095,089	14	$ 22,100,000	0	0	$ -	7,102	1.271E+07	$ 640,000	$ 170,000	$ 33,000,000
	Pump 1													$ 49,331,274			$ -									$ 250,000	$ 49,000,000
	Pump 2													$ 152,444,965			$ -									$ 760,000	$ 152,000,000
	Subtotal	*602,720*	*243,913*					*2,028,032*						*$201,776,239*			*$ 342,306,080*	*225*	*$ 1,335,800,000*	*79*		*$ 54,860,750*	*192,692*	*3.449E+08*	*$ 17,230,000*	*$ 9,410,000*	*$ 1,949,000,000*

[a] Peak rate, average rate, and annual volume are calculated based on Table II-A, II-B, and II-D of the Channel System Design Manual for Southern Alberta (1987).
[b] The design flow represents combined peak flow for all plots serviced.
[c] Well heights of 3 and 5 m are assumed for the booster pumps and river pumps, respectively.
[d] Cost of pipeline is based on construction of a steel pipeline at an installed cost of $6.60/kg ($3/lb).
[e] Unit cost of canal is based on canal capacity (see Figure 4 of the South Saskatchewan River Basin Planning Program - Cost Study Report (Klohn Leonoff Consulting Engineers, 1983)).
A cost adjustment factor of 1.45 was applied for conversion of 1983 dollars to 2001 dollars based on Canadian non-residencial construction indices.
[f] Estimated energy consumption assumes that the pumps are operating continuously for 100 days during the irrigation season (translates to 1.35 ac-ft/ac based on average pumping rate).
[g] Estimated operation and maintenance costs are assumed to be 0.5% of capital costs.
[h] Estimated total cost is the sum of estimated pump station and pump cost, cost of canal, and pipeline cost.

$ Canals = Length x Unit Cost based on canal capacity x Dollar adjustment factor

$ Pipeline = # of pipes in parallel x [pipe wall thickness x pipe circumference x length] x Density x Unit Cost

Where Pipe size and number of required pipes are based on an acceptable peak flow velocity of 4 m/s and a maximum pipe diameter of 2.5 m (approximately 8 ft).

Minimum wall thickness is based on pipe diameter.

Density of steel is 7845 kg/m^3 (490 lb/ft^3).

Unit cost of installed steel pipeline is $6.60/kg.

3.6 Other Capital Works

3.6.1 Irrigation Water Distribution Within Irrigation Blocks

Table 3.6-1 shows the estimated capital and operating costs of irrigation distribution systems within each block (downslope of the distribution locations and the end of the headworks supply pipeline or canal). Unit costs are a function of peak flow rate as well as irrigation block size. Table 3.6-2 provides a summary of development costs by scenario. These costs were estimated based on a previous study by Klohn Leonoff "South Saskatchewan River Basin Planning Program – Cost Study Report." (1983, Figure 9) and were factored upward by 1.45 to reflect the construction cost index as follows:

$ Distribution system in each block = Irrigable area (ha) x Unit cost based on area and region (Klohn Leonoff, 1983) x Dollar Adjustment Factor

Annual operating and maintenance costs were assumed to be 0.5% of the capital costs.

Table 3.6-1 Cost of Irrigation Development Within Irrigation Blocks

Irrigation Plot	Irrigable Area (hectare)	Unit Cost per hectare[1]	Cost of Irrigation Development	Estimated Maintenance & Operating Costs
1a	15,410	$ 4,176	$ 64,400,000	$ 322,000
1b	5,827	$ 2,791	$ 16,300,000	$ 82,000
2	8,547	$ 3,110	$ 26,600,000	$ 133,000
3a	25,900	$ 4,698	$ 121,700,000	$ 609,000
3b	3,108	$ 2,313	$ 7,200,000	$ 36,000
4a_1	4,727	$ 2,632	$ 12,400,000	$ 62,000
4a_2	8,417	$ 3,110	$ 26,200,000	$ 131,000
4b	777	$ 1,563	$ 1,200,000	$ 6,000
5	3,885	$ 1,276	$ 5,000,000	$ 25,000
6a	11,396	$ 3,429	$ 39,100,000	$ 196,000
6b	10,489	$ 3,350	$ 35,100,000	$ 176,000
7a	37,037	$ 4,785	$ 177,200,000	$ 886,000
7b	4,403	$ 2,552	$ 11,200,000	$ 56,000
7c	20,849	$ 4,067	$ 84,800,000	$ 424,000
8a	28,490	$ 4,466	$ 127,200,000	$ 636,000
8b	5,439	$ 2,712	$ 14,700,000	$ 74,000
8c	7,381	$ 3,031	$ 22,400,000	$ 112,000
8d	1,554	$ 1,954	$ 3,000,000	$ 15,000
9a_1	18,130	$ 3,908	$ 70,800,000	$ 354,000
9a_2	4,921	$ 2,672	$ 13,100,000	$ 66,000
9b	8,676	$ 3,126	$ 27,100,000	$ 136,000
10	8,547	$ 3,110	$ 26,600,000	$ 133,000
Total	*243,913*	*$ 3,826*	*$ 933,300,000*	*$ 4,670,000*

[1] Unit costs per hectare are based on Figure 9 of the South Saskatchewan River Basin Planning Program – Cost study Report (Klohn Leonoff Consulting Engineers, 1983), and adjusted by 1.45 to reflect 2001 dollars.

Table 3.6-2 Summary of Development Costs for Irrigation Block of Each Scenario

Scenario	Capital Costs[1] ($)	O & M[2] Costs ($)
1	660 million	3.3 million
2	817 million	4.1 million
3	933 million	4.7 million

[1] Capital Costs include Engeneering Cost estimates.
[2] Annual O & M costs are assumed to be 0.5 % of capital costs.

3.6.2 On-Farm Irrigation

Individual farmers would install and operate their own on-farm irrigation system. The typical system would likely be a ¼ section (160 acre) low-pressure pivot, which irrigates 132 acres per quarter section without a corner swing-system. An electrically operated low-pressure pivot operates for about 1000 hours per season and utilizes roughly 35,000 kW of electricity annually.

The approximate capital and operating costs of on-farm irrigation for various types of systems are provided in Table 3.6-3. As shown, the capital cost of a low-pressure pivot is approximately $85,800 per unit ($1,600/ha) and the annual operating cost is about $77/ha ($31/ac). The operating cost is based on an electricity cost of $0.05 per kWh.

Table 3.6-3 Cost of On-Farm Irrigation Systems

Irrigation System (Electric Power)	Area (Acres)	Capital Cost[1]	Life (years)	Annual R&M[2]	Electrical Energy[3] (kW-h)	Capital Cost		Annual O&M	
						$/ha.	$/acre	$/ha.	$/acre
Hand Move 2 Laterals	160	$ 28,500	20	$ 428	1,750	440	178	34	14
Wheel Roll 2 Lats. (8 hrs.)	160	$ 62,400	15	$ 904	2,505	963	390	53	21
Wheel Roll 4 Lats. (12 hrs.)	160	$ 92,000	15	$ 1,616	2,488	1,420	575	63	26
Pivot 800 m. (85 psi)	510	$239,700	12	$ 7,089	9,774	1,161	470	82	33
Pivot 1/4 High Pres.(70 psi)	132	$ 89,100	12	$ 2,363	2,292	1,667	675	87	35
Pivot 1/4 Low Pres. (50 psi)	132	$ 85,800	12	$ 2,369	1,750	1,606	650	77	31

[1] Includes motors (75-125 hp), switches, vertical turbine pump, and pump house
[2] Repairs and maintenance; hand move = 1.5% of capital costs/year.
[3] Cost of energy is assumed to be $0.05/kWh.
Source: AAFRD, Lethbridge, November 2001.

Two additional capital costs would also accompany irrigation development: three-phase power lines and a rural road grid to support the more intensive agricultural production. Using a one-mile grid, it is estimated that between 1300 and 1900 km (800 and 1200 miles) of additional power line would be required. At an estimated cost of $18,700/km ($30,000/mile), this translates into about or $150/ha ($60 per acre).[3] Over time, the total investment in these power lines would, therefore, probably amount to an additional capital investment of about $24 million, $30 million, and $36 million for Scenarios 1, 2, and 3, respectively.

It is likely that a new rural road grid would also be required to access the newly-irrigated quarter-sections. If a "standard" 1 mile by 2 mile road grid is assumed, the additional rural roads would amount to between 1900 and 2700 km (1200 and 1700 miles). At a cost of about $37,000/km ($60,000/mile), this would translate into about $420/ha ($170/acre), or an additional capital investment of approximately $68 million, $85 million, and $102 million for Scenarios 1, 2, and 3, respectively.[4]

[3] Costs based on current AAFRD estimates, Lethbridge, December 2001.
[4] The estimated cost/mile of a new seven meter wide municipal road, including gravel. Data from Alberta Transportation, Edmonton, December 2001.

Assuming a low-pressure pivot system, the total capital costs for full development of each scenario are given in Table 3.6-4. Annual O&M costs for this system are accounted for in the economic analysis (Section 8) as part of the annual irrigated crop cost-of-production estimates (Appendix Table VI-2).

Table 3.6-4 Summary of On-Farm Irrigation Costs at Full Development

Scenario	Total Irrigation Area		Irrigation Cost[1]	Powerline Cost	Rural Roads Cost	Total Capital Cost
	Hectares	Acres	$ million	$ million	$ million	$ million
1	162,000	400,000	260	24	68	352
2	202,000	500,000	325	30	85	440
3	243,000	600,000	390	36	102	528

[1] Assumes low pressure pivot system at $85,800 capital cost per unit (serves 132 acres).

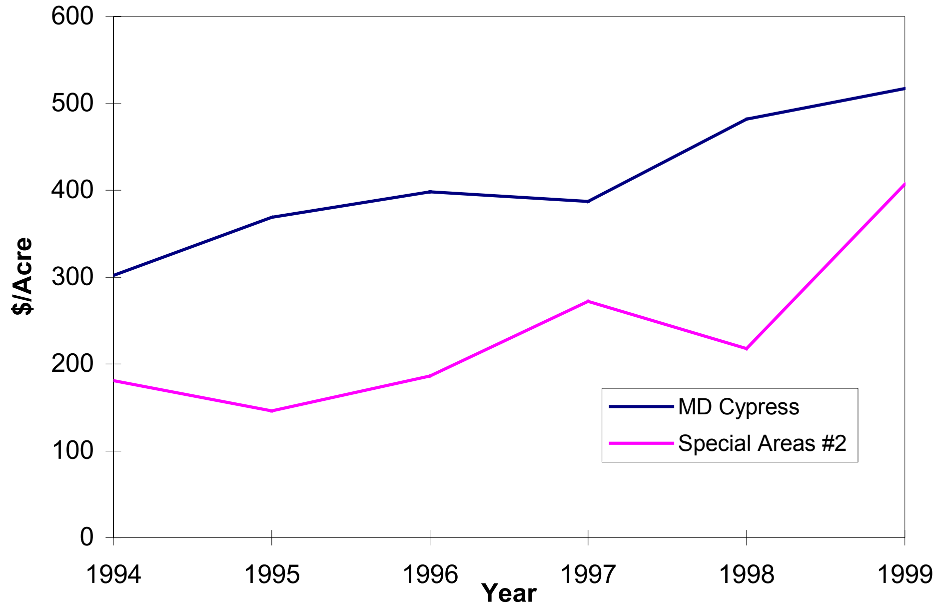
3.7 Land Acquisition

Development of the potential project would involve land acquisition for the dam, reservoir (including an off-set), irrigation delivery system, construction areas, borrow pits, infrastructure re-location, and potential habitat replacement. The area impacted would involve patent land, Department of National Defense land, and Crown land.

Regardless of ownership, land in the Meridian area has a current market value of about $500 per acre (or $1250/hectare), as shown in Figure 3.7-1 (AAFRD, 2000).

The estimated area of the reservoir, plus an additional setback allowance, is based on reservoir area data discussed in Section 3.1.3. With average valley wall heights of approximately 100 m (330 ft), an acceptable 3H:1V slope for stability would result in a set-back allowance of 300 m valley bottom, or roughly 250 m from water's edge. Costs associated with land acquisition for this area are shown in Table 3.7-1. This is based on the current market value of the land, however it is acknowledged that actual acquisition costs may be somewhat higher. There will also be costs associated with the main irrigation distribution system (pipelines and canals), as well as with the relocation of roads as discussed in Section 6.1.1. These estimated costs are shown in Table 3.7-2.

Figure 3.7-1 Average Land Prices in the Meridian Area (Alberta), 1994-1999



A summary of total land acquisition costs based on the above considerations is provided in Table 3.7-3. As shown, the costs are expected to be in the range between $17 million and $31 million for the three scenarios. Consideration has not been given at this stage to areas associated with the actual dam embankment and outlet facilities, irrigation pump stations, construction area, materials stockpiling and borrow areas, or to other requirements such as reservoir clearing.

Table 3.7-1 Estimated Land Acquisition Costs for the Reservoir Area

Scenario	Full Supply Level	Area	Reservoir Length	Average Width	Width with Set-back[1]	Reservoir and Set-back area	Unit Cost	Reservoir and Setback Land Cost
	M	ha	km	km	km	ha	$/ha	
Scenario 1	621.8	6880	112	0.61	1.11	12,432	1250	$ 15,540,000
Scenario 2	635.5	10886	153	0.71	1.21	18,513	1250	$ 23,140,000
Scenario 3	646.2	14973	168	0.89	1.39	23,352	1250	$ 29,190,000

[1] Width assumes a 250 m set-back on both sides of the reservoir (i.e., 500 m total) along the reservoir length.

Table 3.7-2 Estimated Land Acquisition Costs for Main Pipelines, Canals, and Relocated Roads

	Lengths			Right-Of-Way		Total Area	Unit Cost	Total Land Cost
	Pipeline	Canal	Roads	Pipeline	Roads			
	Km	km	km	m	m	ha	$/ha	
Scenario 1	156	53	91	30	50	1082	1250	$ 1,400,000
Scenario 2	164	74	91	30	50	1169	1250	$ 1,500,000
Scenario 3	170	79	91	30	50	1202	1250	$ 1,500,000

Table 3.7-3 Estimated Total Land Acquisition Costs[1]

	Reservoir Area	Pipeline, Canals, and Roads Relocation	Total Estimated Costs
Scenario 1	$ 15,540,000	$ 1,400,000	$ 16,940,000
Scenario 2	$ 23,140,000	$ 1,500,000	$ 24,640,000
Scenario 3	$ 29,190,000	$ 1,500,000	$ 30,690,000

[1] Cost estimate is limited to costs associated with the reservoir area and set-back, main irrigation pipelines and canals, and relocated roads. Cost of land associated with new rural roads and powerlines is not included.

4 EVALUATION OF BENEFITS

4.1 Water Management Benefits

Although this study does not cover a wide range of opportunities or priorities, a reservoir at the Meridian site would enable modifications to existing water management practices in both Alberta and Saskatchewan. A key feature of the potential Meridian Dam is its location at the downstream end of the Alberta SSRB water supply system. Its close proximity to the Saskatchewan border would allow Alberta to optimize management of its apportionment allocation as it would enable a rapid response in terms of meeting apportionment obligations. Depending on operating priorities, the reservoir could also be operated to maximize downstream hydroelectric benefits in Saskatchewan and Manitoba. Further potential management implications include: an ability to modify operating priorities at upstream reservoirs for upstream irrigation intensification; and the possibility of reservoir operation to control of water levels in Lake Diefenbaker.

As this is not a comprehensive planning study, all such opportunities have not been considered in this report. Instead, reservoir operating priorities are limited as follows:

- Priority 1 Irrigation for southeast Alberta and southwest Saskatchewan
- Priority 2 Hydropower
- Priority 3 Recreation, other water supply, flood control.

4.2 Irrigation Benefits

Irrigation benefits are discussed in detail in Section 8.3.1 of this report.

4.3 Hydropower Benefits

There are many benefits associated with the development of a hydroelectric power generating facility. These benefits include:

- If the cost of energy is assumed to be \$50/MWh (consistent with assumptions related to irrigation electrical costs), the associated annual hydropower benefits would be \$18 million for the Scenario 3 80 MW development.
- For the Maximized Hydro Scenario 160 MW development, the potential energy is about 575 GWh per year. At the same price of \$50/MWh, the economic benefits would be approximately \$29 million.
- Power produced from a renewable resource instead of depleting non-renewable resources. Harmful by-products such as SO_2, NO_2, CO_2, etc. are not produced by hydropower as with other fossil fuel sources.
- Assuming that hydropower produced at this facility would be considered "green" energy, and thus could potentially be sold at \$70/MWh instead of \$50/MWh, there would be an additional net benefit of \$20/MWh. For the purpose of this study, this is assumed to be an environmental benefit valued at roughly \$7.2 million annually for Scenario 3 at full development (Section 8.3.6).
- Potential for Greenhouse Gas emissions trading credits.
- The proposed Open Access Transmission Tariff in Saskatchewan creates opportunity in other markets including opportunity within Saskatchewan and adjacent interconnected markets.
- Multi-use of the water resource thus maximizing the intrinsic value of the overall facility.
- Onsite power source minimizing the need for onsite back-up generation in the event of power system interruption.
- Increased Alberta generation reduces the requirement for importing power from other jurisdictions i.e. from British Columbia, Manitoba and US.
- Local economic benefit as a result of the construction, operation and maintenance of the facility.
- Regional power grid stability, reliability and availability. Improvements that may reduce transmission system upgrade expenditures in the region.

4.4 Flood Control Benefits

Development of the Meridian Dam would provide flood control benefits as well as potential economic benefits that could accrue as a result of flood control in both Alberta and Saskatchewan.

In a flood event, direct damage can occur to both buildings and infrastructure due to inundation (hydrostatic effects) and the action of moving water (hydrodynamic effects). Direct flood damages to residential dwellings include both content and structural damages, as well as internal clean-up costs. For commercial properties, flood damages include damaged inventory and damaged equipment and buildings, in addition to clean-up costs. Flood damages may also occur to highways and other infrastructure such as bridges. Typically, most of these infrastructure damages are related to clean-up costs.

Flood events also cause indirect damages. These damages include such things as costs of evacuation, alternative accommodation during the flood event, loss of wages and business income due to disruption of business establishments and transportation routes, administrative costs, flood-fighting costs, general inconvenience, and general clean-up.

4.4.1 Examination of the flood plain

An analysis of 1:50,000 topographical series mapping was undertaken for the area immediately adjacent to the South Saskatchewan River, between the site of the potential Meridian Dam and Saskatchewan Landing Provincial Park located on the western arm of Lake Diefenbaker. The topographic mapping dates from 1979, with the exception of Sheet 72K-13 Leader, which dates from 1993. No flood line data exists for this portion of the study area, however, given the steepness of the valley walls, the analysis was confined to the valley floor (an area delineated by a vertical elevation of ± 50 feet). The land area within this flood hazard zone constitutes approximately 8,000 hectares (20,000 acres).

The flood prone infrastructure and improvements identified within the assumed flood hazard area are detailed in Table 4.4-1 along with order of magnitude damage costs for a 1:500 year event.

Table 4.4-1 Flood Prone Inventory and Estimated Potential Flood Damage

Item Description	Estimated Potential Flood Damage 1:500 year event
Direct Damages:	
Several loose surface all-season and dry-weather roads	± $2,500
± Twenty farm out-buildings	± $40,000
± Two farm dwellings	± $30,000
Ferry crossing at secondary Road 635	± $5,000
Bridge crossing at Highway 21	± $10,000
One pump house building (Happyland Rural Municipality, 109° 28')	± $1,000
Ferry crossing of Highway 21 and buildings associated with Lemford Ferry Regional Park	± $10,000
Ferry crossing and outbuildings at Highway 30	± $10,000
Outbuildings associated with Easton Riverside Regional Park	± $10,000
Outbuildings associated with Saskatchewan Landing Provincial Park	± $10,000
Crop damage (assuming 2,000 – 3,000 acres under agricultural production with one-half of a blended crop, wheat, barley, forage crops destroyed by flooding).	± $60,000
Total Direct Damages	±$188,500
Indirect Damages: (The Canada/Saskatchewan Flood Damage Reduction Program uniformly employs an indirect damage calculation of 20% of the direct damages for all categories. This figure is in keeping with the guidelines developed by the US Soil Conservation Services).	$37,700
Total Damage Estimate	**$226,000**

4.4.2 Potential flood damage/benefits

Order of magnitude damage estimates were developed for the potential flood hazard area based on a consideration of typical damages from other rural areas subject to flooding in both Alberta and Saskatchewan. As indicated in Table 4.4-1, total damages are estimated at roughly $226,000 for a 1:500 year flood event.

Average annual damages represent the cumulative potential damages that would occur from all probable flood events over time, averaged to an annual cost. Employing ratios of total damage to average annual damage observed within other similar rural areas subject to flooding, average annual damages are estimated at $22,600.

The potential Meridian Dam is sized to receive the probable maximum flood (PMF) without requiring downstream discharge through the spillway. Due to its large holding capacity and assuming judicious operation, the dam would also be able to essentially eliminate downstream flood damage associated with a smaller 1:500 year peak inflow. Under 1:500 year conditions,

this would result in benefits in the order of $22,600 per annum. The majority of these potential benefits would accrue to Saskatchewan.

4.5 Recreation Benefits

An initial evaluation of recreation opportunities associated with the Meridian Dam project was conducted as part of this preliminary study. The assessment and evaluation reviewed a variety of biophysical as well as market-oriented factors. It is based on preliminary assessments of pre-design information and/or examinations of biophysical mapping of the potential reservoir site. The principal components of the evaluation included:

- Pre-design assessments of the relationship between reservoir operation and recreational capability;
- Preliminary evaluation of the reservoir's physical characteristics such as topography, road access, aspect, and river gradient, etc.;
- Preliminary evaluation of existing recreational opportunities within the region both upstream and downstream of the potential reservoir;
- Review of potential impacts or changes to local recreational use including hunting, fishing and canoeing;
- Review of land use restrictions associated with Federal lands; and
- Identification of possible opportunities or constraints for recreational development.

Given the nature of this preliminary feasibility study, the recreation benefit assessment is limited to a brief overview of both local and regional factors affecting current and future recreational activity. Further detail and analysis of potential recreational opportunities would require direct field investigations of the river valley, examination of all public and private recreational facilities, examination of local planning issues relating to potential recreational developments, and additional detailed study of both the bio-physical characteristics of the site and the potential dam's operations.

4.5.1 Biophysical Factors Influencing Recreation

Available information on Meridian reservoir levels was used to identify potential opportunities and constraints that may affect recreational activity in the area of the Meridian Dam. The principal elements that will affect recreation potential include:

Reservoir Access

The largest reservoir size evaluated in this study will flood up to 168 km of the South Saskatchewan river valley northeast of Medicine Hat. Much of this valley is characterized by steep slopes, coulee formations and canyons that rise sharply from the valley floor to the adjacent prairie benchlands. A review of topographic mapping, however, suggests that there may be a few locations where less steep conditions could offer suitable reservoir access. Recreational use of the dam site and reservoir will be dependent upon finding suitable locations where relatively gentle and stable slopes can provide public access to the water body. Areas of gently sloping topography located away from public roads and/or the potential dam will provide limited opportunity for public recreation, however, such sites could offer opportunities for private sector development.

Currently, public road access to the potential reservoir area is extremely limited from Medicine Hat to Sandy Point (approximately 20 km upstream of the potential dam). Limited public access throughout the length of the reservoir will generally restrict recreational opportunities and activities to those sites associated with new road developments. Private access may be more abundant however, topographic relief, steep slopes and restricted land uses will similarly limit recreational opportunities.

Dam and reservoir construction will require the rerouting of existing road crossings as discussed in Section 6.1. New transportation links for Highway 41 and the development of dam service roads could offer improved access to the reservoir and therefore opportunities for recreational development. Final selection of transportation routes and internal road development should consider recreational opportunities.

Reservoir Water Quality

Preliminary environmental assessments discussed later in this report suggest that water quality within the reservoir will be altered and will not necessarily be the same as pre-development conditions. Due to shoreline erosion, changes in water depth, and increased nutrient content etc., construction of the reservoir will result in changes to water temperature, turbidity, stratification, and phytoplankton levels.

These changes are not expected to significantly impact recreational opportunities, but may be qualitative changes which could have minor impacts on current activities. For example, increased levels of natural mercury may affect the quality of fish flesh and the nature of fish consumption. This alone however, should not adversely impact the fishery, which can be expected to remain as a viable recreational activity.

It is expected that water quality within the river and reservoir would allow for water-based and water-contact activity such as swimming, boardsailing, and boating.

Land Ownership Issues

Most of the land that would be flooded by the potential Meridian Dam is public land (south and east of the river), or is part of the Suffield Block (north of the river). There are several factors associated with land ownership, however, which would impact the recreational potential of the project. These include:

- C.F.B. Suffield – federally owned lands located adjacent to the reservoir are restricted. Public landings and use of approximately 90 km of the reservoir shoreline are prohibited. Similarly, due to planned activities within the base, access to the river itself is and will continue to be affected from time to time. It is unknown whether current restrictions associated with the Suffield base would be increased following development of the reservoir, but it is presumed that recreational activity adjacent to the military base would be both monitored and restricted.
- Public land acquisitions – typically, provincial acquisition of private lands necessary to develop reservoirs is tied to high water levels and land parcels immediately adjacent to the dam structures and spillways. At the present, the boundaries for land

acquisition have not been defined, however, given the nature of the topography of the river valley it is unlikely that extensive tracts of public land would be created which would accommodate public recreational facilities.

- Private land holdings – the vast majority of lands surrounding and adjacent to the reservoir would remain private and inaccessible for public use. Access would likely be further restricted if private landowners choose to protect their crops or livestock by fencing.
- Some opportunities may exist for private landowners to develop recreational facilities. Such developments would require the approval of Municipal authorities as changes in land use zoning may be required.

4.5.2 Recreation Potential

The recreational potential of a dam and reservoir is dependent on both the operational characteristics of the reservoir, and the topographic features of the site itself. For irrigation or power generation projects, recreational potential is generally adversely affected by factors which are integral to the operation of the dam. With the Meridian Dam project, the long narrow river valley, steep shoreline conditions, and seasonal drawdown of water levels will create reservoir conditions that are typically in conflict with public access and recreational use. At the same time, there are several recreational opportunities that could be developed as secondary benefits to the local and regional populations. These include the expansion of existing recreational activity and the creation of new opportunities as discussed below.

4.5.2.1 Expansion of Existing Recreational Activity

Water-Based Recreation

River access east of Medicine Hat is limited to a few local roads and private property access points. As a result, water-based activity is generally restricted to canoeing enthusiasts and fishermen. The river throughout the region east of Medicine Hat is generally described as providing easy wilderness canoeing experience.

Following the damming of the river it is anticipated that the river valley would still remain an easy canoe route, however, the absence of rapids and reduction in flow velocity may reduce the

appeal of this waterway for some canoeists. Depending on restrictions, increased water depths created by the dam may encourage a greater use of the river by powerboats. River tours are currently being offered down the river valley by private operators based in Medicine Hat. Given the narrow character of the river valley and reservoir it is not anticipated that recreational sail boating or wind surfing would occur unless sites for public access and day use facilities could be developed.

Fishing

Preliminary fisheries and water quality assessments (see Sections 5.2 and 5.6) suggest that the majority of fish species present in the river would survive a transition from a riverine to lacustrine environment. Certain key species, however, may be adversely affected by the loss of critical habitats due to inundation and movement blockage. With the possible exception of lake sturgeon, a viable fishery would be maintained; however, it may need to be supplemented by habitat improvement and/or stocking programs. It is anticipated that reservoir development would encourage a greater use of the area for angling by non-residents during both the summer and winter seasons, although the fishery will be reservoir rather than riverine based. More detailed examination of winter water levels and safety would be required before an accurate assessment of ice fishing potential can be established. Downstream of the reservoir, increased regulation of flows within the river may contribute to improved fisheries within the river and possibly in Lake Diefenbaker.

Hunting

The project area is actively used by local residents who hunt deer, antelope, and wildfowl. Flooding of the river valley would seriously reduce the vegetation, particularly the lower-level vegetation which currently provides habitat for game species. A transition in game species may occur, as some species (i.e. deer and antelope) will be adversely affected by reservoir development while others (i.e., wildfowl) could find greater opportunities. It is anticipated therefore that current hunting of deer and antelope will be seriously reduced in the river valley although, hunting as a recreational activity in the vicinity of the potential reservoir and dam site would continue in other respects. It is not anticipated that significant changes to recreational hunting practices or opportunities would occur downstream of the reservoir.

4.5.2.2 New Recreational Opportunities

Following reservoir development, it is anticipated that a number of new recreational opportunities could be developed both upstream and in the vicinity of the dam. As discussed below, these opportunities include new public day use facilities, camping facilities, and cottage/rural residential developments.

New Public Day Use Activities

Day use demand at reservoir sites is consistently high within the prairie region. Although the few communities and local populations within the immediate vicinity of the potential dam site are small, the general lack of water-based recreation sites in southern Alberta and Saskatchewan suggests that the Meridian Dam would draw both local and regional interest.

Market trends and examples of other similar projects suggest that this reservoir site could include the following activities:

- Picnicking – this activity would cater primarily to local/regional residents.
- Swimming – assuming acceptable water quality, swimming activities would be feasible if locations can be found with safe access.
- Boardsailing – the potential for boardsailing will be tied to the development of publicly accessible day use areas and the size and configuration of the reservoir in the vicinity of such access points.
- Waterfowl Viewing – Eco-tourism and wildlife viewing is being actively promoted throughout the province of Alberta and Saskatchewan. The proximity of the project to Medicine Hat, the Prairie National Wildlife Area, and the Great Sand Hills of Saskatchewan suggests that tours of the region could be developed. It is likely that wildfowl nesting both on and off stream will be encouraged by the size of the reservoir. Further studies will be required to assess the compatibility of wildlife and active recreational use.

Camping

Although small-scale camping facilities would be of interest to local communities, investment by the public sector in campground facilities does not generally yield economic returns and therefore would not likely be supported by the Alberta or Saskatchewan governments. Development of the Meridian Dam, however, would flood an existing campground at Sandy Point that would result in a loss in revenue. Private sector interests in camping activity is unknown but could be considered by local landowners should planning regulations and market demand permit.

Cottaging / Rural Residential Developments

Studies have shown that there is a market demand for cottaging due to limited opportunities for water-based land development. This demand is increased if water levels in a reservoir can be maintained. Reservoir fluctuations during the peak summer season, and the narrow configuration of the Meridian Dam reservoir may reduce the demand for private sector land development at the potential reservoir site.

4.5.3 Summary of Recreational Potential

Preliminary assessment of the Meridian Dam project suggests that the reservoir project will, in general, offer a number of local and regional recreational opportunities. Despite biophysical and operational limitations, potential exists for the development of a variety of recreational activities at the local level. These include the following:

- Public day use facilities including picnic sites, beaches, boat launches
- Hunting and fishing activity
- Canoeing, boating, and sail boarding
- Hiking

The Meridian Dam project would also present the added opportunity of developing more regional recreational amenities such as the following:

- Eco-tourism related to wildlife viewing and scenic canyon tours
- Historic/cultural interpretation

- Camping (given sufficient market demand)

This assessment has not specifically examined the potential for development of private facilities or private recreational services. Such developments will ultimately depend upon the individual analysis of private interests and an assessment of market factors.

4.5.4 Data Gaps

This recreation benefit assessment is based on data and available information pertaining to the design and operation of the project. It is also based on a number of assumptions and observations related to typical reservoir developments. As such, the findings are considered preliminary in nature and would be subject to change following more detailed investigations. If the project proceeds to the next level of feasibility study, it is recommended that a number of specific issues be examined in further detail. These would include the following:

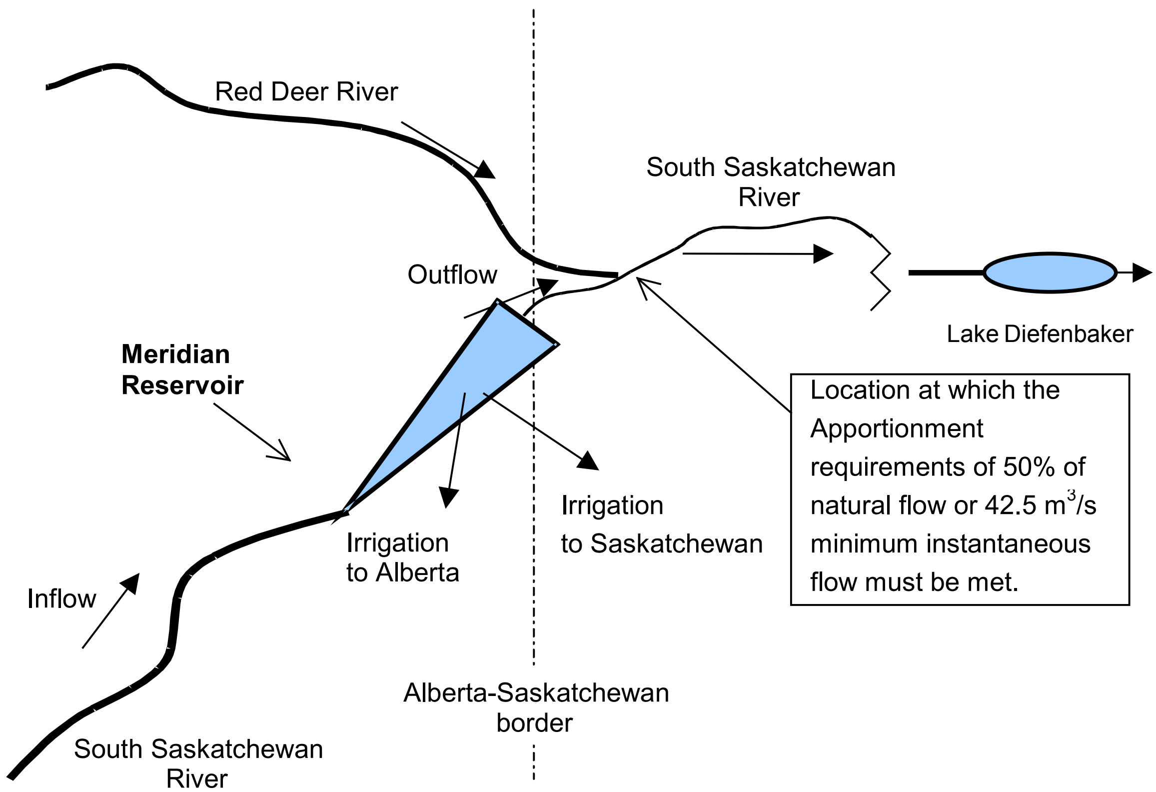
- Detailed site analysis of the river valley to assess potential access points and areas suitable for day use developments. This would include a detailed slope/stability/aspect analysis.
- Develop a visual resource and recreational opportunities impact assessment.
- Market analysis and review of existing regional recreational facilities to determine current demand for additional services.
- Detailed assessment of transportation linkages and design plans to determine potential for accommodating recreational facilities and access.
- Review of detailed engineering designs in order to make recommendations for maximizing recreational opportunities during and after construction.
- Detailed review of historic/cultural resource inventories to determine potential opportunities for interpretive/recreational developments associated with the reservoir.
- Detailed review of local planning authority interests and support for private sector recreational development.
- Preparation of preliminary mapping and site development concepts for recreational sites and/or facilities that could be incorporated into the dam's overall development plan and construction strategies.

5 EVALUATION OF ENVIRONMENTAL IMPACTS

5.1 River Hydrology and Morphology

Development of an on-stream reservoir can change the hydrologic regime and possibly the morphology of a river. Specific impacts depend on the size of the reservoir in relation to river flows, and on the composition of the river itself. The Meridian reservoir would likely impact the South Saskatchewan River downstream of the reservoir, down to Lake Diefenbaker as illustrated in Figure 5.1-1.

Figure 5.1-1 Schematic of Meridian Area River System.



The following discussion pertains primarily to the South Saskatchewan River in the vicinity of the Meridian Dam, between the dam and the Red Deer River confluence. Specific impacts on this reach of the river could include the following:

- **Reduced Flood Peaks:** Reduced flood peaks would be caused by the flow attenuation capability of the reservoir, where runoff from peak flows are stored in the reservoir, resulting in a significant reduction in downstream peak flows. This is beneficial for meeting flood control objectives but it may result in a number of ecological effects including: reduced sediment deposition on flood plains; reduced inundation of land adjacent to the river (with potential effects on vegetation that depends on periodic inundation); and reduced flushing flows that might condition the river bed material to improve fish habitat.
- **River Bed Degradation:** The development of a reservoir tends to interrupt the sediment transport characteristics of a river by trapping the bed load and most of the suspended load. Consequently, the outflow of a reservoir is relatively free of sediment. Such a flow has increased capability for replacing its sediment carrying capacity and therefore there is a greater tendency for river bed and bank erosion downstream of a dam. The river reach between the Meridian Dam site and Lake Diefenbaker would be subject to river degradation (bed lowering) and bank erosion. This impact can be mitigated by erosion protection systems.
- **Reduced Flows:** The withdrawal of river flows enabled by the reservoir will reduce the overall flows in the river downstream of the dam. Most of the reduction will occur during periods of high flow as the reservoir is used to store water for irrigation water supply.
- **Change in River Regime:** A change in river flows caused by the reservoir could change the natural river regime and geomorphic trends of the river. This could result in some bank erosion and relocation of the thalweg.

These impacts cannot be quantified given the current available data. However, they are considered at this time to provide inputs to the environmental assessment and as inputs to estimate cost for mitigation.

5.2 Fisheries

5.2.1 Existing Conditions

The South Saskatchewan River, from the Grand Forks (junction of the lower Bow River and the lower Oldman River) downstream to the confluence with Red Deer River, represents a fishery of over 300 km in length. The limited number of studies that have been undertaken on fish populations and habitat of the South Saskatchewan River include a baseline study for lake sturgeon (Haugen 1969) as well as annual harvest monitoring since 1968 (Alberta Fish and Wildlife Division Sturgeon Management Questionnaire). Considerably less is known about the status and biology of other fish populations, however, Fish and Wildlife Services provided a fisheries overview of the system current to 1980 (Longmore and Stenton 1981), as a part of Alberta Environment's "South Saskatchewan River Basin Water Management Plan". Inventory level work after 1980 includes limnological measurements at selected sites, benthic invertebrate collections, and fish collections during 1983, 1985, 1986, and 1987 (English 1988; Alberta Environmental Protection, Lethbridge, file data). Additional work on lake sturgeon includes investigations of movements, life history, and critical habitats (RL&L 1991) and assessments of harvest regulations (RL&L 1994). The results of these studies contributed to the development of a lake sturgeon management plan for Alberta (Berry 1996).

A basin-wide study of fish populations and habitat characteristics was recently completed at 16 index sites on the lower Bow, lower Oldman, and South Saskatchewan rivers from fall 1995 to fall 1996 (RL&L 1996, 1997). Eight of these sites were on the South Saskatchewan River. A final component of the study included monitoring of fish movements and migrations in the South Saskatchewan River and its major tributaries (RL&L 1998).

The following review is based primarily on the 1995-1997 sampling that occurred on the South Saskatchewan River between the Grand Forks and the Red Deer River confluence, and on the lower Red Deer River (RL&L 1996, 1997 and 1998). This investigation included an instream habitat assessment within index survey sections and fish community sampling utilizing a variety of capture methods such as boat electrofishing, backpack electrofishing, beach seining and set lining. A radio telemetry program was used to determine overwintering and potential spawning-

related movements. Information on angler use was collected based on a creel survey, interviews with fishing groups, and an annual mail out by Alberta Fish and Wildlife Division.

5.2.1.1 Index Sites

During fall 1995, index survey sites were established in representative reaches of the South Saskatchewan River (RL&L 1995). These sites were approximately 5 to 20 km in length and represented typical habitat characteristics for each study reach. The locations of the eight index sites selected and sampled during 1995-96 are listed in Table 5.2-1. Five of these locations (Sites S4 to S7) are within the direct upstream and downstream zone of influence of the potential Meridian Dam development.

Table 5.2-1
Location of Index Sites in the South Saskatchewan and Red Deer Rivers, 1995-1996.

River	Index Site Designation and Name		Upstream Distance from Meridian Dam Site (km)[1]	Sites Within Direct Zone of Influence
South Saskatchewan	S1	Grand Forks	280-294.5	
	S2	Rattlesnake	203.5-215.3	
	S3	Medicine Hat	181.5-198.5	
	S4	Bullpen	104.5-128.5	X
	S5	Boundary	90.5-96.8	X
	S5a	Ferry Crossing	34.5-44.5	X
	S6	Sandy Point	16.3-31.5	X
	S7	Red Deer Forks	-4.5 to –24.5	X
Red Deer	R1	Mouth	-23.7 to –26.4	

1 Km 0 was established at the potential Meridian Dam site; distance was measured on 1:50 000 NTS maps in an upstream direction; negative distance indicates distance downstream of Meridian site.

5.2.1.2 Fish Habitat Characteristics

Between the Grand Forks and the Red Deer River confluence (in the Province of Saskatchewan), the South Saskatchewan River flows northeast for 300 km through partly cultivated or open prairie, with a mean gradient of 0.41 m/km (RL&L 1996). Although the steepest overall

gradients (approximately 0.7 m/km) occur immediately downstream of Medicine Hat (Km 159.5 to Km 179.5), the largest rapids are present between the Bullpen (Site S4; Km 120) and White Rock areas (Km 69.5). The lowest mean gradients (0.2 m/km) are featured in the lowermost section of the river (Km 29.5 to –20.5), from Sandy Point (Highway 41 crossing) downstream to the Red Deer River (Site S7). High water velocities (>0.7 m/s) were encountered in approximately 24% of the sampled river channel at sites S4 and S5 (Bullpen and Boundary); the occurrence of high velocity areas at the remaining sites was much lower (2 - 14%; RL&L 1996). Similarly, mean channel depths were highest at sites S4 and S5 (2.3 and 2.0 m, respectively). Mean depths at the remaining sites were lower (ranging between 1.1 and 1.7 m); however, localised "deep" holes (3.6 m or deeper) were recorded at all sites. The deepest "hole" (9.2 m) was located at Km 120 at Site S4 (Bullpen).

Daily water temperature data were recorded by thermographs installed at Grand Forks (Site S1), Medicine Hat (Site S3), and Highway 41 (Site S4) during May-October, 1996. The highest mean monthly temperatures were recorded in July (21.3°C at the Grand Forks and 21.5°C at both Medicine Hat and Highway 41). The maximum water temperatures recorded at each of these stations were also very similar (ranged from 25.1 to 25.4°C).

Water transparency was low during spring 1996 (ranged from 0.1 to 0.2 m Secchi depth); however, it increased considerably in the summer (0.5 - 0.7 m) and fall (0.6 - 1.5 m). Water conductivity data exhibited little variation between sites and seasons; all collected measurements were within the 310 - 460 µS/cm range. Water turbidity was generally higher during summer 1996 (10.2 - 12.3 NTU) than during fall 1996 (5.7 - 10.4 NTU).

Dissolved oxygen and temperature profiles were measured at sites S1, S2, S4, and S6 during early August 1996. Uniform temperatures and oxygen concentrations from surface to bottom indicated thorough mixing. Dissolved oxygen concentrations varied slightly between sites (from 9.0 to 10.3 mg/L at 16.6 to 21.7°C water temperature range); however, dissolved oxygen saturation approximated 100% at all sites (ranged from 96 to 105%).

The low-gradient and water temperature regime of the South Saskatchewan River provides suitable habitat for many warm water species. The distributions of meso-habitat types within the index survey sections in the South Saskatchewan River were surveyed and described during fall

1995. Although slow-flowing run habitats were predominant at all sampled sites (RL&L 1996), rapids and riffle areas were also recorded at all sites; these fast-water habitats were most common at sites S4 and S5. As previously mentioned, deep-water areas were also recorded at all index sites with the deepest holes (up to 9.2 m deep) recorded at Site S4. Instream cover was provided mainly by boulder gardens and aquatic vegetation and tended to be less widely available at the Grand Forks and Red Deer Forks (sites S1 and S7) than at intermediate sites.

5.2.1.3 Fish Community Characteristics

Species Composition

A total of 23 fish species, including 10 sportfish and 13 non-sportfish species, have been documented in the South Saskatchewan River during recent studies. These species are listed in Table 5.2-2. None of the present species assemblage is considered endangered or threatened, although lake sturgeon is a special management species (Berry 1996). Because of a confined distribution in Alberta, low abundance and vulnerability to anthropogenic impacts, lake sturgeon populations have been the focus of specific management actions for nearly 60 years (McLeod et al. 1999). Previously listed as "vulnerable", the species is presently considered to be "not at risk"(COSEWIC 2001). In a recent assessment, the status of lake sturgeon was also rated as "undetermined" (*The General Status of Alberta Wild Species*, ASRD 2001). In the same publication two other fish found in the South Saskatchewan River, as well as in other drainages in the province, were identified as species of interest. Spoonhead sculpin were categorized as "may be at risk", while sauger were identified as "sensitive".

Relative Abundance

During the 1995-1996 program, the total sample size from the South Saskatchewan River and the mouth of the Red Deer River (all sampling methods, locations, and seasons combined) was 12,288 fish (RL&L 1997). Ten sportfish species contributed 11.0% to the total catch. This included mooneye (3.5% of the total catch), lake whitefish (2.7%), sauger (1.3%), walleye (1.2%), goldeye (1.1%), lake sturgeon (0.7%), and northern pike (0.4%). The remaining sportfish species (burbot, brown trout, and yellow perch) were encountered very infrequently or rarely. Non-sportfish represented 63.4% of the overall catch and were dominated by sucker species, the most abundant being the silver redhorse at 26.9% of overall catch. Cyprinid species contributed 24.7% to the overall catch of which 88% were emerald shiner and river shiner.

Table 5.2-2
Fish Species Encountered in the South Saskatchewan River, 1995-1996
(RL&L Environmental Services 1997)

Category	Common Name	Scientific Name
Sportfish	Lake sturgeon	Acipenser fulvescens Rafinesque
	Brown trout	Salmo trutta Linnaeus
	Lake whitefish	Coregonus clupeaformis (Mitchill)
	Goldeye	Hiodon alosoides (Rafinesque)
	Mooneye	Hiodon tergisus Lesueur
	Northern pike	Esox lucius Linnaeus
	Walleye	Stizostedion vitreum (Mitchill)
	Sauger	Stizostedion canadense (Smith)
	Yellow perch	Perca flavescens (Mitchill)
	Burbot	Lota lota (Linnaeus)
Non-sportfish	White sucker	Catostomus commersonii (Lacepede)
	Longnose sucker	Catostomus catostomus (Forster)
	Shorthead redhorse	Moxostoma macrolepidotum (Lesueur)
	Silver redhorse	Moxostoma anisurum (Rafinesque)
	Quillback	Carpiodes cyprinus (Lesueur)
	Lake chub	Couesius plumbeus (Agassiz)
	Emerald shiner	Notropis atherinoides Rafinesque
	River shiner	Notropis blennius (Girard)
	Spottail shiner	Notropis hudsonius (Clinton)
	Longnose dace	Rhinichthys cataractae (Valenciennes)
	Flathead chub	Platygobio gracilis (Richardson)
	Trout-perch	Percopsis omiscomaycus (Walbaum)
	Spoonhead sculpin	Cottus ricei (Nelson)

By location, the overall catch rates for all fish combined were highest at sites S2, S1, and S6 (25.9, 25.7, and 25.6 fish/10 min, respectively) and lowest at sites S5a and S3 (6.5 and 13.5 fish/10 min, respectively). Sportfish species were most abundant at sites S1 and S6 (4.4 and 3.8 fish/10 min, respectively) and they were captured least frequently at sites S5a and S3 (0.9 and 1.1 fish/10 min, respectively).

5.2.1.4 Fish Movement Patterns

Fish movements in the South Saskatchewan River system were determined by recaptures of fish previously marked with Floy™ tags and aerial tracking of fish implanted with radio transmitters (RL&L 1998). In total, 901 sportfish captured in the South Saskatchewan River during 1995 - 1996 were marked with Floy™ tags and released. Although the tagging program included 11 sportfish species, tag recaptures were obtained for only four species (lake sturgeon, walleye, sauger, and northern pike) and in very low numbers (*n*=8).

To determine overwintering habitat and spring/early summer spawning-related movements, 61 fish (14 lake sturgeon, 30 walleye, 16 sauger, and 1 northern pike) were surgically implanted with radio transmitters in fall 1996. The majority of these fish were released at the Grand Forks (Site S1), Medicine Hat (Site S3) and Boundary (Site S5).

<u>Fall/Winter Movements</u>

During the fall/winter period most lake sturgeon (67%) remained close to their capture locations. However, one fish moved 100 km downstream from the Boundary area (Site S5) to overwinter in Saskatchewan (near Km 2.5 to Km –5.5). Similar results were obtained during the 1985-1989 study of lake sturgeon movements (RL&L 1991); most fish overwintered near their release locations in the Boundary area, but at least 3 of 30 radio-tagged individuals showed extensive (98, 117, and 203 km) downstream movements during late fall.

A high percentage of radio-tagged walleye and sauger (46% and 27%, respectively) showed downstream movements of at least 10 km with several fish exhibiting long-distance (between 55 and 148 km) movements during this period. Two walleye moved from the Boundary area to overwinter in Saskatchewan (near Km –1.5 to Km –3.5 where the only long-distance lake sturgeon migrant overwintered), suggesting that this section of the South Saskatchewan River (approximately 18 km upstream of the Red Deer Forks) may be of special importance to overwintering fish.

<u>Spring Movements</u>

The early spring period (March – late April 1997) was characterized by variable movement patterns. Most lake sturgeon (8 of 12) travelled downstream, with two individuals moving

upstream. These results were similar to those recorded in early spring 1986 (RL&L 1991). Walleye undertook both upstream (19% of fish) and downstream movements (29%); however, the proportion of stationary fish (52%) was considerably greater than that recorded for lake sturgeon during this same period. Early spring appeared to be the season of most pronounced migrations of sauger. Nearly 73% of sauger exhibited extensive downstream movement (97 km on average, and ranging from 24 to 302 km), 4 of 15 fish remained stationary, and none showed movements in the upstream direction. The movements of walleye and sauger during this period were likely related to spawning behaviour (mean water temperature increased to 11°C by late April); however, the lack of recorded concentrations of fish in any particular location suggests that spawning areas were widely distributed along the South Saskatchewan River system.

During late spring 1996 (May) most fish were relatively stationary. The main exceptions to this pattern were two lake sturgeon that moved 15 and 105 km upstream, two walleye that moved 81 and 144 km downstream, and four sauger that moved between 59 and 115 km farther downstream as a continuation of migrations started during early spring. During this period, one walleye and one sauger were located in the Red Deer River (141 and 70 km upstream of the confluence, respectively); these movements were likely related to spawning.

Early Summer Movements

Many fish remained stationary during the early summer, but a small number of individuals exhibited long-distance movements. Three lake sturgeon undertook upstream migrations that ranged from 20 to 79 km in length; one of these fish moved a total of 164 km after leaving the Boundary site in mid-March 1997. RL&L (1991) documented a similar large (209 km) upstream migration of an adult sturgeon to the Grand Forks area during late April to mid June 1986 and attributed it to a spawning migration. Of the two adult lake sturgeon that were tracked between 14 May and 9 July 1997, one may have spawned in the Rattlesnake area (near its over-wintering location) while the other moved 53 km downstream of Site S5 in early spring and remained there throughout the spawning period. One walleye and two sauger exhibited long-distance upstream migrations in summer (between 91 and 167 km in length) to return to the vicinity of their locations in early spring.

To quantify the extent of movements in the South Saskatchewan River system during the 1996-1997 study period, maximum individual ranges were determined. These distances between the

farthest downstream and upstream locations are given in Table 5.2-3. The results indicate that sauger travelled more extensively than the other species, with 70% showing large ranges of 100 km or more. The maximum ranges recorded for walleye and sauger (320 and 385 km, respectively) included not only the South Saskatchewan River mainstem but also the Red Deer River as far as 141 km upstream of the Red Deer Forks.

Table 5.2-3 Maximum Rate of Movement Recorded for Individual Fish in the South Saskatchewan River System, 1996-97.

Characteristic	Lake sturgeon	Walleye	Sauger
Maximum range (km)	165	320	385
Maximum overall distance travelled (km)	165	629	385
Maximum rate of travel (km/d)	7.0 (105 km in 15 d)	20.4 (143 km in 7 d)	19.0 (266 km in 14 d)

Many of the radio-tagged fish remained in the same reaches where they were released, however, some individuals exhibited extensive movements. These were likely movements to spawning and overwintering habitats. One radio-tagged walleye travelled at least 629 km during its return trip between Medicine Hat and the middle reaches of the Red Deer River, displaying a rapid rate of movement (143 km in 7 d, or 20.4 km/d). The study also re-confirmed the trans-boundary exchange of fish between the lower reaches of the South Saskatchewan River (in the Province of Saskatchewan) and the middle and upper reaches in Alberta (RL&L 1991, McLeod et al. 1999). Significant movements between the upper and middle reaches of the South Saskatchewan River and the Red Deer River were recorded for at least two sportfish species. Although only a small number of fish were involved (6% of sauger and 3% of walleye), the overlapping use of these two rivers may be an important characteristic of the fish populations in the South Saskatchewan River Basin.

5.2.1.5 Critical Habitats

Sportfish use of habitats within the index sites in the South Saskatchewan River was assessed on the basis of the seasonal patterns of fish abundance and distribution, presence of juvenile and adult size-classes, and sexual conditions of fish during the spawning period (Table 5.2-4). Although spawning activities were not confirmed, they likely occurred at the indicated sites based

on the capture of adult fish in gravid, ripe, or spent condition, and/or the availability of suitable spawning habitat. The assessments of overwintering habitat use are based on the results of the radiotelemetry program.

Table 5.2-4 Critical Habitat Functions at Index Sites in the South Saskatchewan River, 1995-1996 (RL&L1997)

Species	Site S1 Grand Forks	Site S2 Rattlesnake	Site S3 Medicine Hat	Site S4 Bullpen	Site S5 Boundary	Site S6 Sandy Point	Site S7 Red Deer Forks
Lake sturgeon	JR, AF	JR, AF, OW		JR, AF	JR, AF, OW	JR, AF	JR, AF, OW
Brown trout				SP			
Lake whitefish	SP, AF	SP, AF	SP, AF	SP, AF	SP, AF	SP, AF	SP, AF
Goldeye	SP, AF	SP, AF	AF	AF	AF	JR, AF, OW	JR, AF, OW
Mooneye	SP, JR, AF	SP, AF	SP, AF	SP, JR, AF	AF	SP, JR, AF	SP, AF
Northern pike		AF	AF		AF	JR, AF	
Walleye	JR, AF, OW	JR, AF, OW	JR, AF, OW	SP, JR, AF, OW	JR, AF, OW	SP, JR, AF	JR, AF, OW
Sauger	AF, OW	SP, AF	AF, OW	JR, AF	AF, OW	JR, AF	JR, AF, OW
Yellow perch			JR	JR			JR
Burbot	JR, AF	AF		AF	AF		

SP = spawning; JR = juvenile rearing; AF = adult feeding; OW = over-wintering

Spawning Habitat

Suitable spawning areas are widely dispersed in most reaches of the South Saskatchewan River. Capture of mature individuals in post-spawning condition indicated that walleye likely spawned near downstream sites S4 and S6, whereas Site S2 may have been used for spawning by sauger. Pre-spawning concentrations of mooneye were recorded at all sites sampled in spring 1996. Mooneye appeared to be more abundant at sites S1 and S2, suggesting that the upper reaches of the river were more suitable for spawning habitat than the lower reaches. Goldeye in post-spawning condition also were captured at sites S1 and S2, indicating that they likely spawned in similar areas as mooneye, but earlier in the season.

Concentrations of lake whitefish in pre-spawning condition were recorded at all sites sampled in October 1995; however, they were nearly absent from the same sites during the October 1996 sampling events. Brown trout was the only other fall spawning sportfish species recorded in the

South Saskatchewan River. Although one ripe female brown trout was captured in a small riffle area at Km 154 in October 1996, it was probably a displaced individual from the lower Bow or Oldman River (i.e., brown trout spawning in the South Saskatchewan River is likely not a regular event).

Rearing Habitat

The South Saskatchewan River, throughout the study area, provides suitable rearing habitat for most fish species. Juvenile or sub-adult lake sturgeon were recorded at all index sites except Site S3. Most were captured in deep water habitats at sites S2, S4, and S5. Juvenile walleye were also captured at all sites, however, young-of-the-year and Age 1 fish were recorded only at site S3 and farther downstream. Juvenile sauger were also captured primarily in the downstream reaches (sites S4, S6, and S7).

Overwintering Habitat

On the basis of movements of radio-tagged fish, overwintering areas for lake sturgeon were identified at sites S2, S5, and S7. Walleye and sauger overwintering was recorded in selected areas throughout all reaches; however, some individuals underwent long-distance migrations to overwinter in downstream areas. Based on radiotelemetry results, the Red Deer Forks area may provide important overwintering habitat for goldeye, walleye, and sauger.

5.2.2 Recreational Importance

Based on their value to the recreational fishery and discussions with Alberta Sustainable Resource Development (T. Clayton, Area Fisheries Biologist, Lethbridge, pers.comm.), the following sportfish species within the South Saskatchewan River have been designated as high priority management species:

- lake sturgeon
- walleye
- sauger
- goldeye
- mooneye

Angling use of the South Saskatchewan River, except for the urban area of Medicine Hat, is limited by access, and is generally focused on less than a dozen locations (RL&L 1991). Due to Canadian Forces Base Suffield, which forms the eastern boundary of 68 km of the South Saskatchewan River, plus overlaying another 20 km, and the large amount of private rangeland, a considerable amount of the river is inaccessible by road. A majority of anglers are local residents; during a stratified creel survey of the river conducted in 1985, over 40% were Medicine Hat residents, with the next largest component originating from Calgary (RL&L 1991).

Lake sturgeon are targeted by the majority of anglers and at present one guiding operation is located in Medicine Hat (T. Clayton, pers. comm.). The majority of sturgeon fishing in Alberta is concentrated on the South Saskatchewan River. Twenty groups of anglers fishing in the South Saskatchewan River were interviewed during 1995-1996. Their total catch (all species) consisted of 35 fish (combined CPUE of 0.3 fish/rod-Hdsph), of which half (n = 17) were lake sturgeon. The highest catch rates for lake sturgeon were recorded at the Rattlesnake and Bullpen areas (0.64 and 0.32 fish/rod-h, respectively). Alberta Fish and Wildlife Division have employed an annual mail-out Sturgeon Management Questionnaire since 1968 to collect angler harvest data on sturgeon. In 2000, a total of 164 lake sturgeon were reported captured, of which 159 were taken from the South Saskatchewan River (Clayton 2001). The major locations for sturgeon fishing activity are Rattlesnake (Site S2), Bullpen (Site S4) and Boundary (Site S5), although several other sites are also utilized, including the confluence with the Red Deer River and a hole just downstream of the Alberta/Saskatchewan border.

Walleye are generally the second “most sought after” species (RL&L 1997).

5.2.3 Potential Impacts of the Project

5.2.3.1 Potential Effects of Reservoir Formation

The development of an on-stream reservoir will result in the transformation of a lotic, or riverine, environment to one that more closely resembles a lentic or lake-like, environment. This has significant implications for the aquatic habitats present, as well as for the aquatic fauna that inhabit the section of river affected. The following issues would need to be addressed in an environmental assessment of reservoir construction.

Reservoir Construction

During the construction phase of the potential project, regardless of the construction strategy employed, sediment will be introduced into the South Saskatchewan River. Potential impacts resulting from the input of sediment would depend on a number of variables, such as the volume of material introduced, and the timing of the sediment events. Impacts associated with increased suspended sediment levels include: temporary reduction in primary and secondary productivity due to decreased water clarity, damage to fish tissues such as gill epithelium, and the loss of incubating eggs downstream of the construction site. However, assuming that good construction practices are followed and disturbed surfaces are stabilized as soon as possible, this impact, although negative, is expected to be of minor magnitude and of short term duration.

The placement of a dam, in the absence of an effective mitigation strategy, will result in the blockage of fish movements. The consequences of blocking fish movements in this section of the South Saskatchewan River are significant, because species such as lake sturgeon, walleye and sauger may be isolated from one or more critical habitats (e.g., spawning or overwintering habitats). This issue is discussed further under the reservoir operation phase of the potential project.

An additional concern related to the construction of a dam and associated infrastructure is the accidental introduction of toxic materials (e.g. petroleum products). The consequences of an accidental introduction of toxics to the South Saskatchewan River would depend on the type and volume of the substance entering the watercourse and the aquatic fauna within the zone of influence at the time of the spill.

Reservoir Operation

Although the reservoir would resemble a lentic environment, there is little similarity in the biological functioning of a reservoir compared to a natural or man-made lake.

Table 5.2-5 Summary of Potential Impacts Resulting From Reservoir Formation

BIOTIC EFFECTS		ABIOTIC EFFECTS
Primary Productivity	• Loss of periphyton, (attached algae) and aquatic macrophytes • Increased zooplankton and phytoplankton	• Shoreline erosion • Increased turbidity • Reduced light penetration • Altered water quality • Nutrient sink • Altered thermal regime • Increased evaporative losses • Sedimentation
Secondary Productivity	• Loss of benthic invertebrate production in the littoral zone	
Fish	• Altered habitat favours lacustrine fauna over riverine fauna • Obstruction to migration • Loss of critical riverine habitats due to inundation (e.g., riffle/run spawning/feeding areas) • Potential isolation from critical habitats due to presence of dam (e.g., downstream situated spawning areas) • Potential loss of food base • Increased mercury levels in fish flesh	

The transformation of a riverine environment into a lacustrine environment involves a series of abiotic changes that significantly affect the biotic resources (Table 5.2-5). Reservoir development often induces shoreline erosion, resulting in increased turbidity and reduced light penetration in the waterbody. Water quality in the reservoir generally does not resemble conditions in the free-flowing river (see Section 5.6). Typically, a reservoir acts as a nutrient sink, with fewer nutrients being released downstream than enter the reservoir. The reservoir also acts as a heat sink. In this respect, the reservoir and section of river downstream of the dam take longer to warm up in the spring, and more time to cool in the fall. It also is likely that the reservoir will stratify, with cooler and possibly oxygen-poor waters occurring in the deeper portions of the reservoir. There is also a possibility that ammonia levels in these waters may be elevated. Due to the expanded surface area of the reservoir, increased evaporative losses would occur. This can result in a net decrease in water available for release downstream or for irrigation off-take. The reservoir would also function as a sediment trap, and over the long term may lose habitat capacity through infilling.

The consequences to the biota of these abiotic changes would likely include a loss of periphyton and aquatic macrophyte communities (i.e., associated with increased turbidity from shoreline erosion, which hampers photosynthetic processes). Shoreline erosion is often a temporary process and, over time, turbidity levels generally decline and light penetration improves. However, due to the annual reservoir drawdown regime, periphyton and attached macrophytes generally do not establish in the littoral zone, where the majority of biological productivity occurs. Likewise, benthic invertebrate productivity is generally low in this zone of the reservoir as a result of dewatering and freezing and the absence of algae and macrophytes which serve as cover and food for the benthos. A reservoir may experience increased phytoplankton and zooplankton productivity due to the presence of a standing water body and the greater availability of nutrients.

The formation of an on-stream reservoir dramatically alters the type and availability of fish habitat. Typically, these changes in habitat occur to the detriment of riverine fish species, and to the benefit of species that prefer lake-type environments. Some of the sportfish species currently occupying the potentially inundated reaches of the South Saskatchewan River may adapt to conditions in the reservoirs (i.e., species known to occupy rivers, lakes and reservoirs in other geographic settings). Others may not flourish in the reservoir due to habitat limitations associated with the drawdown regime and movement blockage. Species such as northern pike and yellow perch require aquatic macrophytes for critical life stages such as spawning and rearing. As such, may not successfully colonize the reservoir unless this habitat type is developed or is available in the river upstream of the reservoir. However, these species may thrive during the first few years following reservoir filling due to the abundance of flooded vegetation. They generally decline as the terrestrial vegetation decomposes and is not replaced by aquatic vegetation (i.e., effects of drawdown regime). Species such as lake sturgeon, walleye and sauger may not spawn successfully in the reservoir due to the absence of suitable gravel/cobble areas for spawning or due to sediments covering suitable areas following dam construction.

The dam will permanently obstruct upstream fish movements (i.e., unlikely that a functional fish ladder could be constructed to bypass a 70 m high dam). Downstream movements may occur sporadically during reservoir spilling periods, but these events may also result in fish mortality. Downstream movements through the reservoir outlet, which is equipped with a hydropower turbine, would result in mortality. As a result, the power intake would have to be properly screened. Thus, species such as sauger and walleye, which appear to move downstream to access

spawning habitat, would be precluded from such movements. If suitable habitat for critical life history stages such as spawning is not present upstream of the reservoir, or in the reservoir itself, these species may be eliminated completely from this region of the river.

Based on available data, it appears that some downstream fish movements in the South Saskatchewan River are related to finding suitable overwintering habitats (e.g., near Red Deer River confluence) Although these movements will be blocked by the dam, the reservoir may provide suitable habitat for overwintering.

The riverine species that rely heavily on benthic invertebrates, such as lake sturgeon, lake whitefish and possibly mooneye and goldeye, may experience a reduction in their food base within the reservoir. The production of benthic invertebrates, and in particular the large-bodied forms that are important food items for many fish, would largely be absent from the reservoir due to the presence of an unstable, non-productive littoral zone.

Typically, during the first ten years of reservoir operation, mercury levels in fish tend to increase, potentially to the extent that frequent consumption by humans is discouraged. This is the result of bacterial methylation of mercury present in the flooded soils, and bioaccumulation of mercury in the food chain.

The production of fish biomass may be greater in the reservoir than in the natural river reach prior to flooding. This would not reflect improved habitat conditions in the reservoir, but rather be due to the presence of a much larger body of water.

Reservoir Decommissioning

Until recently, reservoir decommissioning was an unknown practice; however, it is becoming more prevalent, particularly in the United States. Reservoir decommissioning can result in short term negative impacts on the riverine environment. If a mature reservoir is drained, there may be a significant sediment load introduced to the downstream river from material that has accumulated in the former reservoir. In addition to the typical problems associated with downstream sediment delivery, the concern may be heightened if there is toxicity associated with these sediments. Significant sediment loading may also occur during the actual dam removal, regardless of the method employed to handle the accumulated sediments behind the dam.

Accidental spillage of toxins into the river from machinery used to decommission the dam is also a concern. despite the short term negative effects discussed, decommissioning would allow fish access to upstream and downstream reaches of the river and would facilitate a return to a more natural hydrograph.

5.2.3.2 Overview of the Effects of River Regulation

Impounding a free-flowing river initiates a sequence of changes in the downstream channel and the associated riparian habitats (Petts 1984). Due to the large number of processes involved, the effects of flow modification can be extremely variable and the extent and severity of such changes are predictable in only general terms.

Petts (1984) identified a number of biotic and abiotic impacts associated with river impoundment (Table 5.2-6). The formation of a reservoir results in increased evaporation, and thus a reduction in annual runoff. The storage of water for subsequent release alters the natural flow pattern. Chemical and thermal changes in downstream water quality are experienced, and are influenced by the level at which water is discharged from the reservoir. Annual plankton loads in the downstream riverine environment may be increased by 150 to 200 times. The release of sediment-free water can cause channel-bed degradation and accelerated erosion rates, and an increase in the average size of substrate particles.

The regular release of clear-water discharges onto stable substrates may cause an increase in the growth of periphyton and macrophytes on a year-round basis. Changes may be experienced in the vegetative community on the floodplain, with a reduction in diversity, density and productivity as the soils dry out. Depending on the degree of regulation, a dense, rich but narrow riparian vegetation zone may develop; it is often dominated by species such as willows. Changes in water quality and quantity, channel morphology and substrate particle size distribution results in altered species composition and abundance of benthic invertebrates.

Table 5.2-6 Summary of Downstream Impacts Resulting From River Impoundment [Modified from Petts (1984)]

Biotic Effects		**Abiotic Effects**	
Primary Productivity	• Increased light penetration • Increased substrate stability	*Reduced turbidity*	
Invertebrates	• Loss of thermal cues • Substrate sedimentation • Stranding and enhanced drift	*Channel erosion*	• Tributary rejuvenation • Increased channel depth • Coarser sediments
Fish	• Obstruction to migration • Delayed migration • Increased plankton loads • Elimination of warmwater species • Gas supersaturation • Deterioration of spawning gravels • Loss of flood-season spawning habitat	*Increased evaporative losses*	• elevated winter temperatures • reduced dissolved oxygen concentrations • increased pollution and salinity
		Channel Aggradation	• Flushing of fine sediments
		Floodplain erosion	• Cessation of silt enrichment
		Encroachment of terrestrial vegetation	• Reduced wetlands • Floodplain stabilization

The native fish species composition may change, and some species may be eliminated downstream of reservoirs because of adverse habitat changes. Such changes include alteration or loss of spawning areas, blockage that precludes access to spawning areas, and an altered thermal regime. The altered hydrologic regime can cause changes in channel morphology, water quality characteristics, and primary and secondary productivity, all of which are important to the well-being of the fishery resource, for up to 100 km below some dams (Petts 1984).

5.2.3.3 Variable Interactions

River water quality is largely dictated by the climate and geological characteristics of the drainage basin (Petts 1984). The impoundment of river water in reservoirs causes physical, chemical and biological changes within the stored water, which defines one component of the macrohabitat in the downstream riverine environment. Through the use of mathematical models, and predictions of the flow and quality of reservoir releases, estimates of water quality in the regulated river can be developed, as can the distance required before that quality returns to an

approximately natural or pre-impoundment condition. Design or operational alternatives may also be pursued in this planning process to preclude the development of any undesirable water quality characteristics.

Predictions are required from hydrologists and fluvial geomorphologists regarding the effects of altered river flows on the existing channel characteristics Bovee (1982) noted that instream flow investigators are faced with one of two choices in terms of channel dynamics: determine a flow regime that would prevent channel change, or, predict the new channel shape, should a channel change be inevitable. The latter choice is obviously more risky, and less desirable.

Two concepts are involved in addressing channel maintenance issues from the biological perspective. The first is the question of how the channel may change in the regulated stream. A primary responsibility of the biologist is to determine the quality of microhabitats that will exist in the regulated river channel. If structural changes in the river channel are predicted, a definition of these changes is required to assess the effects of a potential flow regime, or to provide estimates of the amount of flow required to provide habitat of a certain quality in the altered channel.

The second issue, which is important to the biologist in terms of channel maintenance, is the concept of a flushing flow. A flushing flow is defined as the flow that is required to flush or remove the fine sediments from the stream gravels. The purpose of such a flow is to maintain the quality of highly productive and important habitats such as spawning areas, or riffles where benthic invertebrate productivity is the highest. Thus the concept of maintaining existing channel geometry, and protection of that channel from the undesirable consequences of sedimentation are interrelated in terms of maintaining desired channel characteristics.

Another issue that must be considered is the effect of flow regulation on vegetation. A wide array of issues are involved in this component of the analysis, ranging from the importance of primary production by the aquatic flora (periphyton through to macrophytes) through to the significance of riparian vegetation for ecosystem integrity.

The majority of aquatic plants are not adaptable to lotic or running-water systems as they cannot resist detachment or damage from increases in water velocity, and since they are unable to

recover from significant losses of attached flora resulting from substrate movement under high flow conditions (Petts 1984). Flood frequency and duration often define the species composition of the instream flora, as the frequency of floods which may be tolerated by any particular species is dependent at least in part upon the growth rate of the species after the damage has occurred.

Macrophytes in lotic systems tend to establish their own microhabitats, by trapping the organic and inorganic material which is transported by the river, as well as organic debris from death of their own parts, creating their own enriched sediment. This microhabitat is conducive to the continued growth of the macrophytes. These aquatic plants contribute significantly to primary production in the river or stream, as well as provide a substrate for the development of periphyton and invertebrates (Welch 1980), and cover for certain life stages of fish. The result is a positive benefit to the river ecosystem.

Flow regulation may be conducive to the development of aquatic macrophytes due to: the increase in water clarity and thus light penetration downstream of a reservoir; the stable flow-pattern which often occurs; the creation of an ice-free zone; the reduction in flows which cause substrate disturbance; and the deposition of fine sediment particles downstream of tributaries or effluent sources (Petts 1984). The result may be extensive macrophyte growth which could cause dissolved oxygen problems, a competition for space with other biota in the river, clogged water supply intakes, and a significant reduction in the aesthetics and recreational suitability of the watercourse. When such conditions present themselves, the macrophytes are obviously no longer a potential benefit to the aquatic ecosystem.

Attached algae are also an important component of the aquatic flora that tend to dominate the fast-flowing, turbulent, clear headwaters of free-flowing rivers, particularly under the conditions provided by stable, mid-summer flows (Petts 1984). The algae tend to decrease in abundance in downstream areas of the free-flowing river because of reduced light penetration, higher suspended sediment loads, increased concentrations of dissolved organic matter, and increased water depths.

Reservoir development can result in the creation of reservoir releases that mimic headwater conditions. In combination with stable flows, these can be very conducive to the extensive and rapid growth of algae below the reservoir. Attached algae can provide an important microhabitat

for the growth of invertebrates, and in fact certain kinds of algae have been reported to be an important food for trout (Petts 1984). However, extensive algal beds are undesirable as they can result in: the development of undesirable taste and odour in the water; dissolved oxygen depletion due to photosynthesis and decay; reduced intragravel flow; clogged water intakes; and restricted fishing, boating and water-contact sports (Petts 1984). The instream flow assessment team must determine the likelihood for development of excessive macrophyte or algal beds in the regulated river, define the extent of any such problem, and develop measures to preclude or minimize the occurrence of such a problem.

The third aspect of vegetation associations, which must be considered in assessing instream flow needs in a regulated river, is that of the riparian community. The vegetation that grows along a free-flowing river, and is dependent upon the stream water for survival, is very important to fish and wildlife, and for the maintenance of aquatic habitats (Risser and Harris 1989). Riparian vegetation provides water temperature regulation, assists in maintaining water quality, and may be critical to the maintenance of aquatic community structure and productivity. Streamside vegetation and the associated woody debris stabilize stream channels and floodplains, trap sediments and store nutrients, and can affect the magnitude and duration of floods. On the other hand, regular periods of high discharge are required to preclude the encroachment of terrestrial vegetation into the river channel. Riparian zones are also typically the focal point for recreation, as well as other potentially detrimental activities such as cattle grazing.

The extreme variability in riparian systems, both between streams and within reaches of the same stream, complicates description and analysis of this feature of the aquatic ecosystem (Risser and Harris 1989). Due to the diversity of physical characteristics that regulate the growth of streamside vegetation, and the degree to which these physical characteristics may change within a very short distance along the stream, the prediction of impacts on riparian vegetation as a result of flow regulation is difficult. This sort of situation leads to the development of mitigation measures that may, of necessity, be speculative.

A significant body of knowledge has, however, been assembled as a result of studies which document the effects of flow regulation on riparian habitats, and the numerous undertakings designed to mitigate the effects of river regulation on this component of the aquatic ecosystem. Research being conducted at the University of Lethbridge is in the forefront of identifying the

factors involved in the loss of riparian poplar stands along regulated rivers, thus providing insight into methods which may be used to avoid this undesirable consequence of river regulation.

The stream benthic invertebrate community is also unquestionably important in terms of the total functioning of the stream ecosystem (Ward 1976). The macroinvertebrates that provide the food base for many of the stream fishes are adapted to a particular set of conditions that prevail in a free-flowing river. Patterns of flow, temperature variation, and in particular substrate particle-sizes and stability are the dominant factors controlling macroinvertebrate distributions (Ward and Stanford 1979).

The life cycles of many riverine invertebrate species have evolved to coincide with the seasonal variations in discharge, while many of the life-cycle stages such as hatching, growth and emergence are dependent on the thermal cues provided by the river (Petts 1984). A common reproductive strategy employed by many adult stream insects is colonization and reproduction in upstream areas. In this regard, reservoirs may act as a barrier to the airborne, colonizing adults, while precluding the passive downstream drift of the immature life stages. Dam construction typically results in changes to the downstream flow regime, water quality, as well as the channel morphology, all of which dictate the species composition and relative abundance of the benthic invertebrate population in the river.

The most common response by the benthic invertebrate community to river regulation is a reduction in species diversity, and often an increase in the overall abundance of organisms (Stanford and Ward 1979). This consequence is typically the result of creating uniform habitat conditions in the regulated river. The species that are suited to the particular set of relatively uniform conditions in the regulated river do very well, as indicated by the increase in the overall abundance of organisms. However, the remainder of the species assemblage which find these conditions intolerable is lost, as reflected by the reduction in species diversity. This may be of particular concern for an apparently rare form of mayfly found in this region of the river, which is presently under investigation in Saskatchewan.

The changes in the benthic invertebrate community which may be anticipated below a reservoir relate to the pattern of reservoir releases, the chemical, physical and biological quality of the released water, the changes to channel morphometry, substrate composition and stability, as well

as the distribution of aquatic plants (Petts 1984). As these factors are coming to light, improvements are being made in predicting the impacts of river regulation on the benthos. Several mathematical models (e.g., IFIM, RIVPACS) have been developed to assist practitioners in assessing impacts on this component of the aquatic ecosystem (Gore and Petts 1989). The facility does therefore exist to identify design or operational features that are found to be particularly harmful to the benthic community, which may be addressed in the project planning stage.

Initial efforts to address fisheries values in regulated rivers played a large role in expanding the scope of instream flow investigations, as the health of the fishery is so strongly related to the ecological integrity of the entire aquatic ecosystem. A review was conducted on 81 dam projects in the Pacific Northwest, which provides a summary of potential conflicts between water management and fisheries issues (Burt and Mundie 1986).

Due to the economic value of salmonid populations, Burt and Mundie (1986) reported that most flow regulation projects in the Pacific Northwest are undertaken with at least some consideration for the protection of fish. Their review revealed, however, that the flow regulation projects had a poor record of success in preserving natural salmonid stocks. In the 63 cases where sufficient information was available to reach a conclusion, 76% resulted in a decrease in salmonids following flow regulation.

The most frequent causes of fish stock decline were identified as the removal of large volumes of water (the overall volume available for fish was reduced) and the alteration of the natural seasonal pattern of flow, resulting in reduced volumes during periods which were critical to the fish life stages. In case-histories where improvements in fish populations were reported, the main factors identified for these successes were an increase in mean annual flow, an increase in monthly flows during periods when these flows were limiting to the fisheries resource, or no changes in post-project flows.

The second most frequent cause of declines in fish stocks below dams was the blockage of adult migrations to habitats above these water control structures (Burt and Mundie 1986). In many cases, no fishways were provided at the dams, and no attempts were made to truck fish upstream. As the majority of the fish populations under study in the Pacific Northwest were salmon, which

return to their natal stream for reproduction, this factor caused the extinction of some runs. In other cases, attempts were made to compensate for losses of natural fish through artificial propagation.

The third most frequent cause of reduced salmonid productivity was deterioration in the quality and quantity of habitat as a result of the loss of the freshet. A major shortcoming of many instream flow studies that were reviewed was emphasis on minimum flow requirements, with insufficient regard for the rejuvenating effects of peak flows in the systems. Significant flow reductions during the freshet have been identified as causing an increase in fines in spawning gravels, less development of pools and undercut banks, and vegetation encroachment, all of which result in a deterioration of habitat quality. For those case histories where fish stocks improved, or did not decline, a reduction in habitat quality was typically not a problem, as flushing was provided by increased or relatively unchanged post-project flows.

A further cause of decreased fish stocks was identified as rapidly fluctuating flows. Typical consequences of such water management activities were stranding of juveniles, reduction in benthic invertebrate populations, and scouring of habitats.

Emphasis was placed on the evaluation of post-project predictions in the review conducted by Burt and Mundie (1986). In general, these authors found that documentation of predicted effects was lacking, and follow-up studies were not designed to test predictions. Only two exceptions were found in the review of the 81 projects, both of which involved predictions of improved natural salmonid stocks. In one case, the population was found to improve; in the other, the fish stocks actually declined.

Burt and Mundie (1986) also identified the fact that the predictive success of instream flow methods for determining minimum protection flows for fish has not yet been established by follow-up studies.

The most promising method which has been employed for addressing instream flow needs for fishes is the Instream Flow Incremental Methodology (IFIM), which involves the use of sophisticated computer models to compare predicted microhabitat conditions in the regulated river with the habitat preferences of fishes that are present in the system (Bovee 1982). A key

component of such a procedure is, however, recognition of the fact that this type of analysis is only addressing microhabitats, or how depths and velocities change with river flow, and how suitable these microhabitats are for use by the fish fauna. The prediction and evaluation of macrohabitats that are present in the regulated river are equally as important. For example, even if an ideal assemblage of depths and velocities is provided for the fish, but the water quality is unsuitable, the fish fauna will not be able to take advantage of the microhabitats that are present.

5.2.3.4 Hydropower Generation

For the purpose of this analysis, it is assumed that the turbines in the potential Meridian Dam would be placed in the diversion tunnel (comparable to the one in the Oldman Dam), with a hypolimnetic discharge. It is also assumed that hydropeaking, and the potential negative effects of hydropeaking would not occur. Potential losses of fish through contact with the turbine blades is considered unlikely, assuming that there is stratification in the reservoir, and that use of the hypolimnetic zone of the reservoir by fish does not occur. In order to confirm this analysis, the above-noted assumptions would have to be validated.

5.2.3.5 Issues and Uncertainties

The issues related to the aquatic environment and potential development of the Meridian Dam have been outlined in the preceding discussions. There is a high level of uncertainty which precludes a credible impact assessment, even at an overview level. Much more information on the basic life histories of the fish fauna in this region of the river is required, as is information on critical and sensitive habitats for this fauna. Likewise, information on the physical and chemical nature of the reservoir is required to enable a credible analysis of biological productivity. A detailed instream flow needs study of the South Saskatchewan River is also required, as well as information on the potential operating strategy for the reservoir.

5.2.4 Mitigation Works and Costs

Mitigation works, possibly within the reservoir as well as upstream and downstream of the dam, will be required to meet the policy of "no net loss" of the productive capacity of fish habitat. Costs for this type of compensation are substantial: monies spent to mitigate the effects of

constructing the Oldman River Dam on fish habitat were $5.5 million up to 1995. It may be determined that fish passage must be provided at the dam site due to concerns over movements by species such as lake sturgeon. The technical feasibility of installing a fish ladder would thus have to be investigated. Alternatively, labour-intensive strategies such as capture-and-haul may have to be implemented.

An additional mitigation measure that may have to be employed to maintain acceptable water quality downstream of the dam is the installation of multiple ports in the dam. This would enable the release of waters from various levels within the reservoir.

5.2.5 Data Gaps and Study Needs

To enable a thorough impact assessment, the following data gaps would need to be remedied: basic information on the fish fauna and their habitat in this region of the South Saskatchewan River, and possibly the lower reach of the Red Deer River; information on the physical and chemical environments that would exist within the reservoir; and a multi-discipline instream flow needs study of the South Saskatchewan River, from the dam site quite possibly as far downstream as Lake Diefenbaker. Preliminary Environmental Impact Assessement (EIA) costs are discussed in Section 7.3.3.

5.3 Protected Areas

5.3.1 Existing Conditions

There are two designated or proposed protected areas within the project area :

- The Prairie Coulees Natural Area (PCNA); and
- The Suffield National Wildlife Area (SNWA).

These areas are discussed in the sections below.

5.3.1.1 Prairie Coulees Natural Area (PCNA)

Ecological Conditions

The PCNA is representative of the Dry Mixedgrass Subregion of southeastern Alberta (Strong and Leggat, 1992). The area encompasses 1,787 ha (4,416 ac) of the natural river breaks, coulees and uplands associated with the South Saskatchewan River. The South Saskatchewan River is canyon-like in places, and is one of two river canyons that occur in the mixed grasslands of Alberta. A portion of this canyon forms the western boundary of the PCNA. Few extensive river valley systems remain in Canada that contain natural grassland habitats with badland and coulee features (PCNAPT, 2000).

The PCNA is located about 35 km northeast of Medicine Hat along the east side of the South Saskatchewan River and consists of three main blocks located primarily in Twp17 and 18, Rge 3 and 4, W4M as shown in Figure 5.3-1. Two of the blocks are identified as the Bull Springs Coulee and the White Rock Coulee. The area is not accessible by road other than by trails, and the South Saskatchewan River serves as the primary access.

Protection and Management Status

The Prairie Coulee Natural Area was designated in 1997 as part of the system of protected areas established under the Wilderness Areas, Ecological Reserves and Natural Areas Act (WAERNA) and the Provincial Parks Act. Protected status of the PCNA is afforded under provincial legislation only. No Federal protected status currently exists for the area. In Alberta, seven legislated protected areas currently exist within the Dry Mixedgrass Subregion. Two of these are less than 10 km^2 in size.

Within the WAERNA Act, Natural Areas have two specific intents:

1) to protect sensitive or scenic public land from disturbance; and

2) to ensure the availability of public land in a natural state for use by the public for recreation, education or other purposes.

Figure 5.3-1 Protected Areas and Native Grassland Habitat within Southeastern Alberta

Management of the PCNA is conducted under the Prairie Coulees Natural Area Management Plan (PCNAPT, 2000). The plan was developed by a multi-stakeholder, planning study conducted by Alberta Environment and Public Lands Division of Alberta Agriculture, Food and Rural Development. The approval statement of the plan "reflects the Governments' commitment to conserve the natural features and ecological diversity of the Prairie Coulees Natural Area for present and future generations" (PCNAPT, 2000).

5.3.1.2 Suffield National Wildife Area (SNWA)

The proposed Suffield National Wildlife Area (SNWA) encompasses two large blocks of native grassland bordering the South Saskatchewan River along the eastern boundary of the Suffield Military Base (see Figure 5.4.1). Like the PCNA, it is representative of the Dry Mixedgrass Subregion of Alberta, incorporating both river valley and upland habitat. The SNWA lies along a 55 km stretch of the South Saskatchewan River and covers approximately 459 km^2.

Ecological Conditions

The SNWA has been extensively studied and mapped in recent years (Canadian Wildlife Service 1997). Ecological land classification and vegetation cover type mapping has been produced and digitized at a scale of 1:20,000 allowing both qualitative and quantitative assessment of natural resource conditions (Adams et al 1997). Within the Dry Mixedgrass Ecoregion of southeastern Alberta, the SNWA supports a variety of upland, valley and wetland landforms, each of which can be further classified according to dominant vegetation structure and composition.

Significant plant species documented within the SNWA include 41 species that are provincially rare in Alberta, of which 8 are considered nationally rare in Canada (Macdonald, 1997). In addition, 13 species were identified that were regionally rare (having no other known locations within 150 km of the study area). A total of 40 locally rare species were found (having no other known locations between 50 km and 150 km of the study area).

Protection and Management Status

The Suffield National Wildlife Area (SNWA) was proposed through a Memorandum of Understanding between the Department of National Defence and Environment Canada in 1992. Any protected status for the area would therefore be governed by Federal legislation. The area

was proposed because of "its national significance as habitat for a large variety of wildlife, including several species considered endangered, threatened, vulnerable or otherwise decreasing in the Canadian prairie biome".

Currently, formal protected status of the SNWA awaits amendment to the Canadian Wildlife Act (1973) which was established to facilitate the protection of wildlife habitat throughout Canada through the establishment of National Wildlife Areas. To date, amendments have been drafted and are currently part of Bill C-5 (Species at Risk Act). Should the Bill be passed, the Minister of the Environment could authorize the Minister of National Defence to formalize the protection status of the SNWA. Activities within the NWA are controlled through permits issued under the National Wildlife Act Regulations.

5.3.1.3 Additional Designated Lands

In addition to the two designated and proposed Protected Areas within the study area, other lands have also been identified for their natural habitat and heritage value. These include :

- Ducks Unlimited Project Lands
- Heritage Resource Sites

The location and status of these sites would require further assessment as part of any formal environmental impact assessment.

5.3.2 Potential Impacts of the Project

Potential impacts are discussed here in terms of habitat loss, the cumulative effects of habitat loss, and the loss of biodiversity. These impacts are also discussed in a Wildlife context in Section 5.5.

<u>Habitat Loss</u>

For both the PCNA and SNWA, potential impacts concern the loss of habitat as a result of reservoir inundation. Each of the three reservoir scenarios would involve loss of riparian and valley side (coulee) habitat commensurate with the full supply level of the reservoir under the 1, 2 and 3 million acre-ft of storage options. While actual areas of each habitat type have yet to be

determined, the general magnitude of riparian habitat loss would be considerable, given that flooding would inundate the majority of the existing valley bottom lands under the 1 million acre-ft scenario. No irrigation works are proposed within either of the protected areas.

Cumulative Effects of Habitat loss

The cumulative impacts of habitat loss as a result of the project would likely be significant. Such impacts must be evaluated in both a local and regional context. The protection mandate for both the PCNA and SNWA is strongly oriented towards preservation of representative landscape features and characteristics of the Dry Mixedgrass Subregion. Loss of riparian and valley bottom habitat must therefore consider all of the existing and planned developments which could affect the Dry Mixedgrass Subregion, particularly within river valley settings. This assessment would likely extend beyond the Alberta provincial boundary to include Saskatchewan.

Loss of Biodiversity

Both the PCNA and the SNWA currently provide a degree of protection of representative Dry Mixedgrass habitat within southeastern Alberta. Within a national context, Canada is committed to the preservation of biodiversity in all parts of the country (Canadian Biodiversity Strategy, 2001). The potential Meridian Dam project would compromise this commitment within the Grasslands Ecoregion, given the significant loss of riparian and native grasslands expected under the three scenarios currently proposed.

5.3.3 Issues and Uncertainties

Key issues associated with the potential impact of the project can be summarized as follows:

Loss of Riparian Habitat

Within the SNWA, the maximum reservoir level (Scenario 3) would flood 25 square kilometres of the area that DND and DOE have agreed to protect as a National Wildlife Area. These riparian areas represent less that 1% of the total area of CFB Suffield NWA (Environment Canada 2001). The loss of this nationally significant habitat would have a direct negative impact on the ecological integrity and biodiversity of the wildlife area, including a number of COSEWIC listed species (see Section 5.5 – Wildlife). Approximately 80% of the bird species found at CFB

Suffield NWA occur in the riparian areas, such as those within and leading from the South Saskatchewan River Valley (Avifauna Component Report, CFB Suffield National Wildlife Inventory, December 1999).

A digital elevation model of the river valley shows that at full operating level (Scenario 3) a large proportion of the riparian gallery forests, Manitoba Maple stands, plains cottonwood stands, woody sage flats, golden sedge community, ravine tree and tall shrub complexes, and lentic and lotic wetlands would be under water (Environment Canada 2001). Studies by Environment Canada and others indicate that the highest levels of biodiversity exist within these riparian habitats.

<u>Indirect Habitat Disturbance</u>

Indirect habitat disturbance would occur as a result of changes in hydrology and reservoir drawdown. Reservoir operations would produce fluctuations in water levels that would in turn affect shoreline and future riparian habitat conditions. Such fluctuations are not conducive to the establishment of a natural shoreline and make the interface prone to localized erosion and siltation, further limiting the re-establishment of a riparian habitats similar to the habitat that existed prior to inundation. Changes in groundwater flow patterns could also affect habitat adjacent to the reservoir through changes in discharge and re-charge areas. In addition, altered salinity patterns could affect vegetation growth and species distribution.

<u>Increased human use and access</u>

Increased risk for fire, litter and damage to sensitive areas, including rare and endangered plant and animal species, may occur if recreational use increases as a result of the reservoir development.

5.3.4 Mitigation Works

Mitigation of habitat losses may include the enlargement of currently protected area boundaries to compensate for a reduction in areas lost through reservoir inundation. Alternatively, new areas representative of the lost areas may be acquired for protected status to provide a “no net loss” of protected areas as a result of the project. Habitat enhancement measures may also be considered both within the existing protected areas and elsewhere in similar habitat types.

5.3.5 Data Gaps and Study Needs

Data gaps focus on the need to determine the types and areas of habitat affected (both directly and indirectly) within the protected areas for the three reservoir scenarios. This would require surveyed contour boundaries to be established on the ground for subsequent field surveys. Information would include, but would not be limited to, vegetation community characterization, rare plant habitat inventory, and quantitative analysis of habitat losses. To address the cumulative effects of habitat losses, the information would need to be compared to similar information collected within the study area and within the region. A comprehensive description of riparian plant communities affected by the project and their relationship to the South Saskatchewan River flow dynamics would also be required. This is important in the assessment of impacts for both upstream and downstream vegetation communities. Literature reviews and field surveys should be conducted to determine the effects of similar reservoir projects on protected areas in similar grassland environments. The success of mitigation measures such as habitat enhancement projects should also be assessed in this context.

5.4 Native Grasslands and Biodiversity

The following sections provide a discussion on native grasslands and biodiversity that may be affected by the potential Meridian Dam project. Existing conditions are outlined, as well as potential impacts of the project and particular issues of concern. Much of the discussion also relates to the Prairie Coulee Natural Area and to the proposed Suffield National Wildlife Area as discussed previously in Section 5.3.

5.4.1 Existing Conditions

5.4.1.1 Dry Mixed Grass Subregion

The potential Meridian Dam project is located within the Grassland Natural Region. This Natural Region comprises four subregions: Foothills Fescue, Northern Fescue, Mixedgrass and Dry Mixedgrass. The project is located entirely within the Dry Mixedgrass Natural Subregion (Strong and Leggat, 1992) which is the largest grassland subregion occupying 47,000 ha (7% of the Province of Alberta). The Dry Mixedgrass Subregion is located in the southeast corner of the

province, from the Montana Border to Consort, Alberta and from the Saskatchewan Border to Bassano, Alberta, with the exception of the Cypress Hills region.

The Dry Mixedgrass Subregion is dominated by low-relief ground moraine but also includes large areas of hummocky moraine, glaciofluvial outwash, glaciolacustrine sand plains, fine-textured glaciolacustrine lake deposits, and eroded plains. Elevation ranges from 600 m near Empress, Alberta to 1,300 m near the Cypress Hills. The major river drainages include the North Saskatchewan, Bow, Red Deer, Oldman, South Saskatchewan and Milk Rivers. These rivers have carved deeply into the bedrock to expose Cretaceous shales and sandstones, creating extensive badlands in some areas. The characteristic soils are Dark Brown Chernozems, although Brown Solonetz soils are common in the extreme southeast of the subregion. In badlands, coulees and wetland dominated regions, Regosols, Brunisols and Gleysols occur.

The Dry Mixedgrass Subregion has the warmest and driest climate in the Province. The climate is continental with long cold winters, warm summers, and low precipitation. Because of the warm summer temperatures and a high average wind speed, the rate of evaporation is high throughout the summer months. The mean annual temperature is 4 degrees celsius, with summer (May - September) temperatures averaging 16 degrees celsius and winter temperatures averaging -7 degrees celsius. The low vegetation cover and low elevations, especially within badland regions, result in a high daily range in temperatures.

Total annual precipitation is 260-280 mm which is lower than any other subregion in the province. Spring is the wettest season, peaking in June, with about two-thirds of the annual precipitation falling as rain. Winter snow cover is relatively low as is the number of days of continuous snow cover. Winter chinook winds reach this region on average 10 to 20 days per year. The combination of warm summer temperatures and low precipitation produce high evapotranspiration deficits which exceed 100 mm per month.

Both short and mid-height grasses dominate this natural subregion. The dominant grasses on well drained uplands with Brown or Dark Brown Chernozems include needle grass (*Stipa comata*), western wheat grass (*Agropyron smithii*), and June grass (*Koeleria micrantha)* (Strong and Leggat, 1992). Drier sites are dominated more commonly by Blue grama (*Bouteloua gracilis),* while moister sites are more typically dominated by Northern wheat grass *(Agropyron*

dasystachyum) and western porcupine grass *(Stipa curtiseta*). Other commonly occurring plant species include prairie selaginella (*Selaginella densa*), pasture sagewort (Artemesia ludoviciana), moss phlox (*Phlox hoodii*), and thread-leaved sedge (*Carex filifolia*). Solonetzic soils are typically dominated by western wheatgrass and blue grama. Sand dune areas are dominated by needle grass, sand grass *(Calamovilfa longifolia*), June grass, and sagebrush *(Artemisia cana*). Other poorly-drained soils and coulees are dominated by silverberry *(Elaeagnus commutata*), buckbrush (*Symphoricarpos occidentalis)*, and prickly rose *(Rosa acicularis*). Riparian areas are typically grass and shrub dominated, although trees such as plains cottonwood (Populus angustifolia) and willows (Salix spp.) occur and provide important wildlife habitat. Coulee slopes, badlands, and riparian areas also provide important habitat for rare plants.

The dominant human use of the Dry Mixedgrass Subregion is agricultural croplands and converted rangelands. Lands used for crop production are often irrigated to grow crops such as sugar beets, alfalfa, vegetable crops, wheat, oats, and barley. Approximately 50% of the subregion has been converted for agricultural use. Natural rangelands are also common and within the Special Areas are managed by the Special Areas Board of the Province of Alberta. Public lands outside the Special Areas are managed by Public Lands Sustainable Resource Development. The lands within the Suffield Military Base are also maintained in a natural state.

The South Saskatchewan River Valley runs northwestwards from Medicine Hat to join the Red Deer River near Empress (Figure 1.1-1). The river valley comprises upper benchlands and shallow to steeply-sloping escarpments with some areas characterized by exposed bedrock or steep cutbanks (gravel or clay slopes). Several areas are comprised of coulees or badland topography. Old terraces, floodplains, riverbanks and active channel areas extend throughout the valley bottom. Ephemeral wetlands and alkali springs also occur in some areas. There are several distinct vegetation communities within these valley areas that include upland native grasslands, terrace grasslands, sparely-vegetated badlands, riparian wetlands, low shrublands, tall shrublands, and riparian gallery forests.

The South Saskatchewan River Valley is largely untouched by human development and provides several unique habitat types due to topography, micro-climate, and associated vegetation communities. These combine to provide habitat for several uncommon or rare plant species, and

habitat for many species of birds, mammals, amphibians and reptiles. There are currently no dams or man-made restrictions to natural river flows within the study area.

5.4.1.2 Biodiversity

In 1992, more than 160 countries, including Canada, signed the United Nations Convention on Biological Diversity (the Convention) at the United Nations Conference on Environment and Development (the Earth Summit), held in Rio de Janeiro, Brazil. The goals of the Convention are to conserve the ecosystem, species and genetic diversity, to ensure that the Earth's biological resources are used wisely and to ensure that the economic benefits from using these resources are shared fairly and equitably. Conservation of biodiversity and sustainable use of biological resources are necessary to ensure that the economic, societal, and environmental benefits can be available to current and future generations (Noss and Cooperrider, 1994).

One of the key obligations of parties that ratified the convention was to prepare a national biodiversity strategy. The Canadian Biodiversity Strategy (2001) was prepared as a response to this obligation and has been developed as a guide for implementation, in cooperation with stakeholders and members of the public and collaboration with other federal agencies, provincial and territorial environmental and resource management agencies, and industry. Alberta is a signatory to the National Strategy. The Strategy supports wildlife biodiversity and conservation and increases the focus on integrated and ecosystem-based approaches to conservation based on Canada's existing legislation. The goals of the strategy are to:

- Conserve biological biodiversity and sustainable use of biological resources.
- Improve our understanding of ecosystems and increase our resource management capacity.
- Promote an understanding of the need to conserve biodiversity and sustainable use biological resources.
- Maintain or develop incentives and legislation that support biodiversity conservation and sustainable use.
- Work with other countries to meet the objectives of the Convention.

Federal, provincial and territorial Ministers met jointly in September 20, 2001, to discuss Canada's strategy to protect biodiversity in all parts of the country. Ministers agreed to collaborate on four implementation priorities for biodiversity issues of Canada-wide concern. The priorities are to: develop a biodiversity science agenda, enhance capacity to report on status and trends, deal with invasive alien species, and engage Canadians by promoting stewardship.

The potential Meridian Dam development would present a challenge to meeting the goals Canada has established for the maintenance of biodiversity within the Grasslands biome.

5.4.2 Potential Impacts of the Project

The key impacts to native grasslands focus on the loss of botanically significant grassland and riparian communities and rare plants within a local, regional and national context. This results primarily from flooding of the South Saskatchewan River Valley and the effects of irrigation on native grasslands. The extent and magnitude of such impacts are undetermined as yet; however the context of potential impacts can be discussed in general terms of habitat loss, the cumulative effects of habitat loss and the loss of biodiversity.

<u>Habitat Loss</u>

Native grasslands would be affected by construction of the dam, reservoir inundation, and irrigation development. In addition, infrastructure such as roads, borrow pits and irrigation works would affect native grasslands during both construction and operation of the project. The scope of impacts is primarily dictated by the size of the reservoir (1, 2 or 3 million acre-ft of storage) and the area of land that would potentially be irrigated. Under the most conservative estimate of the three reservoir scenarios (1 million acre-ft), the majority of the South Saskatchewan River floodplain and valley bottom lands within the study area would be flooded by the reservoir (Alberta Environment, 2001). This represents approximately 90 % of the valley bottom between Empress and Medicine Hat (Figure 3.1-2).

The area of native grasslands affected by irrigation ranges from 162,000 ha for Scenario 1 to 243,000 ha for Scenario 3 (Alberta Environment, 2001). The location and area of potential irrigation plots is shown in Figure 3.5-1. The extent of impact on native grasslands resulting from their conversion to irrigation lands is unknown at this time; however large areas of both native

grassland and improved pasture would likely be affected when superimposed on the existing land uses for these areas.

Cumulative Effects of Habitat Loss

Impacts on native grasslands have been highlighted in recent years as a result of an increasing awareness of the limited areas of this ecosystem remaining within Canada (World Wildlife Fund 1989). In particular, native grasslands are considered under most stress, given the fragmented condition of these areas and continued pressure which exists in terms of land use. The cumulative impact of further losses to native grasslands would likely be significant. Limitations in native grassland restoration successes further highlight the concern for habitat loss, although reclamation of disturbed areas using native grass species and transplanting/sod replacement efforts, etc. have had various degrees of success depending on the application.

Loss of Biodiversity

The loss of native grasslands as a result of the potential Meridian Dam project would likely have implications for Canada's ability to meet its commitment to the preservation of biodiversity within the Grasslands biome. In particular, the loss of river valley habitat is a key concern, given the restricted number of river valleys which remain unaltered within the Prairie region of Canada.

5.4.3 Issues and Uncertainties

A preliminary review of issues and uncertainties expands on the key impacts of habitat loss and loss of biodiversity as follows:

Loss of Habitat through Reservoir Inundation

Loss of botanically significant vegetation communities and rare plants from reservoir inundation is a key issue, in both a local and regional context, and particularly in the valley bottom and coulee landscapes. It is a major topic of discussion in terms of habitat loss compared to economic benefits (e.g., CIDA 2000; McCully 1998).

The development of the dam would be tied to increased irrigation activities and expansion of ancillary infrastructures. This raises concerns about the amount and quality of native grasslands

within the region that would be lost or affected by future conversion from rangelands to irrigated crops, and other secondary activities. Potential losses or disturbances from conversion of native grasslands to irrigated lands may range from 162,000 ha to 243,000 ha in size (Figure 3.5-1). The extent to which this may affect native grasslands and rare plant species is currently unknown.

Loss or Disturbance of Vegetation Communities and Rare Plants

Loss of natural and/or botanically-significant vegetation communities and rare plants due to irrigation on farmland is a significant concern. Native grasslands and rivers are among the most endangered ecosystems in prairie Canada and in North America (World Wildlife Fund 1989). In the Mixedgrass Prairie sub-region of western Canada, livestock grazing and rangeland conversion to croplands and seeded pastures frequently associated with irrigation development, have reduced and fragmented native grassland habitat. As a result only approximately 6% of this important grassland sub-region remains unaltered by agriculture or resource development.

Fragmentation of Native Grassland Habitat

In western Canada, CFB Suffield is the largest contiguous area of intact prairie grassland where ecological systems remain unaffected by agriculture. Consequently, it is an area where the numbers and abundance of native plant and animal species have not declined. Development of the Meridian Dam project would further fragment native grassland habitat through loss of river valley habitat and through the development of irrigation lands and associated works.

Figure 5.3-1 shows the distribution of native grassland expressed in terms of adjacent quarter-sections of continuous habitat (Environment Canada 2001). Large portions of contiguous native grassland occur within the SNWA and in those lands to the east of the South Saskatchewan River where irrigation is proposed. Superimposing the potentially irrigated lands on the areas of contiguous native grassland habitat indicates that further fragmentation is an issue.

Maintenance of continuous native grassland is an important element in preserving essential habitat characteristics and functions within both a local, regional and national context. The presence of rare and endangered species within large contiguous areas of native grasslands is in part a function of the remote location and the variety of habitats that occur within such large areas.

Changes in Vegetation Community Composition

In addition to the loss of native habitat, changes in vegetation structure and species richness can be expected as a result of dam operations and the conversion of native grasslands to irrigated croplands. This is especially true of downstream vegetation communities that may be affected by altered hydrologic regimes (particularly reduced flooding events) (Rood and Heinz-Milne 1989).

Loss of Biodiversity Within a Local and Regional Scale

The loss of biodiversity as a result of the project can be assessed through the quantification of habitat losses expressed as a proportion of the remaining habitat within both a local and regional scale. However, while areas and percentages of losses provide a relative basis of comparison, the significance of reduced biodiversity is more complex and difficult to ascertain. For example, indicators of biodiversity such as landscape, population, and individual and genetic diversity are inter-related, making assessments of component losses difficult to quantify, particularly in a regional setting. There is also considerable debate concerning threshold concepts of sustainability for natural systems, such as the minimum size of native grassland habitats or the minimum population size of plant or animal species required in order to be maintained. These issues of sustainable biodiversity will require robust assessment in any detailed evaluation of impacts of the project.

Changes in Downstream River Flows

Extensive literature documents the importance of dynamic, natural hydrological conditions in the maintenance of downstream vegetation communities (e.g., Rood and Heinz-Milne 1989; Rood and Mahoney 1991). Changes in downstream flows could affect vegetation composition and distribution (e.g. riparian gallery forests, shrub lands). The importance of spring flooding and overbank flows are particularly important in the regeneration of cottonwood forests and associated vegetation communities. Of particular concern is the oldest grove of cottonwoods in Saskatchewan located a short distance downstream of the Alberta-Saskatchewan border. The potential impact of the project on downstream vegetation is a major issue given the difficulties in

mitigation and in recreating large flood event conditions which may be necessary for long-term sustainability of cottonwood forests.

Cumulative Effects

The cumulative effects of the project on native grasslands must consider landscape processes, habitat fragmentation and loss of keystone species that could have widespread ecological effects within the region (CIDA 2000; Environment Canada 2001). The potential development of irrigation lands on native grasslands and changes in the distribution of native to agricultural lands is also an important component of cumulative effects. Other considerations include existing recreational values, existing flow modification in the river system, and environmental disturbance from the relocation of existing infrastructure (roads, utilities, gas, wells, etc.).

Additional Concerns

Additional concerns regarding habitat and biodiversity include: increased soil erosion and sedimentation; changes in vegetation composition and distribution within the reservoir drawdown zone; increased soil salinity adjacent to flooded areas; and elevated metals in the aquatic environment. These issues are discussed in other sections of this report.

5.4.4 Mitigation Works

Mitigation measures to compensate for loss of native grassland habitat is problematic given the difficulties involved in "restoration" of such ecosystems. Although reclamation efforts have had varying degrees of success using minimal disturbance methods, re-seeding using native species, and innovative transplanting/sod replacement techniques, complete restoration of disturbed native grassland is still beyond current technologies. Practical mitigation measures therefore focus on the following approaches:

Protection of Existing Native Grasslands

Minimizing the extent of both direct and indirect losses/disturbances to native grasslands should be incorporated into the earliest stages of project planning and facility siting. Avoidance of impacts is the chief mitigation measure to ensure protection of this resource. The acquisition of

native grasslands adjacent to the reservoir and associated project components could provide a source of protected land to partially compensate for those lands that are lost and/or disturbed.

Specific techniques may include:

- Purchase of native grassland blocks of similar value and importance elsewhere within the region to be designated as protected status.
- Perimeter fencing of an appropriate protected land base around project components (e.g., a reservoir buffer zone).
- Implementation of range management plans for integrated use of pasture lands by wildlife and cattle.
- Development of reservoir clearing guidelines to minimize removal of trees, shrub and native grassland.

Habitat Enhancement

Native grasslands exist in varying degrees of "naturalness" within the study area (Figure 5.3-1). Enhancement techniques such as reclamation of existing disturbances or the provision of planting of native grasses/shrubs and trees may be beneficial in certain situations as part of a program to both protect and enhance natural grassland areas. Such measures are closely linked to the enhancement of wildlife habitat function and use by wildlife species (Smreciu and Hobden 1991).

Specific techniques may include:

- Enhancement of existing tree and shrub communities through snow fencing to improve soil moisture conditions.
- Tree and shrub plantings.
- Native grassland seeding programs in degraded (eroded or over-grazed) grassland areas.
- Wetland enhancement.
- Reclamation of borrow areas and other point or linear disturbances.

5.4.5 Data Gaps and Study Needs

Data gaps focus on the need to identify the magnitude and extent of native grassland losses associated with all aspects of the potential project. This should include an inventory of the types of grasslands to be affected, an assessment of the relative proportion of those type which would remain within a local and regional context, and an assessment of the significance of such losses with respect to project and cumulative effects. Quantification of the value of habitat losses would also be important in a regional and national context.

Rare plants and botanically significant communities affected by the project would need to be assessed in more detail to determine the habitat types affected, the losses of rare plant localities expected, and the context of such losses evaluated within a local and regional setting. This is particularly important in the context of Bill C-5 (Species at Risk).

An evaluation of mitigation measures that have been used in similar developments would be important to determine the relative success of such measures with respect to native grassland habitat management. Examples could include both literature and field studies associated with the Oldman River Dam, Gardiner Dam and the Rafferty-Alameda Dam Projects in Canada, as well as similar projects in the United States. Hindsight evaluations of those projects would provide site-specific examples to assess impact assessment predictions and mitigation measure successes against a series of goals and objectives. This would likely form a major component of any further impact assessment.

5.5 Wildlife

The following discussion is intended to provide an overview assessment of the current situation related to wildlife and habitat, and to explain how these may be affected by the potential Meridian Dam development. Data gaps, study needs and mitigation issues are also investigated.

Much of the recent information related to the wildlife and habitat within the general project region, has been extracted from the studies conducted by the Canadian Wildlife Service (CWS) on the proposed Suffield National Wildlife Area (SNWA). Other areas of native vegetation occur

along the remainder of the South Saskatchewan River system and would also be conducive to supporting the wildlife species discussed in the following sections.

From a regulatory perspective for wildlife, the following regulations and policies are considered relevant to the potential project: Migratory Birds Convention Act 1994 and its regulations; 1996 Accord for the Protection of Species at Risk; Bill C-5: The Species at Risk Act (in second reading); Canada Wildlife Act 1973; the Canadian Environmental Assessment Act; and, a Wildlife Policy for Canada as adopted by the Wildlife Ministers Council of Canada in 1990. [A guiding principle of the policy is that wildlife is an integral part of the environment in which Canadians live and is a key indicator of environmental health (Wildlife Minister's Council of Canada 1990). The province of Alberta is a co-signatory to this policy statement (Environment Canada issues document submission 2001)].

5.5.1 Existing Conditions

Existing conditions in the potential inundated and irrigated areas are described below.

<u>Wildlife Habitat</u>

The area potentially flooded by the creation of the Meridian dam and associated reservoir would impact a significant portion of the Alberta portion of the South Saskatchewan River, the extent of which is dependent on the reservoir's full supply level. Because of its location and position relative to the CFB Suffield military base, this section of the river remains remote and relatively unaltered, and as such provides important habitat locally, regionally, and nationally for numerous wildlife species. CFB Suffield is the largest contiguous area of intact prairie grassland in western Canada. The association of the river, riverine habitat and valley habitat with this expanse of natural grassland, provides a habitat mosaic that is conducive to supporting numerous wildlife species that have been affected by habitat loss in the regional area of Alberta and Saskatchewan. Additional discussion regarding native grasslands and biodiversity is presented in Section 5.4.

The wildlife species located in and along the South Saskatchewan River valley vary depending on the time of year, the habitat type, the condition of the habitat, water levels, natural population cycles, and other influencing factors (e.g., crop type and location, human disturbance). The habitat types within and adjacent to the South Saskatchewan River valley include, but are not

necessarily limited to, upland grasslands, grassed side slopes, coulee complexes (grass, shrub and tree cover), tree (Cottonwood Stands) and shrub riparian areas, marsh areas, bottom grasslands, sandbars, beaches, and open water. The types of vegetation supported in these areas are related to the exposure, soil type, aspect, slope, land use, moisture, and flooding regime (where applicable). With this variety of habitat types, the ability of the area to support a broad spectrum of wildlife species is enhanced. These habitat types can be of year-round importance (e.g., for mule deer) or of seasonal importance (e.g., for waterfowl or neo-tropical migrants).

The final scope of impacts associated with the potential development would ultimately depend on the full supply reservoir level (i.e., how much habitat is flooded) and on the operating regime of the reservoir. It must also be recognized that the wildlife habitat affected could be somewhat distant from the actual Meridian Dam project (e.g., downstream or upland habitat). This depends in part on the types of activities supported by the project (e.g., irrigation) and on the operating regimes which affect downstream flow. Irrigation activities could result in further habitat fragmentation or loss of upland areas at a distance from the actual reservoir. It should also be recognized, however, that reservoir flooding would likely create other types of habitat or conditions that may be conducive to different wildlife uses (e.g., staging habitat for migrating waterfowl).

As discussed in Section 5.4, significant natural areas that would be impacted by the project include the Prairie Coulees Natural Area (PCNA), the proposed SNWA, and classified wildlife habitat in and along the river valley in Saskatchewan. The PCNA recently released a management plan for the area (January 2000) and the SNWA has received considerable attention and study by the CWS in a 3-year biophysical study. The work that has been completed by the CWS within the Suffield base and the SNWA is thorough, and forms the background for much of this evaluation related to wildlife. In addition to a portion of the SNWA, the Ellis Ranch, Ducks Unlimited and CFB Suffield cooperative waterfowl habitat project at Old Channel Lake (33-14-5 W4M) may be flooded. To date, Ducks Unlimited has invested considerable funds to manage this wetland, including water pumps and pipes, rock islands and earth islands (Jay Bartsch, pers. comm. 2001).

In a letter of submission, the CWS notes that "as one of the few extant large blocks of unaltered Dry Mixed grass Prairie, the proposed CFB Suffield NWA hosts over 1,100 catalogued species

including 244 vertebrates, 462 plants, and 436 invertebrate speices". Of this rich species assemblage, at least 14 are listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2001) as Species at Risk, and at least 78 species of animals and plants are listed in the Status of Alberta Wildlife 2000 as "at risk" or otherwise "sensitive" because of declining numbers.

In Saskatchewan, the South Saskatchewan River valley and adjacent native grasslands are classified as important for species such as mule deer, white-tailed deer, pronghorn antelope, golden eagle, prairie falcon, sharp-tailed grouse, and ring-necked pheasant. The portion of the South Saskatchewan River valley from Medicine Hat, Alberta to the Saskatchewan border, has areas along the river bottom classified as being important winter ranges but they are primarily Class 3, with slight limitations (i.e., climate, landform) to the capability for ungulates (CLI 1972b). Important winter areas are located in the CFB Suffield Base (op. cit.). For waterfowl, the river bottom may not be useful for waterfowl production, but may be important as migration or wintering areas (CLI 1971), while the valley slopes have severe limitations for the capability for waterfowl. The adjacent uplands range from limited areas of Class 4 (moderate limitations) to Class 7 (severe limitations), for the production of waterfowl. Limitations include aridity, lack of soil moisture, and adverse topography. This classification system ranges from Class 1 (lands with no significant limitations) to Class 7 (lands which have such severe limitations that almost no waterfowl are produced).

The Canada Land Inventory (CLI 1972) classifies the reach of the South Saskatchewan River valley in Saskatchewan, nearest the Alberta border as ranging from Class 3 (slight limitations) to Class 5 (moderately severe limitations) for the land capability for ungulates (antelope and deer). Limitations for ungulates is related to climate, exposure or aspect, and landform. For waterfowl, this river, in the same area is classified as being important as migration or wintering areas (CLI 1970). The remainder of the valley has severe limitations to the capability for waterfowl, related to topography.

Overall, the habitat of the CFB Suffield and associated grasslands provides a large tract of contiguous habitat with limited fragmentation. Further, the river and valley serve as a transportation corridor for numerous terrestrial, aquatic, semi-aquatic and avian species during

different times of the year. These travel corridors can be related to dispersal, daily feeding patterns, or seasonal migration patterns depending on the species of interest.

Mammals

The PCNA management plan identifies American beaver, coyote, mule deer, mountain cottontail and pronghorn as mammal species thought to inhabit the Prairie Coulees area. Studies and surveys completed by the CWS provide distribution maps, habitat evaluation, and population estimates for mule deer, antelope and white-tailed deer, as well as for cattle distribution and moose observations (Shandruk et al. 1998).

The presence of carnivores within the SNWA was also reported by Carbyn et al. (1999) in the CWS report. Observations include: coyote, red fox, swift fox, American badger, striped skunk, long-tailed weasel, racoon and bobcat and there is also the potential for cougars, wolves, mink and least weasel to occur in the region. Elk have also been observed sporadically along the valley.

Reynolds et al. (1999) reported on small mammals within the SNWA for the CWS. Species listed include: prairie shrew, mountain cottontail, white-tailed jack rabbit, Richardson's ground squirrel, thirteen-lined ground squirrel, northern pocket gopher, olive-backed pocket mouse, Ord's kangaroo rat, beaver, western harvest mouse, deer mouse, northern grasshopper mouse, bushy-tailed woodrat, meadow vole, sagebrush vole, muskrat, house mouse, porcupine, little brown bat, long-eared bat, long-legged bat, western small-footed bat, big brown bat, and hoary bat. The report provides distributions, abundance and habitat analysis for these species in the region.

Avifauna

Dale et al. (1999) reports on bird populations in the SNWA. The report indicates that 194 species were encountered, or present historically. In all, 111 species were proven or expected to breed in the study area and most of the 60 migrant species were associated with woody vegetation. The authors noted that as "large as it is, the SNWA does not support bird populations in isolation. Without other river valley habitat nearby, many of the species associated with woody habitats in ravines/slopes or riparian segments would not occur. Adjacent grassland habitat (the remainder of CFB Suffield, Remount Pasture and pastures to the south and across the river) add to the high

value of the SNWA for grassland birds, by creating a large habitat block." The PCNA Management Plan (January 2000) lists 37 species of birds thought to inhabit the coulee habitats.

The CWS study (Dale et al. 1999) found that most migrants used riparian habitats and since many of these species were rare or declining, this habitat helps to maintain regional biodiversity; wetlands and ravines also supported a few breeding, regionally unique bird species. Typically, most bird species using ravines/slopes, wetlands or riparian habitat were present in low numbers.

In 1995, a flood on the South Saskatchewan River inundated all riparian areas and the lowest portion of many ravines (Dale et al. 1999). The report goes on to say that "should a permanent water level change occur (a dam placed downstream from the SNWA), it would have a devastating effect on SNWA local and regional diversity through the loss of species numbers and rare species''.

The raptor component of the CWS study was completed by Banasch and Barry (1998), and provides information on habitat availability, species observed and management considerations. The study reported 18 raptor species: 10 species were confirmed nesters during 1994 and 9 species were confirmed nesters in 1996. Raptor species reported in the region include: northern harrier, sharp-shinned hawk, Cooper's hawk, red-tailed hawk, Swainson's hawk, broad-winged hawk, rough-legged hawk, ferruginous hawk, golden eagle, bald eagle, prairie falcon, merlin, American kestrel, osprey, long-eared owl, short-eared owl, great horned owl and burrowing owl. Species noted to nest in cliff-bank habitat were golden eagle, prairie falcon, merlin and American kestrel (Banasch and Barry 1998). Nest sites and sightings of nesting raptor species observed in the river valley were: red-tailed hawk, golden eagle, prairie falcon, merlin, American kestrel and great-horned owl.

Herpetofauna

The reptile and amphibian wildlife component of the SNWA study was completed by Didiuk (1999). Presence and breeding at the SNWA was confirmed for 5 species of amphibian: boreal chorus frog, great plains toad, plains spadefoot toad, northern leopard frog, and blotched tiger salamander.

Five species of snakes were found to be present and breeding at the SNWA: prairie rattlesnake, bullsnake, wandering garter snake, plains garter snake and plains hognose snake (Didiuk 1999). In total, 11 hibernacula were detected in searches of high potential habitat along the river. In addition, this report identifies high, moderate and low potential habitat for snake hibernacula in the south and north blocks of the SNWA area. The South Saskatchewan River valley is one of four key valley habitats in prairie Canada, which provide year-round habitat, including critical over-wintering habitat, for prairie rattlers and bullsnakes.

<u>Listed Species</u>

The diverse habitat types along and adjacent to the South Saskatchewan River provide suitable habitat for a number of listed species. The following discussion includes those species directly affected by the flooding of habitat, and those potentially effected by the operating regime of downstream dams or water availability. The evaluation focuses on those species listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and by the provinces of Alberta and Saskatchewan.

Table 5.3.1
Listed Species Potentially Affected By The Meridian Dam Project

SPECIES	ALBERTA RANK (2000)	SASKATCHEWAN RANK (2000)[1]	COSEWIC RANK (2001)
BIRDS			
Piping Plover	At Risk	At Risk	Endangered
Burrowing Owl	At Risk	At Risk	Endangered
Ferruginous Hawk	At Risk	May Be At Risk	Special Concern
Long-billed Curlew	May Be At Risk	May Be At Risk	Special Concern
Short-eared Owl	May Be At Risk	Sensitive	Special Concern
Loggerhead Shrike	Sensitive	Sensitive	Threatened
Sprague's Pipit	Sensitive	May Be At Risk	Threatened
MAMMALS			
Swift fox	At Risk	At Risk	Endangered
Ord's Kangaroo Rat	May Be At Risk	Sensitive	Special Concern
Long-tailed Weasel	May Be At Risk	Secure	Not At Risk
Western Small-footed Myotis	Sensitive	May Be At Risk	Not Listed
Long-Eared Myotis	Secure	May Be At Risk	Not Listed
Bushy-Tailed Woodrat	Secure	May Be At Risk	Not Listed
REPTILES/AMPHIBIANS			
Northern Leopard Frog	At Risk	Sensitive	Special Concern
Western Hognose Snake	May Be At Risk	Sensitive	Not Listed
Western Rattlesnake	May Be At Risk	Sensitive	Not Listed
Canadian Toad	May Be At Risk	Secure	Not Listed
Great Plains Toad	May Be At Risk	Sensitive	Special Concern
Plains Spadefoot	May Be At Risk	Undetermined	Not Listed

[1] Source: CESCC 2001

General habitat characteristics for listed species are as follows:

- Piping Plover: Gravel beaches on freshwater or saline waterbodies (Semenchuk 1992).
- Burrowing Owl: Open short grass areas, with nests located in unoccupied ground squirrel burrows (Semenchuk 1992).
- Ferruginous Hawk: Sparsely treed dry mixed grass prairie, nests in trees and on coulee ledges, river banks and hillsides (Semenchuk 1992).
- Long-billed Curlew: Large tracks of open grassland with low vegetative cover, nests in ground depressions on ground in short grass cover (Semenchuk 1992).
- Short-eared Owl: Found in open grassland, pastures, stubble fields, nesting in slight depression on ground with heavy grass cover (Semenchuk 1992).
- Loggerhead Shrike: Found in lightly wooded river valleys and coulees, with nests built in tree or shrubs (Semenchuk 1992).
- Sprague's Pipit: Grassland areas. Nests in highly concealed nests found on the ground (Semenchuk 1992).
- Swift Fox: Found in open grassland, badlands and other arid habitat (Smith 1993; Pattic et al.1999).
- Ord’s Kangaroo Rat: Extremely local distribution in sandy soil areas with sparse grass cover (Smith 1993).
- Long-tailed Weasel: Found in grassland, parkland and conifer forests (Smith 1993).
- Western Small-footed Myotis: Found in arid and prairie regions primarily along riverbanks, ridges and rocky outcroppings (Smith 1993; Pattic et al. 1999).
- Long-Eared Myotis: Found in river valleys and coulees where rock outcrops provide shelter (Smith 1993).
- Bushy-Tailed Woodrat: Inhabit rocky outcrops (Smith 1993; Pattie et al. 1999).
- Northern Leopard Frog: Typically associated with clear water that is relatively fresh to moderately saline, and breed in backwaters and oxbows of rivers (Wagner 1997).
- Western Hognose Snake: Sandy areas within grassland regions; most captures in Alberta have been near CFB Suffield (Wright 1998).
- Western Rattlesnake: River and coulee bottoms, in grassland areas; hibernacula typically in south facing slopes (Watson 1997).

- Canadian Toad: Found in grassland, aspen parkland, and boreal forest regions; hibernation sites are usually located in areas of sandy soils in upland areas, rather than in wet, muddy substrates (Hamilton 1998).
- Great Plains Toad: Grassland species that breeds in seasonal wetlands (James 1998).
- Plains Spadefoot: Found in grassland areas that include unvegetated sand dunes, sand dunes with willow and cottonwood, upland prairie, desert, short and mixedgrass prairie; distribution strongly correlated with the presence of sandy, gravelly, or sandy loam soils (Lauzon 1999).

Other sensitive species potentially effected by the project include:

- Birds:
  - American Bittern
  - American White Pelican
  - Baird's Sparrow
  - Bald Eagle
  - Black-crowned Night-Heron
  - Bobolink
  - Brewer's Sparrow
  - Golden Eagle
  - Grasshopper Sparrow
  - Great Blue Heron
  - Horned Grebe
  - Lark Bunting
  - Pied-billed Grebe
  - Prairie Falcon
  - Sharp-tailed Grouse
  - Swainson's Hawk
  - Upland Sandpiper
  - Western Grebe

- Mammals
  - American Badger

Bobcat
Olive-backed Pocket Mouse
Pronghorn

- Reptiles/Amphibians
  Bullsnake
  Plains Garter Snake
  Western Terrestrial (Wandering) Garter Snake

Lake Diefenbaker and downstream reaches of the South Saskatchewan River provide suitable habitat for piping plover. Several studies have been undertaken over the years to assess the population and/or the effects of the operating regime of the Gardiner and Qu'Appelle dams on this species habitat (Espie et al. 1992; Saskatchewan Water Corp 1993; Jung et al. 1998).

Arthropods

As a component of the CWS wildlife inventory, Finnamore and Buckle (1999) reported on the stinging wasps and spiders found on the CFB SNWA (primarily grassland areas). The study spanned two years and produced approximately 3 million arthropod specimens, including 237 species of aculeate Hymenoptera, and 97 species of spiders, 1 species of solpigid and 2 species of harvest spiders. In addition, the report lists 10 species of click beetles, and 14 species of butterflies.

The 237 species of aculeate wasps found on the SNWA represent the most species-rich assemblage known in Canada, largely the result of the location near the northern limits of the midcontinental grasslands, the aeolian grasslands present, and the relatively unaltered vegetation (Finnamore and Buckle 1999). The authors note that the SNWA is acting as a northern refugium for these species, and therefore functioning as a reserve of national significance.

Spider species assemblages were found to rely on various vegetation structures, with some species having very narrow habitat preferences (op. cit.). The management implications for arthropods would need to consider the fate of species associated with specific vegetation structures, when this vegetation is altered through changes in land use (e.g., grazing) or flooding, and the direct amount and type of habitat loss.

5.5.2 Potential Impacts of the Project on Wildlife

The project is anticipated to have negative and positive impacts related to wildlife, dependant on the species. The scope and magnitude of these impacts would also vary with the species in question, and may have temporal limitations (e.g., staging habitat for geese would only be appropriate during the spring and fall migration periods).

Habitat Loss/Alteration

Direct loss of riparian, coulee, bottom land and valley side habitat would occur due to flooding, and even at the lowest potential level, this loss would be considerable. The final amounts of each of these types of habitat lost would ultimately depend on the full supply level of the reservoir. As an example of the potential for this type of habitat loss, the CWS estimated that at the maximum probable water level associated with Scenario 3 the reservoir would flood 24 km^2 of the SNWA. Riparian areas within that 24 km^2 area represent less than 1% of the total area of the SNWA. The CWS predict that the loss of this nationally significant, irreplaceable habitat, and rarest in the wildlife area, would have a direct negative impact on the ecological integrity and biodiversity of the wildlife area, including COSEWIC listed species. Alteration or loss of adjacent upland areas could also result where upland native vegetation habitat parcels are altered for use as agricultural production. Erosion and slumping caused by wave action could also lead to loss of habitat along the edge of the reservoir, with the extent depending on the level and operating regime.

Changing flow regimes could alter downstream riparian vegetation including the oldest grove of cottonwoods in Saskatchewan. Alterations to habitat quantity and/or quality would be expected to result in a change in wildlife use of that habitat. This change could be an alteration to the species diversity using the habitat, or a decrease in the carrying capacity of that habitat. The creation of the reservoir, and the resultant change in flows, could also affect downstream users and the operation of Lake Diefenbaker. Depending on the year, over 19% of the prairie Canada breeding population and over 7% of the Canadian breeding populations have used Lake Diefenbaker. Preliminary investigations suggest that, in most years, modest reductions in reservoir filling rates may result in substantial increases in piping plover productivity (Jung et al. 1998).

The riparian areas in prairie ecosystems typically provide critical habitat on a seasonal basis. Some prime examples of this are ungulate wintering habitat, rattlesnake hibernacula habitat and neo-tropical migrant nesting/rearing habitat. Due to the topographical relief, diverse vegetation mosaic and limited human disturbance, the riparian areas are critical for the maintainance of regional populations of numerous wildlife species.

Habitat Fragmentation

By replacing the river with a reservoir, the potential for terrestrial, aquatic and semi-aquatic wildlife species to disperse across the valley would be decreased. As such, the habitats on either side of the reservoir would be functionally fragmented as they relate to use by most species. The habitat loss discussed above would also result in a fragmentation of the mosaic of riparian, bottom land, valley side and upland grassland habitat that currently exists. This impact would relate to a decrease in the overall biodiversity of the region (see Section 5.4).

Increased Human Disturbance

Increased human disturbance (e.g., noise, human activity) could likely result from increased recreational activity on the reservoir such as yachting, boating, or cottage developments. The amount of this disturbance would depend on recreation development in this area where access is generally limited by local topography. In addition, increased agricultural activity such as irrigation and haying in uplands adjacent to the reservoir could limit or even preclude some species of wildlife from those areas.

Change in Biodiversity

The South Saskatchewan River valley and the associated upland grasslands are unique areas that provides a mosaic of environmental conditions and a level of biodiversity from a wildlife perspective that appear to be regionally and nationally significant. The size and juxtaposition of various natural habitat types in and along the South Saskatchewan are suitable components to maintain important prairie biodiversity on a seasonal and year-round basis.

With the loss of habitat and habitat fragmentation, it is likely that the number of wildlife species that currently occupy the project area will be reduced. Depending on the mobility of the species, some individuals and even local populations (e.g., habitat specific small mammals) could be lost

or displaced. With the extent of flooding projected, it is likely that some loss of genetic diversity would occur. The most noticeable effect to genetic diversity would be in those wildlife species that depend on the altered or flooded habitat types, or those species that are unable to move to alternative habitat types in the region, if there are any.

Travel Corridor Disruption

The river valley is a travel corridor for numerous wildlife species because of the cover provided and because it extends great distances and typically intersects numerous habitat types. This allows dispersion from areas of concentration to fringe areas that are capable of sustaining a more limited population level due to past land-use practices or habitat degradation. The habitat within and adjacent to the valley also provides “rest areas” for migrant species that utilize the habitat as a stop-over during their spring and/or fall migrations.

Habitat Creation

The potential reservoir would create different types of habitat that could increase the use of the area by certain species on a year-round or seasonal basis. The amount of new water edge habitat that would be created depends on the topography, the extent of the coulee complexes, and the reservoir water levels. Given the fluctuation in water levels, a large area of drawdown would likely be sparsely vegetated. A naturalized riparian zone would not likely be established. However, the amount of staging habitat for migrating waterfowl would likely be increased and the water would likely attract shorebirds (e.g., potentially piping plovers) and waterfowl during the breeding/nesting periods. As an example, the creation of Lake Diefenbaker by flooding downstream reaches of the South Saskatchewan River ultimately led to the creation of habitat types preferred by piping plovers. Lake Diefenbaker has also become an important staging area for white-fronted geese, snow geese, and Canada geese.

Cumulative Effects

The extent of cumulative effects related to the potential Meridian project would be dictated, at least partially, by the determination of spatial boundaries. As the project is directly related to water control, considerations must be given to the operating regime, and to the impacts on downstream vegetation, shoreline habitat, shoreline stability, and the related wildlife populations that rely on these habitat types for seasonal and/or year-round use.

5.5.3 Issues and Uncertainties

The issues from a wildlife and wildlife habitat perspective have been outlined in the preceding sections of this report. A credible impact assessment is precluded, however, due to a lack of data related to habitat types and vegetative species composition, the juxtaposition of habitat types, wildlife species and their distribution throughout the entire affected project area, and the reservoir operating regime. Much more information on the basic life histories of the wildlife species in this region of the river and adjacent upland habitats is required to supplement the more thorough information collected by the CWS for the CFB Suffield area. Information on critical and sensitive habitats (e.g., cliff nests, stick nests, mineral licks, leks, wintering areas, hibernacula) is also required, as well as information on wildlife movements and wildlife species inventories. Likewise, information on the physical nature of the reservoir, and the operational regime is required to enable a credible analysis of impacts to habitat and wildlife in downstream reaches of the South Saskatchewan River below the dam. This also impacts the types of shoreline habitat that would be created, and the potential impacts to wildlife species such as piping plover.

5.5.4 Mitigation Works

The mitigation approach, as it relates to wildlife, would likely be a habitat based assessment using valued ecological components (VEC). This approach quantifies and qualifies the available habitat, which enables the amount and quality of habitat lost to be determined. This information is required to determine the level of mitigation required and depends on the goal of the mitigation plan. If the ultimate goal is for "no net loss" of habitat, techniques such as Habitat Evaluation Procedures (U.S. Fish and Wildlife Service 1981) could be used. This technique uses the area (in ha) of a given habitat multiplied by its habitat suitability index (HSI ranges from 0 to 1) to provide a numerical value for the habitat value. From this the habitat units (HUs) provided by that habitat can be calculated. For example, a 10 ha parcel of land that has an HSI value of 0.2 (poor habitat) for blue-winged teal habitat would result in that parcel having 2 HUs. The same principle is also used to determine the type and level of mitigation required. For the blue-winged teal example, 2 ha of excellent habitat (HSI value of 1.0) could mitigate the lost habitat. This would allow a transparent approach to habitat evaluation based on VECs.

Potential wildlife VECs have been presented in the previous sections, and may include species such as northern leopard frog, prairie rattlesnake, mule deer, sharp-tailed grouse and great blue heron. The final VECs should be determined based on several parameters such as the ecological knowledge base, the species sensitivity to disturbance, its distribution and status, the likelihood of the species to be impacted, and its economic, ecological, biodiversity or cultural importance. This evaluation should include meaningful input from stakeholders. Further, the involvement of stakeholders should occur as early as possible to ensure that all concerns are identified and addressed as early in the process as feasible.

The major difficulty related to the potential project is the large amount of high-quality habitat, suitable for listed or sensitive wildlife species, that is located in and along the portion of the South Saskatchewan River that will potentially be flooded. This poses difficulties in attempting to create, protect or enhance habitat in the region that would compensate for the habitat lost or altered, and compensate for the wildlife that is impacted by direct loss or displacement.

Mitigation options for this type of project are outlined briefly below, with more detail provided in Section 5.4 for native grasslands.

- Protection of Existing Natural Habitats – designing the project to limit the disturbance of natural habitats and enacting protection measures for upland habitats that could be under pressure for development.
- Habitat Enhancement – use environmental design to enhance existing habitat parcels with elements such as winter cover, artificial nest platforms or engineered wetlands.
- Project Mitigation – determine the habitat units created for the VECs, as a direct result of the creation of the project. For example, breeding habitat for blue-winged teals may increase over the pre-project condition.
- Habitat Creation – create wildlife habitat on lands that are currently under cultivation. This would entail designing the land parcels to maximize the wildlife suitability for the VECs selected for the project, and could involve grass seeding, shrub and tree planting, wetland creation and the development of new bottomland habitat in adjacent areas.

The mitigation costs for the potential Meridian dam project would ultimately depend on the habitat amounts and quality lost, and the overall goal of the mitigation options adopted. The mitigation for wildlife would have to be considered in relation to vegetation mitigation, and would be very costly ($5 to $10 million). Considering the sensitivity of many of the potentially impacted wildlife species, the potential for success of these options for habitat mitigation is not currently known.

5.5.5 Data Gaps and Study Needs

The data gaps that would need to be addressed to complete an impact assessment include basic information on the wildlife and their habitat in this region of the South Saskatchewan River, and in downstream reaches of the river. An extensive literature review would be required to determine the level of existing information prior to final determination of field programs. This review would include searching the Biodiversity Species Observation Database (BSOD), the Alberta Natural Heritage Information Centre (ANHIC), and the Saskatchewan Conservation Data Centre (SCDC) for relevant wildlife listings, as well as discussions with regional biologists and conservation groups. The assessment would also include the following: determination of appropriate VECs; habitat delineation; habitat assessment to determine vegetation composition; surveys to determine wildlife species use of the various habitat types at different times of the year; creation of habitat evaluation models for wildlife species (if none are available); and completion of wildlife surveys (i.e., track counts, pellet counts, browse surveys, small mammal trapping, breeding bird surveys, lek surveys, bat surveys, stick nest surveys, winter aerial surveys, beaver lodge surveys, waterfowl surveys, shorebird surveys, amphibian call surveys, reptile searches). These surveys would be required to determine population, distribution and habitat use of small mammals, carnivores, aquatic and semi-aquatic fur bearers, ungulates, waterfowl, shorebirds, raptors, passerines, amphibians, reptiles and potentially insects, for all of the river valley and adjacent uplands that could potentially be impacted by the project and related structures. Downstream reaches of the river would also be included.

In addition, the development of the mitigation plans would require selection of appropriate lands and approaches, evaluating the potential for success of the approaches, designing the mitigation lands, purchasing land as required, implementing the action plan and maintaining the mitigation lands. The cost of the land and the implementation (i.e., preparing, planting, maintaining) of the

plan would depend on the amount and types required for mitigation. In addition, a long-term monitoring program would likely be required to determine the success of the mitigation options; as such, residual work may be required in the event that mitigation projects are not achieved.

5.6 Water Quality

A discussion of potential impacts, issues, uncertainties and mitigation measures related to water quality is provided in the following sections.

5.6.1 Baseline Water Quality

Alberta Environment maintains a Water Data System (WDS) database for water quality information from surface waters throughout Alberta. The WDS was queried to determine what water quality information is available for the South Saskatchewan River downstream of Medicine Hat. A total of four stations have been maintained in this reach of the river; however, the WDS database does not contain any data more recent than 1986 for any of the four stations. The most complete and recent water quality record is available for a station at the Highway 41 bridge near the potential Meridian Dam site. There is water quality data available for this site from 1970 to 1986.

Seasonal summary statistics for water quality at this station are provided in Table 5.6-1. Total dissolved solids (TDS) concentrations range from 140 to 310 mg/L, with the exception of one data point at 462 mg/L (Figure 5.6-1). TDS levels meet water quality guidelines for irrigation. Ammonia concentrations are below concentrations that would impact aquatic life. Total suspended solids (TSS) concentrations are variable and tend to be relatively high in the late winter and spring, and occasionally in the summer and fall. Relatively high seasonal TSS concentrations would contribute to siltation in the potential reservoir. Total phosphorus concentrations follow an annual pattern of low concentrations in the summer, increasing through the fall and winter and then declining throughout the spring (Figure 5.6-2). The total and dissolved phosphorus concentrations are relatively high and could support eutrophic conditions in the reservoir. Upgrades to municipal wastewater treatment plants may have improved phosphorus levels in the lower South Saskatchewan River since 1986.

Table 5.6-1. Water Quality in the South Saskatchewan River at the Highway 41 Bridge

Parameter	Units	Winter (1970-1986)				Spring (1970-1986)				Summer (1972-1986)				Fall (1971-1986)			
		median	min	max	n	median	min	max	n	median	min	max	n	median	min	max	n
Field measured																	
pH		7.8	7.2	8	4	-	7.8	8.3	2	8.1	7.4	8.5	9	7.7	6.6	8.3	6
Specific Conductance	uS/cm	245	189	509	12	278	232	353	8	310	245	370	21	325	250	479	12
Temperature	°C	0	0	8.2	55	13.0	1.0	18.0	21	20.9	11.8	24.5	34	12.9	7.8	19.0	22
Dissolved Oxygen	mg/L	11.7	7.6	14.8	28	10.2	9	11.2	3	8.5	7.3	10.4	13	10.7	8.7	12.1	11
Conventional Parameters																	
Conductance	uS/cm	436	311	610	48	374	326	480	20	326	261	405	35	420	295	520	24
Dissolved Organic Carbon	mg/L	2	2	4	24	3	2	5	16	3	2	4	16	3	2	4	11
Hardness	mg/L	194	134	286	27	174	149	186	5	141	119	178	11	152	135	192	9
pH		8	6	9	59	8	8	9	21	8	7	9	35	9	7	9	25
Total Alkalinity	mg/L	152	95	190	59	121	106	165	21	113	83	145	35	118	96	151	25
Total Dissolved Solids	mg/L	254	215	462	19	220	195	241	4	198	140	239	10	233	179	285	10
Total Organic Carbon	mg/L	4	< 2	24	7	5	4	5	3	5	3	20	9	5	4	12	6
Total Suspended Solids	mg/L	9	< 1	1140	39	109	28	1908	20	50	< 1	484	32	10	1	1990	19
Major Ions																	
Bicarbonate	mg/L	-	183	219	2	-	161	165	2	138	127	162	4	146	144	169	3
Calcium	mg/L	47	24	76	12	40	36	56	3	33	29	37	9	32	21	45	5
Carbonate	mg/L	-	< 0.5	< 0.5	2	-	< 0.5	< 0.5	2	< 0.5	< 0.5	< 0.5	4	< 0.5	< 0.5	7.32	3
Chloride	mg/L	7	< 1	31	45	5	2	7	19	3	< 1	26	25	6	1	8	19
Magnesium	mg/L	19	9	34	22	14	11	17	4	15	10	20	13	17	2	21	10
Potassium	mg/L	2	1	10	23	1	1	2	4	1	1	2	14	2	1	13	10
Sodium	mg/L	14	8	114	23	15	14	20	4	11	5	26	14	23	11	46	10
Sulphate	mg/L	60	6	168	31	72	41	90	5	48	23	91	14	71	45	103	11
Nutrients and Chloropyll *a*																	
Nitrogen – ammonia	mg/L	0.2	0.03	0.4	29	< 0.1	0.03	0.4	16	< 0.1	0.01	< 0.1	26	< 0.1	< 0.01	< 0.1	17
Nitrogen – Kjeldahl	mg/L	0.46	0.23	2.6	9	0.56	0.52	0.68	3	0.45	0.26	2.88	8	0.42	0.31	2.04	6
Phosphorus, total	mg/L	0.1	0	2.9	54	0.195	0.045	0.92	20	0.081	0.007	0.4	30	0.0235	0.008	0.88	22
Phosphorus, dissolved	mg/L	0.077	0.006	0.19	30	0.025	0.003	0.076	18	0.009	0.003	0.042	27	0.007	0.003	0.34	17
Chlorophyll *a*	mg/L	-	-	-	-	-	-	-	-	0.006	-	-	1	0.013	-	-	1

Parameter	Units	Winter (1970-1986)				Spring (1970-1986)				Summer (1972-1986)				Fall (1971-1986			
		median	min	max	n	median	min	max	n	median	min	max	n	median	min	max	n
Biological Oxygen Demand																	
Biochemical Oxygen Demand	mg/L	1.6	0.6	17	29	1.6	1	6.6	5	1.3	0.8	2.7	11	1.05	0.8	3.2	10
General Organics																	
Total Phenolics	mg/L	0.003	< 0.001	0.045	29	0.001	< 0.001	0.005	5	0.002	< 0.001	0.007	13	0.001	< 0.001	0.002	7
Total Metals																	
Arsenic (As)	mg/L	0.002	-	-	1	0.0008	-	-	1	0.001	0.001	0.0032	3	0.0025	-	-	1
Cadmium (Cd)	mg/L	0.001	< 0.001	0.009	10	-	-	-	-	< 0.001	< 0.001	< 0.001	3	< 0.001	< 0.001	< 0.001	4
Chromium (Cr)	mg/L	0.001	< 0.001	0.03	10	-	-	-	-	0.005	0.001	0.007	3	0.005	0.002	0.009	4
Chromium – hexavalent (Cr6+)	mg/L	< 0.002	< 0.002	< 0.002	5	< 0.002	-	-	1	< 0.002	< 0.002	0.003	4	-	< 0.002	< 0.002	2
Cobalt (Co)	mg/L	0.004	< 0.001	0.016	8	-	-	-	-	0.004	0.001	0.02	3	< 0.001	< 0.001	< 0.001	3
Copper (Cu)	mg/L	0.0045	< 0.001	0.035	8	-	-	-	-	0.009	0.001	0.041	3	0.003	0.002	0.018	3
Iron (Fe)	mg/L	0.1	< 0.1	0.4	7	-	-	-	-	-	0.6	2.6	2	-	< 0.1	0.3	2
Lead (Pb)	mg/L	0.0095	< 0.001	0.033	10	-	-	-	-	0.001	0.001	0.008	3	0.001	< 0.001	0.014	4
Manganese (Mn)	mg/L	0.006	< 0.001	0.569	7	-	-	-	-	0.016	0.012	0.066	3	0.006	0.004	0.025	3
Mercury (Hg)	mg/L	< 0.0001	<0.0001	0.0075	20	< 0.0001	< 0.0001	<0.0001	4	< 0.0001	<0.0001	0.0013	11	< 0.0001	<0.0001	<0.0002	10
Molybdenum (Mo)	mg/L	0.008	< 0.001	0.075	3	-	-	-	-	-	-	-	-	-	-	-	-
Nickel (Ni)	mg/L	0.008	< 0.001	0.049	8	-	-	-	-	0.001	< 0.001	0.002	3	< 0.001	< 0.001	0.003	3
Selenium (Se)	mg/L	0.0075	0.005	0.01	4	-	-	-	-	-	-	-	-	-	-	-	-
Silver (Ag)	mg/L	0.003	< 0.001	0.007	3	-	-	-	-	-	-	-	-	-	-	-	-
Zinc (Zn)	mg/L	0.02	0.008	0.216	7	-	-	-	-	0.01	< 0.01	0.3	3	0.02	< 0.01	0.02	3
Dissolved Metals																	
Arsenic (As)	mg/L	0.0004	0.0002	0.0008	5	0.0018	-	-	1	0.0021	-	-	1	-	0.0005	0.0005	2

Figure 5.6-1.Total Dissolved Solids Concentrations in the South Saskatchewan River at the Highway 41 Bridge

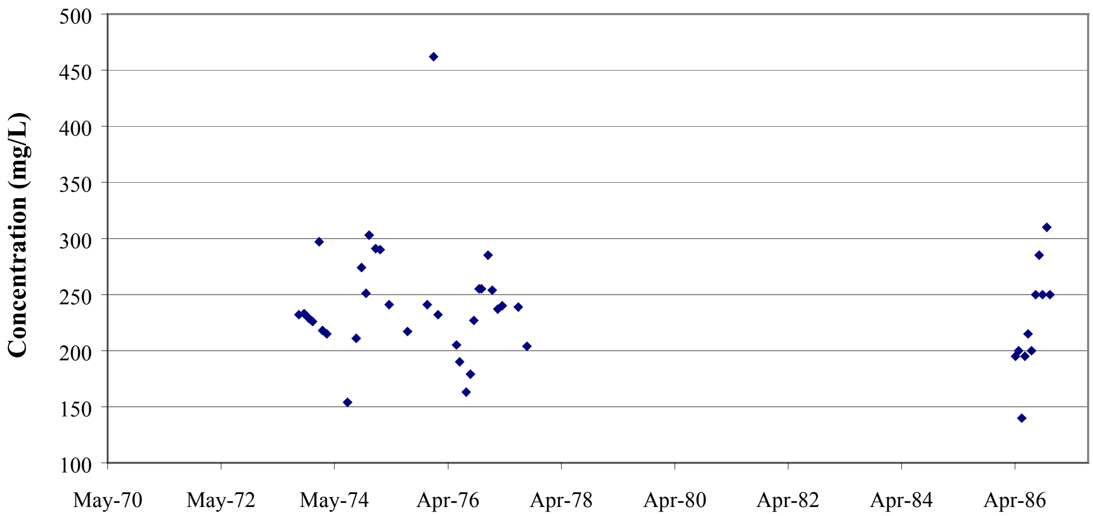
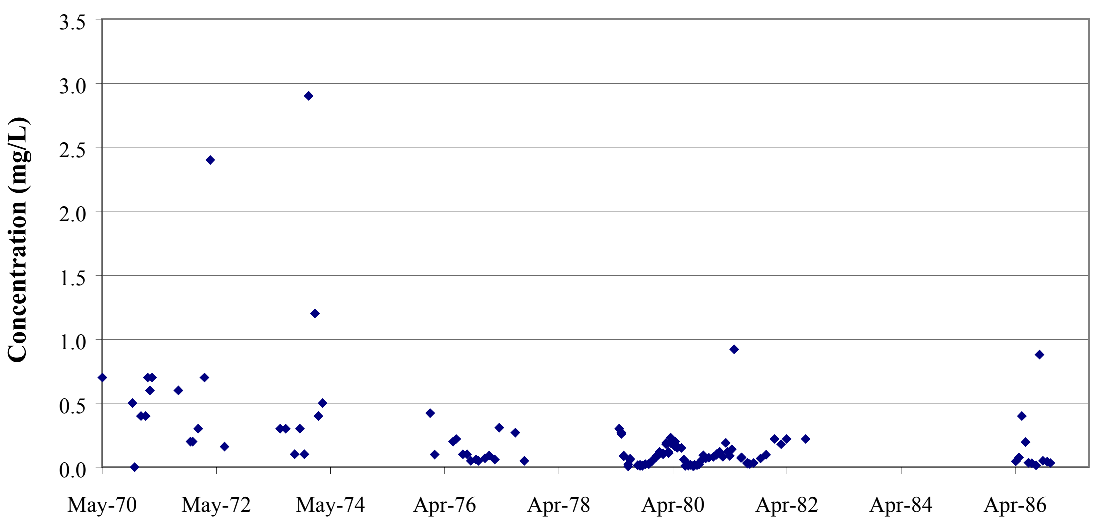


Figure 5.6-2.Total Phosphorus Concentrations in the South Saskatchewan River at the Highway 41 Bridge



5.6.2 Potential Impacts of the Project

A reservoir affects water and sediment quality both within the reservoir and in downstream reaches. In most cases these changes are considered adverse. Creation of a reservoir may result in changes in the distribution of organic and inorganic particles, which in turn affects nutrient

levels in the reservoir and downstream. A reservoir serves as a more effective settling trap than the river it replaces and will generally remove organic and inorganic matter that would otherwise be carried to downstream river reaches. Plant material and organic soils from newly flooded areas may also cause increases in inorganic solids in the reservoir, which could potentially be transported downstream. These changes could have an adverse impact on water quality and sediment quality, with the most direct impact being to the benthic invertebrate communities.

The outlet of the potential reservoir may be a bottom release design. This type of design typically has adverse effects on downstream water quality. For a deep waterbody, the absence of strong winds to promote vertical mixing often results in stratification of the reservoir during the summer with colder and denser water at the bottom. Thus, summer water temperatures can be significantly lower than what would occur naturally without the dam, and the temperature of water released from the reservoir bottom may be below temperature preferences or tolerances for some aquatic life stages. This effect may persist for some distance downstream of the reservoir. Denser water released from the bottom of the reservoir could also have higher total suspended solids (TSS) and total dissolved solids (TDS) concentrations that would alter downstream water quality.

Winter and summer stratification and oxygen demand from bed sediments can result in periodic anoxia developing near the bottom of the reservoir, especially near the outlet where water depths are greatest. Anoxia promotes the release of phosphorous, ammonia and some metals from sediments at the bottom of the reservoir. As a result, the bottom release outlet structure may result in the periodic release of anoxic water, along with elevated concentrations of ammonia, phosphorous and some metals. These conditions have the potential to cause toxicity to aquatic life both within and downstream of the reservoir. There is a large amount of literature documenting the increased uptake of methyl mercury in food chains following flooding of a new reservoir. Hall et al. (1998) noted that predators had about a 3-fold increase in methyl mercury concentrations after flooding compared with a 20-fold increase in water concentrations and a 4 to 5 fold increase in small-bodied fish concentrations. Tremblay and Lucotte (1997) suggested that suspended particulate matter eroded from flooded soils by wave and ice action and bacterial activity enhanced by the release of labile carbon and nutrients from the flooded soils may indirectly transfer methyl mercury from flooded soils to insect larvae. In many cases, fish in newly flooded reservoirs had mercury concentrations well in excess of consumption guidelines.

Within the reservoir, excessive addition of silt, organic matter, and plant nutrients from both anthropogenic and natural sources could promote biological production during open water conditions. Biological production could result in nuisance algae and weeds, which may cause major water quality problems within and downstream of the reservoir. Water quality problems expected under high biological productivity include dissolved oxygen depression from decaying algae and weeds, toxic blue-green algae, poor aesthetics and odour from floating and decaying plants, and high turbidity, suspended solids, and colour. Excessive silt loading into the reservoir can also result in high turbidity and suspended solids occurrences, especially during windy periods of the open water season.

The water quality in a newly flooded reservoir is commonly characterized by an initial trophic upsurge (i.e., increase in biological productivity) due to nutrient release from newly flooded land, followed by a decrease back to or below pre-flood trophic status. The productivity of the fishery within the reservoir often parallels the pattern of the trophic status with an appropriate time lag.

5.6.3 Issues and Uncertainties

The potential water quality impacts of the project are subject to large uncertainties which depend on the design and operation of the reservoir and the upstream water quality and flow conditions. Hydrodynamic and water quality modelling can quantify specific impacts and expected water quality conditions within and downstream of the reservoir. Modelling would also help identify and refine mitigation options, including reservoir design and operation alternatives as well as best management practices within the upstream watershed for controlling the water quality of the reservoir inflows.

5.6.4 Mitigation Works

Some of the water quality impacts associated with reservoir construction and operation can be mitigated. One mitigation option is a multi-port or variable port outlet structure that can release water from different reservoir depths. This allows the operator to respond to different water quality conditions in the reservoir and to mitigate downstream impacts on water quality. Upstream watershed management could also be implemented in addition to appropriate design

and operation of the reservoir to reduce the adverse effects of the reservoir on water quality and the aquatic ecosystem.

5.6.5 Data Gaps and Study Need

As described above, hydrodynamic and water quality modelling assessments are required to quantify the impacts of the reservoir on water quality and aquatic life. A baseline-monitoring program may also be required to augment historical water quality and flow monitoring data.

5.7 Groundwater Effects

A geological overview of the dam and reservoir site was undertaken by J.D. Mollard and Associates (2001) and is summarized in Section 3.1.3. The complete report is also presented in Appendix III. This section provides an overview of the groundwater effects of the potential Meridian Dam project based on information presented in that report and supplemented with hydrogeological data obtained from the Alberta Environment Groundwater Information Service database (water well inventory).

5.7.1 Hydrogeology

The regional hydrogeology map of the area (Borneuf and Stevenson (1970) Figure 9 in Appendix III) identifies several springs as issuing from both the west and the east sides of the South Saskatchewan River valley, both below the dam site and in the reservoir area. The elevations of these springs are not indicated on the map, hence their source is uncertain. Mollard (2001) suggested that these springs issue from more permeable sandstone layers in the Oldman Formation; however, it also possible that the springs may be associated with the Empress Formation-bedrock contacts. The presence of springs in the valley sides is indicative of groundwater discharge, and the movement of groundwater towards the river valley.

A review of water well records from the Alberta Environment water well database for Range 1, Townships 20, 21 and 22 indicated the presence of 84 water wells for that area. The depths of the wells vary from very shallow (2 to 3 m) up to of the order of 150 m (492 ft). Based on the typical depths of overburden across the area, the wells up to 50 m (164 ft) in depth are probably tapping

aquifers in the surficial geologic materials. Wells greater than 50 m in depth are probably tapping aquifers in the bedrock beneath the area, most likely the Foremost and Oldman Formations.

The static water levels in the wells decrease as the depths of the wells increase. For example, a 3.35 m deep well had a static water level of 1.31 m; a 91.44 m deep well had a static water level of 51.82 m; and a 150.88 m deep well had a static water level at 106.68 m depth. This decrease in static water level with increasing depth is indicative of a downward hydraulic gradient. This is a situation in which groundwater is moving downward from ground surface to depth to recharge the regional groundwater system. In this area, groundwater then probably moves laterally towards the valleys to discharge into either the Red Deer River, or the South Saskatchewan River Valleys. The valley of the South Saskatchewan River is a major regional groundwater discharge zone, and the adjacent upland areas are groundwater recharge zones.

The hydrogeological map of the Medicine Hat area (Figure 9 in Appendix III) presents contours of the elevation of the non-pumping water levels in wells in the area. The contours are a subdued reflection of the topography, and indicate that the non-pumping water levels represent the water table which is relatively close to the ground surface. The contours also indicate that in the potential dam and reservoir area a groundwater divide is located to the west of the valley of the South Saskatchewan River and east of the thalweg of the preglacial Oldman Valley. To the east of this groundwater divide, groundwater is flowing east towards the valley of the South Saskatchewan River. To the west of the divide, groundwater is flowing to the west towards the preglacial Oldman Valley. The maximum elevation of the groundwater in this divide is 731.5 m (2,440 ft). However, the main area of the divide is between 701.0 m (2,300 ft) and 731.5 m (2,400 ft). In the vicinity of the dam axis, groundwater elevations of 670.6 m (2,200 ft) are indicated. The potential FSLs of the reservoir are 621.82 m (2040 ft), 635.5 m (2085 ft) and 646.2 m. (2120 ft), which are all lower than the indicated elevations of the groundwater divide. Hence the regional hydrogeologic conditions would appear to offer some degree of hydrogeologic containment, in that hydraulic heads adjacent to the South Saskatchewan River valley would appear to be higher than the potential reservoir water levels.

5.7.2 Potential Seepage Pathways and Mechanisms

For a geologic formation to represent a potential seepage pathway from the reservoir or around the dam site that would be a potential cause for concern, two conditions must be met. Firstly, the formation must have a relatively high permeability such that significant quantities of water could be conducted through the formation. Secondly, the hydraulic head in the formation must be lower than the potential levels in the reservoir so that flow can occur outwards from the reservoir into and through the formation.

The Oldman Formation, which is exposed in a significant portion of the reservoir sidewalls, has a low permeability. Groundwater currently discharges from this formation into the river valley. Based on the very limited groundwater data available, it appears that hydraulic heads in the Oldman Formation are higher than the anticipated reservoir full supply levels. Consequently, as a result of reservoir filling, the regional discharge of groundwater into the river valley (reservoir) would likely be reduced, and locally in the base of the river valley may actually be reversed. However, due to the low permeability of the formation, the flow out from the reservoir, should this reversal of hydraulic gradients occur, is expected to be small. In the vicinity of the dam, as noted by Mollard (2001), the permeability of the formation may be locally enhanced due to the opening and weathering of joints and fissures in the river valley walls. Consequently, it may be necessary to grout the formation in the dam abutments to reduce seepage.

The surficial deposits that infill the valley bottom have a relatively high permeability, and represent a major significant pathway for seepage beneath the dam after its construction. Consequently, it would be necessary to grout these valley bottom sediments, both to limit seepage and to ensure the stability of the dam.

The surficial deposits, and in particular the Empress Formation, that overlie the bedrock in both the reservoir and dam site area have relatively high permeabilities. The Formation is exposed in the valley sides at elevations that will be below the potential reservoir full supply levels, particularly in the downstream portion of the reservoir, and in the dam site area. Based on the very limited groundwater data available, it is possible that hydraulic heads in the Empress Formation may be higher than the potential full supply reservoir levels, thus limiting the potential for seepage through this Formation. However, in the lower portion of the reservoir, and

particularly at the dam site, it is anticipated that hydraulic heads in the Formation would be at or below the potential reservoir full supply levels. Consequently, the potential for seepage through the Empress Formation in the vicinity of the dam is considered high, and extensive grouting and/or the construction of cut off walls to limit seepage would probably be required. It is also possible that the Empress Formation may be present below the potential FSLs in the two buried valleys that are tributaries of the Oldman Valley, and reportedly cross the South Saskatchewan valley in the reservoir area. These buried valleys could represent potential seepage pathways from the reservoir into the Oldman buried valley.

In addition to the issue of seepage from the reservoir, the impoundment of water in the reservoir will disturb the natural balance in the area between the groundwater recharge areas (uplands between the major river valleys), and the groundwater discharge areas (the river valleys themselves). For example, the position of the groundwater divide located to the west of the South Saskatchewan River Valley could move east closer towards the valley. This could result in the expansion of groundwater discharge areas and an associated rise in groundwater levels in the low lying areas to the west of the South Saskatchewan River valley, and consequently increased potential for soil salinization.

5.7.3 Data Gaps and Study Needs

To better understand the interaction between the impounded reservoir and the regional groundwater regime, it would be necessary to undertake a regional hydrogeological investigation of the area. This would involve a field drilling program to more fully define the geology and hydrogeology of the area. The investigation should comprise the drilling of boreholes and the installation of monitoring wells in the different formations at depth. These wells would be used to determine the permeability characteristics of the various sub-surface formations, and the location of the water table and the distribution of hydraulic head with depth. These data could then be used to develop a regional hydrogeologic model that would facilitate computer modelling, and a quantitative assessment of the impacts of the reservoir impoundment on the regional groundwater flow system. The model could also be used to identify areas where rising groundwater levels could potentially cause salinization problems, and to qualitatively assess reservoir seepage losses.

5.8 Reservoir Sedimentation and Erosion

Creation of a reservoir would result in a large body of standing water that would act as a significant sediment sink. Because of low or negligible flow velocities, sediment carried by inflowing water would be deposited within the reservoir along with sediments eroded from the reservoir banks.

Due to the operating regime of an irrigation reservoir, there is a significant fluctuation of water levels on an annual basis. This tends to preclude the full development of a littoral zone and the absence of vegetation further enables shoreline erosion due to wave action. Potential erosion impacts are related to alterations in wildlife habit in riparian areas, decreased aesthetic value of exposed shorelines, changes in reservoir water quality due to increased sediment loads, and related impacts on fisheries resources.

A report detailing reservoir erosion and sedimentation, along with reservoir geology and physiography, was produced as part of this study. The erosion and sedimentation analysis is provided in Part E of the report by J.D. Mollard and Associates Ltd. (2001). The complete report is included as Appendix III and a summary is given below.

5.8.1 River-Borne Suspended Sediment

A Water Survey of Canada sediment sampling and gauging station was established in 1966 on the South Saskatchewan River near the Highway No. 41 bridge crossing (station 05AK001). Sampling of sediment concentrations was discontinued in 1989, however streamflow measurements continued until 1994. The average annual sediment load measured at this station for the period from 1966 to 1984 was $2.7x10^9$ kg/yr. This annual sediment load corresponds to an annual sediment volume of approximately 270,000 m^3, based on an average density of clay, silt and sand of 1004 kg/m^3 (see Appendix III).

5.8.2 Wave-Eroded Bank Sediment

A first-order estimate of the annual volume of bank sediment expected to erode from the potential Meridian reservoir shore zone is based on results from previous studies on reservoirs in the

western Canada prairie region. Primary factors controlling bank erosion rates are the wave energy impacting the shore zone and the erodibility characteristics of the bank materials. The estimate provided is based on a number of simplifying assumptions, and is intended to represent a first-order approximation of long-term average erosion rates. Short-term rates may be significantly higher owing to extreme storm events during periods of high water levels in the reservoir.

In order to provide a quantitative estimate of eroded sediment volume, moderate wave energy was assumed for the entire reservoir. Narrow headlands that project into the reservoir would experience higher than average wave energy whereas intervening coves and bays that are largely protected from wave attack would likely receive sediment from the adjoining eroded headlands. Owing to steep valley walls, relatively little nearshore wave energy dissipation is expected to occur.

Dominant bank materials around the reservoir shore zone include weakly cemented sandstone, siltstone and shale in the Bearpaw, Oldman and Foremost formation. Local occurrences of strongly cemented bedrock strata, till, glaciolacustrine clay and silt, and glaciofluvial sand and gravel also occur around the reservoir shore. The bedrock sediments back from a weathered more friable surface zone would be more resistent to wave erosion than till and stratified glaciofluvial and glaciolacustrine sediments. A range of erodibility coefficients (K_e) from 0.0002 to 0.00005 m^2/tonne was assumed for calculation purposes.

Based on these assumptions, wave-eroded sediment volumes of 430,000 m^3/yr to 2,200,000 m^3/yr have been estimated for the potential Meridian reservoir (see Appendix III), assuming no armouring of the reservoir shoreline.

5.8.3 Total Sediment Entering the Reservoir

Total estimated river-borne and wave-eroded sediment entering the reservoir each year is summarized in Table 5.8-1. Based on a reservoir capacity-to-inflow ratio of 0.25 for Scenario 3 and 0.7 for Scenario 1, the reservoir trapping efficiency of the proposed Meridian reservoir would be approximately 94% to 97% (see Figure 14 of Appendix III).

Table 5.8-1 shows that the sediment filling rate ranges from 673 to 4,054 years depending on the scenario and soil erodibility. Considering the effects of shoreline armouring, the filling time may be much longer.

Table 5.8-1
Estimated Annual Volume of Sediment Entering the Potential Meridian Reservoir

FSL	Reservoir Capacity	Shoreline Length	Annual River-Borne Sediment	Annual Wave-Eroded Bank Sediment (m^3/yr)[1]		Total Sediment Entering the Reservoir (m^3/yr)[1]		Number of Years to Fill the Reservoir[1]	
(m)	(m^3)	(km)	(m^3/yr)	K_e= 0.00005	K_e= 0.0002	K_e= 0.00005	K_e= 0.0002	K_e= 0.00005	K_e= 0.0002
621.8	$1.2x10^9$	216	270,000	432,000	1,782,000	702,000	1,782,000	1,714	673
635.5	$2.5x10^9$	284	270,000	568,000	1,988,000	838,000	2,258,000	2,864	1,063
646.2	$3.7x10^9$	309	270,000	618,000	2.163,000	888,000	2,433,000	4,054	1,480

1 Assuming no armouring of the reservoir shore.

5.8.4 Annual Bank Recession Rates

Based on previous studies of other reservoirs in a similar geographic setting and with similar wave energy and bank material characteristics, long-term average horizontal bank recession rates in the potential Meridian reservoir would likely be in the order of 0.25 to 2.0 m/yr. Higher initial recession rates are anticipated at exposed headlands, where short-term erosion rates of 3 to 5 m/yr may occur. As well, short-term erosion rates during storm events may exceed long-term average rates by a factor of two or more, depending on wind velocities, reservoir water level, and local anomalous conditions in the reservoir shore zone.

A large number of landslides in the South Saskatchewan River valleyside are visible in small-scale 2-D airphotos of the reservoir area (see Figure 15 of Appendix III). Many of the landslides are located above river-undercut slopes. Many also appear to be actively creeping, as indicated by bare failure scarps and sharp ridges, as well as by a narrowing in the river channel at the toe of the slide. Removal of valleyside sediment by bank erosion would likely further destabilize already failed slopes and could initiate new slope failures. This, in turn, may lead to accelerated landward recession of the top of the failure scarp at these locations.

A more simplified geological cross-section showing the approximate positions of the riverbed profile and the 621.8 m (2040 ft) and 646.2 m (2120 ft) FSL shorelines relative to the Foremost,

Oldman and Bearpaw formation boundaries is shown in Figure 16 of Appendix III. The southern part of the potential Meridian reservoir is located in the Foremost Formation whereas the northern part of the valley is located in the Oldman Formation. Whether any northern part of the reservoir is located in the Bearpaw Formation is unknown. At an FSL 646.2 m, the reservoir shoreline could be in Bearpaw Formation near the proposed dam site. The shoreline would be in the Oldman Formation in the central part of the reservoir and in the Foremost Formation in the south. At an FSL of 621.8 m (2040 ft), approximately the northern two-thirds of the reservoir shoreline would be in the Oldman Formation whereas the southern one-third of the reservoir shoreline would be in the Foremost Formation.

5.9 Historical Resources

Historical resources are finite non-renewable resources that are especially susceptible to the impacts associated with construction and operation of reservoirs. Historical resource issues in relation to the potential Meridian Reservoir would be managed and regulated under the provisions of legislation established for these purposes in both Alberta and Saskatchewan. Along with other types of natural resources, the Natural Resources Transfer Act of 1930 ceded jurisdiction over historical resources to the Provinces. Although the potential development traverses lands that are currently managed by the of the Department of National Defense (DND), ultimate ownership of the Suffield Military Reserve (SMR) lands remains with the Crown in Rights of Alberta. Archaeological and palaeontological resources are crown-owned resources in both provinces.

In Alberta, Historical Resources are managed under the provisions of *the Alberta Historical Resources Act* (1987) as administered by Alberta Community Development (ACD). In Saskatchewan these resources are managed under the provisions of *The Heritage Property Act* (1980) as administered by Saskatchewan Municipal Affairs and Housing (SMAH). Both pieces of legislation have been in effect for more than twenty years and have established programs for review of developments and for effective implementation of management programs.

Historical resources are defined by the Alberta Historical Resources Act (1987) as:

"any work of nature or man that is primarily of value for its palaeontological, archaeological, prehistoric, historic, cultural, natural, scientific or aesthetic interest, including but not limited to, a palaeontological, archaeological prehistoric, historic or natural site, structure or object."

A similar definition is applied by the Saskatchewan Heritage Properties Act. Since all but a minor portion of the potential reservoir is contained in Alberta, and many of the legislative provisions in both jurisdictions are complementary, the following discussions will highlight Alberta conventions with respect to terminology. Accordingly, historical resources include the sites where events took place in the past, all of the objects that they contain and any contextual information that may be associated with them, and would aid in their interpretation, including natural specimens and documents or verbal accounts. Historical resources are generally divided into three types: prehistoric archaeological, historic period archaeological and structural, and palaeontological. Natural objects and features have also been occasionally managed under the provisions of the Historical Resources Act but these are rare occurrences and none occur near the potential reservoir.

Heritage legislation in both Alberta and Saskatchewan enables the responsible provincial Minister to require any proponent to undertake Historical Resources Impact Assessments (HRIA) when there is likelihood that significant heritage resources could be affected. The results of these studies are reviewed independently of other environmental issues. As well, the legislation permits establishment of any mitigative measures considered necessary to offset the effects of a project before approval to proceed with development is granted. Mitigative measures typically entail avoidance or recovery, analysis and interpretation of scientific specimens and information. Other measures may be required depending on the nature of the resources affected and the types of impact anticipated, however, these are less common. In both jurisdictions the ability to protect heritage resources is legislatively reinforced in the case of highly significant resources that have been designated as Provincial Historical Resources. In these cases Ministerial approval is required to alter the sites by any means. Substantial penalties can be levied in both jurisdictions for contravention of the Acts or requirements issued under their provisions.

In the absence of specific legislation to manage heritage resources, the federal government may review projects for potential effects on historical resources under the provisions of the Canadian Environmental Assessment Act (CEAA). The CEAA defines environmental effects as "*any change that the project may cause in the environment, including any effect of any such change on health and socio-economic conditions, on physical and cultural heritage, on the current use of lands and resources for traditional purposes by aboriginal persons, or on any structure, site or thing that is of historical, archaeological, paleontological or architectural significance,…*". (CEAA, Section 2(1)). The triggers for a federal review of any proposed development include environmental effects on federal lands including inland waterways. This jurisdictional situation would ensure application of the CEAA to the project and would likely result in a joint federal/provincial review that would consider historical resources involving one or more federal agencies. Nevertheless, any findings made by these agencies are binding on the federal government and would relate to conditions for issuance of a permit under one or more federal Acts.

5.9.1 Existing Conditions

The existing historical resource base within and adjacent to the potential reservoir is based entirely on the results of previous studies. These studies were not undertaken for purposes of a comprehensive examination or assessment of the lands that might be affected by the potential Meridian Dam project. Consequently, it cannot be said that a full inventory has been completed of historical resources contained within the project landscapes. Many historical resources are concealed within geological deposits or are obscured by existing vegetative cover, and as such, considerable expertise is necessary to identify and them. In addition, the significance of these resources remains largely unknown because in most cases dedicated subsurface investigations would be necessary to provide a professional assessment of the value of most currently known historical resources.

Nevertheless, a wide variety of historical resources have been recorded within the project area indicating that a rich resource base is present. This would require careful management should the project proceed to more detailed stages of planning. The following sections of this report present the information currently available for historical resources in the project area. Given the sensitivity of this information, precise site locations have been omitted in certain circumstances to

limit the possibility of vandalism or unregulated collection. These discussions are divided into the three classes of heritage resources typically considered under existing management systems.

5.9.1.1 Palaeontological Resources

The South Saskatchewan River traverses a relatively simple geological sequence from Medicine Hat to the Alberta-Saskatchewan border. The Mezozoic Era bedrock comprises mainly Late Cretaceous facies (Jackson et al. 1981, Eberth 1997). Fossilized vertebrate fauna are well characterized, both from locations along the river and outcrops from equivalent formations elsewhere in Alberta. The potential for occurrence of significant fossils of this age is considered high throughout much of the extent of the reservoir. Definition of this potential is provided in the Royal Tyrrell Museum of Palaeontology's Sensitivity Zone map (Alberta Culture 1984). With the exception of two areas, Brush Flats and Drowning Ford, where potential is considered low as the valley widens and limited bedrock exposures are present, the potential for Mesozoic Era fossils is rated as high or moderate. Some areas of unknown potential occur north of Medicine Hat. The zone ranking provided in this Sensitivity map is displayed in Figure 5.9-1.

In addition, ACD maintains an official Listing of Significant Historical Sites and Areas (ACD 2001). This listing is regularly updated and captures areas that are considered significant for palaeontological resources and would require careful management should development take place within those areas. Table 5.9-1 provides a current listing of the sections potentially affected by the reservoir which have been identified for management of palaeontological concerns under the Alberta Historical Resources Act.

Table 5.9-1 Sections near the Meridian Reservoir Identified for Palaeontological Concerns (Listing of Significant Historical Sites and Areas, ACD 2001)

Twp/Rge	Sections	Historical Resource Value[1]
Twp 18, R 3	19	4
Twp 19, R 2	18,19,20, 21,22, 23, 26, 27, 28, 29, 35, 36	4
Twp 20, R 1	6, 7, 18, 19, 27, 28, 29, 30, 31, 32, 33, 34, 35	4
Twp 20, R 2	13, 24, 25	4
Twp 21, R 1	2, 3, 10, 15, 16, 21, 22, 25, 26, 27, 28, 35, 36	4

[1] HRV 4 = Buffer zone

Figure 5.9-1 Historic, Prehistoric, and Mesozoic Era Historical Resource Sites

The exposed, poorly consolidated Quaternary Period deposits span a time range between 1,000,000 years before present through Post-glacial sediments of relatively recent age. These have also been relatively well characterized in studies produced in the late 1960s and early 1970s (Stalker 1969, 1972, 1976; Stalker and Churcher 1970, 1972; Stalker and Mott 1972; and Westgate et al 1978). These seminal studies form the basis of much of our current understanding of Quaternary events in the Canadian Prairie Provinces. The sections recorded, along with the faunal material collected, represent significant resources in purely scientific terms as well as in their relation to the history of geological study in Canada.

Mezozoic Geology and Palaeoenvironments

From Medicine Hat north to TP19 the South Saskatchewan cuts through outcrops of the Foremost Formation. The Foremost represents brackish nearshore environments along the coast of the Bearpaw Sea, which covered parts of Southeastern Alberta during the Late Cretaceous. Occasionally, the Foremost interdigitates with transgressive marine sediments of the Pakowki Formation. Variably distant from the banks of the river are sandstones, sandy shales, ironstone, and bentonitic sediments of the overlying Oldman Formation. This unit was deposited by freshwater fluvial systems during a regressive period of the Bearpaw Sea. From TP19:R2 northwest to the provincial border, the river flows exclusively through Oldman Formation rocks.

Along its course from TP17-TP19 the South Saskatchewan bisects shales of the Bearpaw Formation, which overlie adjacent Foremost and Oldman sediments. Near the potential dam site, sediments of the Late Cenezoic Empress Group, glacial deposits, and terrace gravels overlie Mesozoic formations.

The South Saskatchewan River Valley is notable for fossils of Cretaceous terrestrial vertebrates, particularly dinosaurs and other reptiles. Compared to more inland deposits of equivalent age, South Saskatchewan macrofossils and teeth indicate greater relative abundance of herbivorous horned ceratopsians than that of armored ankylosaurs or small, dome-headed pachycephalosaurs (Brinkman et al. 1998). However, good pachycephalosaur material is known from the Foremost (Baszio 1997), and ankylosaur fossils have been recently excavated from Oldman deposits near Hilda, AB. Remains of tyrannosaurids and smaller carnivorous dinosaurs are comparatively rare.

The Foremost and Oldman deposits are not as profuse in reported articulated vertebrate remains as the overlying Dinosaur Park and Horseshoe Canyon Formations. However, Oldman microsites (accumulations of small fossils) in Alberta record a habitat rich with freshwater rays, sharks, and bony fish; mammal and bird remains have also been collected from microsite deposits. Microsites have emerged in recent years as extremely important for reconstructing ecology (distribution and abundance of organisms) in palaeoenvironments.

Quaternary Geology and Palaeoenvironments

Exposed sediment sections in the river valleys of the prairie provinces reveal highly significant information on Ice age events and "nowhere in that region are such sections better displayed than along the valley of the South Saskatchewan River valley"(GSC 1984). The portion of the potential reservoir that occurs immediately north of Medicine Hat and is ranked as having unknown potential for fossils (Alberta Culture 1984) but corresponds with one of the most productive areas in the province for non-fossilerous faunal remains of the Ice Age. North of Medicine Hat seven sediment sections have been described as representing key locations for defining portions of the Quaternary record for southwestern Canada. The locations of these sections area illustrated in Figure 5.9-2 and the time periods represented in each are detailed in Table 5.9-2 below.

The sediments in these sections represent gravels, sands and silts that were deposited on former river floodplains during interglacial intervals or glacial outwash events at varying times in the past. Most of the silts and clays were deposited into glacial lake waters during periods of prolonged glacial retreat. The coarser materials tend to be the sources of larger animals, the bodies of which were washed onto gravel and sand bars, then were buried. The finer sediments tend to contain the remains of smaller species.

Figure 5.9-2 Key Pleistocene Geological Section and Faunal Collection Locales

Table 5.9-2 Known Quaternary Sections and Faunal Collection Locales within the Potential Meridian Reservoir

Locale	Period Represented	Age
Mitchell Bluff	Postglacial Sangamon Kansan	>15,000 B.P. 80,000 - 13,0000 600,000 – 1,000,000
Island Bluff	Older Wisconsin Sangamon Yarmouthian Kansan	60,000 - 80,000 80,000 - 13,0000 400,000 – 600,000 600,000 – 1,000,000
Low Bluff	Postglacial Kansan	>15,000 B.P. 600,000 – 1,000,000
Scouts Falls Bluff	Yarmouthian Kansan	400,000 – 600,000 600,000 – 1,000,000
Evilsmelling Bluff	Sangamon Yarmouthian Kansan	80,000 - 13,0000 400,000 – 600,000 600,000 – 1,000,000
Lindoe Bluff	Postglacial Yarmouthian Kansan	>15,000 B.P. 400,000 – 600,000 600,000 – 1,000,000
Twin Cliffs	Kansan	600,000 – 1,000,000

The sediment sections recorded during the 1960s and 70s are those situated near Medicine Hat where Quaternary sediments occur near the riverbed and are easily accessible for observation. Elsewhere along the valley, the river has carved a deeper canyon and sediments of this age occur higher up the valley walls. However, equally valuable sediment sections may occur elsewhere near the river bed. The Old Channel Lake/Brush flats area and downstream of the Drowning Ford appear to exhibit suitable exposures of this nature. Other areas may also exhibit potential in this regard. Some of these areas may have already seen some level of examination but since quaternary sections and collection locales are not often recorded as historical resources, and research tends to proceed at a relatively slow pace, information in this regard is difficult to access.

The remains of Ice Age animals occur in both profusion and variety in the defined Quaternary sections within the Saskatchewan River Valley. Many of the species identified represent extinct mammals that define a sequence of evolutionary events brought about during the sequence of glacial advances and retreats that characterize the period. Table 5.9-3 lists the species identified as of 1982. Additional finds are likely to have been made since. Potential also exists for

additional exposures elsewhere in the valley segments that will be affected by development of the Meridian Reservoir.

Table 5.9-3
Mammalian Species identified in Quaternary Sections near Medicine Hat

Section	Mammalian Species
Kansan	Ground sloth, ground squirrel, beaver, dog/wolf, stilt legged ass, horse, llama, camel, neartic deer, pronghorn
Yarmouthian	Prairie dog, Colombian Mammoth, camel
Sangamon	Grouse, hawk, ground sloth, hare, rabbit, prairie dog, ground squirrel, pocket gopher, field vole, muskrat, porcupine, Black Footed Ferret, Red Fox, Grey Wolf, raccoon, Pleistocene lion, lynx, Colombian Mammoth, Mexican Ass, horse (2 species), llama, camel, White Tailed Deer, Wapiti, caribou (2 species), moose deer, pronghorn, mountain sheep, giant bison
Older Wisconsin	Siberian mammoth, Mexican Ass, camel
Postglacial	Grey Wolf, Imperial Mammoth, camel, pronghorn, bison

Many of the taxa present exhibit a tolerance for a wide range of climates but the mix of species that would be normally associated with both warm and cold climatic conditions indicates ecologies that are considerably different from those present today. The smaller mammalian species are more climatically sensitive than the larger species and may reveal a more in-depth picture of Ice Age environments. This information may be of considerable predictive value for future climate change.

5.9.1.2 Archaeological Resources

Archaeological resources can span the full range of time represented by human presence in the region from the earliest known occupations in Late Pleistocene times through the arrival of Euro-Canadian explorers and settlers to the development of the current agricultural and industrial land use patterns. During these later periods there is an overlap with historic period structural resources, as historic period sites often contain archaeological materials on surface or buried in association with the structures that are of historical interest.

Archaeological sites are recorded in a nation-wide system known as the Borden system. This system divides Canada into grids based on longitude and latitude and assigns a unique alpha

numeric code to sites located in each block measuring ten minutes of latitude by ten minutes of longitude. The potential Meridian Reservoir intersects or lies adjacent to the Borden blocks listed in Table 5.9-4.

Table 5.9-4 Borden Blocks affected by the Meridian Reservoir

Borden Block	Number of sites recorded	Borden Block	Number of sites recorded
EaOp	49	EdOo	43
EaOq	46	EdOp	125
EbOo	40	EdOm	34
EbOp	183	EdOn	24
EbOq	151	EeOm	52
EcOo	55	EeOn	17
EcOp	151	EfOm	61
EcOq	270		

These sites were recorded during a wide range of studies that began with inventories conducted by the Glenbow Institute in the late 1950s. Some of the early studies completed during the 1970s (e.g Adams 1976, Brumley 1972, 1975, Byrne 1975) were undertaken by personnel from the University of Calgary for research purposes. The regionally comprehensive studies have been associated with proposed energy developments within the Suffield Military Reserve by agreement between DND and Alberta Culture (Brumley 1978, Brumley and Willis 1976, 1977, Brumley and Brumley 1977, Brumley and Dau, 1980, 1985, Dau 1981, 1984, 1985, Brumley et al 1981, Saylor 1982). A wide range of specific studies have also taken place in the vicinity of the potential reservoir to fulfill management requirements issued by Alberta Culture in the 1980s, Alberta Culture and Multiculturalism in the early 1990s and Alberta Community Development recently. These requirements have entailed Historical Resources Impact Assessments (e.g. Amundsen 1995, Landals 1997, Lifeways 1976, 1977, McCullough 1989, 1991, Saylor 1983, Head 1997, etc.) and mitigation studies conducted in relation to proposed energy development outside the Suffield Military Reserve (Brumley 1992, Head, 1992, Unfreed 2001)

A significant mandate of ACD is establishment of a listing of the province’s most significant historical resources. This listing is publicly available and is used as an important tool for managing these resources in relation to development impacts. Table 5.9-5 below presents the

sections of land identified in the Listing of Significant Historical Sites and Areas (ACD 2001) as important for management of concerns for archaeological sites.

Table 5.9-5 Sections near the Potential Meridian Reservoir Identified for Management of Archaeological Concerns
(Listing of Significant Historical Sites and Areas, ACD 2001)

Township/ Range	Sections
Twp 15, R 3	3 (HRV 3), 4 (HRV 4), 5 (HRV 3), 9 (HRV 1), 15 (HRV 4), 16 (HRV 4)
Twp 16, R 5	3 (HRV 4), 15, (HRV 3)
Twp 20, R 2	1 (HRV 4), 2 (HRV 4)

HRV = Historical Resource Value: 1= Provincial Historical Resource, 3 = Significant Site, 4 = Buffer Zone

Eighty-five archaeological sites have been recorded in or near the potential inundation zone for the Meridian Reservoir. These are listed in Table 5.9-6 below and are illustrated in Figure 5.9-1. Table 5.9-6 presents summary information for each site obtained from the inventory records maintained by ACD. Sites that lie above the reservoir pool but are sufficiently nearby to elicit concerns for site integrity due to shoreline erosion or the possible inclusion of a reservoir perimeter road in development plans have been included in this list. The significance of these sites varies widely depending on the character of the remains present and on the level of investigations completed. At the inventory stage basic characteristics and locational information are recorded and site inventory forms submitted to ACD. Detailed assessment information often only takes place when there is likelihood of conflict with development. Consequently the available information for most of these resources is impressionistic, based on surface observations and will require more detailed study before final values can be assigned. However in several instances this level of information is available as result of detailed previous study. Detailed study will be required to determine which of these sites might face direct impact.

Table 5.9-6 Archaeological Sites Within or Adjacent to the Potential Meridian Reservoir Inundation Zone.

Borden Number	Class	Type	Condition	Significance	Reference	Comments
EaOp-1	Prehistoric	Lithic Scatter	Disturbed	Low	Wilson 1969 (Archaeological Survey site files)	
EaOp-2	Prehistoric	Isolated Find	Partially Disturbed	Low	Wilson 1969 (Archaeological Survey site files)	1 flake
EbOp-1	Historic	Homestead	Undisturbed	Unknown	Brumley and Willis 1977 CRM 28	
EbOp-14	Prehistoric	Campsite	Disturbed	Low	Landals 1997 CRM 20	
EbOp-16	Prehistoric	Campsite	Disturbed	High	Byrne 1975, Brumley 1972, 1975 Brumley and Willis 1977	Cactus Flower Site
EbOp-17	Historic	Homestead	Undisturbed	Unknown	Brumley and Willis 1977	
EbOp-18	Prehistoric	Workshop	Undisturbed	Low	Brumley and Willis 1977	
EbOp-20	Prehistoric	Stone Feature	Undisturbed	Low	Brumley and Willis 1977	
EbOp-21	Historic	Homestead	Undisturbed	Moderate	Brumley and Willis 1977	Foundation, 2 pits, debris
EbOp-22	Prehistoric	Campsite	Partially Disturbed	Moderate	Brumley and Willis 1977	Stemmed point, choppers
EbOp-23	Prehistoric	Campsite	Partially Disturbed	Low	Brumley 1972 Brumley and Willis 1977	5 Flakes
EbOp-25	Prehistoric	Stone Feature	Partially Disturbed	Low	Brumley and Willis 1977	1 Cairn
EbOp-33	Prehistoric	Campsite	Partially Disturbed	Moderate	Brumley 1978	Besant
EbOp-48	Prehistoric	Campsite	Partially Disturbed	Low	Brumley and Willis 1977	
EbOp-50	Prehistoric	Campsite	Partially Disturbed	Low	Brumley and Willis 1977	
EbOp-56	Prehistoric	Campsite/Stone Feature	Undisturbed	Moderate	Brumley and Willis 1977	
EbOp-75	Prehistoric	Lithic Scatter	Disturbed	Low	Brumley and Willis 1977	2 flakes, 1 chopper
EbOp-78	Historic	Settlement	Partially Disturbed	Moderate	Brumley and Willis 1977	Foundation, pumphouse, ditch
EbOp-79	Historic	Settlement	Partially Disturbed	Low	Brumley and Willis 1977	3 Foundations
EbOp-125	Prehistoric	Stone Feature	Partially Disturbed	Low	Brumley and Willis 1977	1 cairn, 2 (?) cairns
EbOp-126	Prehistoric	Stone Feature	Undisturbed	Moderate	Brumley and Willis 1977	1 cairn, 4 rings
EbOp-128	Prehistoric	Stone Feature	Partially Disturbed	Moderate	Brumley and Willis 1977	6 rings
EbOp-168	Prehistoric	Lithic Scatter	Disturbed	Low	Wondrosek 2000	
EbOp-169	Prehistoric	Stone Feature	Disturbed	Low	Landals 1997	
EbOp-178	Prehistoric	Campsite	Unknown	Moderate	Landals 1997	
EcOo-1	Prehistoric	Campsite/Killsite	Undisturbed	High	Byrne 1975	Possible jump site

Borden Number	Class	Type	Condition	Significance	Reference	Comments
EcOo-2	Prehistoric	Stone Feature	Undisturbed	Moderate	Byrne 1975	12 rings
EcOo-5	Prehistoric/ Historic	Lithic Scatter/Settlement	Undisturbed	Moderate	Brumley 1972	
EcOo-6	Prehistoric	Campsite	Partially Disturbed	Low	Brumley 1972	
EcOo-7	Prehistoric	Stone Feature	Undisturbed	Low	Brumley 1972	
EcOo-29	Prehistoric	Lithic Scatter	Partially Disturbed	Low	Loveseth and Van Dyke 1986	
EcOo-31	Prehistoric	Campsite/Stone Feature	Partially Disturbed	Moderate	Brumley 1992	Avonlea, Pelican Lake
EcOp-1	Prehistoric	Stone Feature/Workshop	Undisturbed	Moderate	Byrne 1975, Brumley and Willis 1976, 1977	Rings, tools
EcOp-17	Prehistoric	Stone Feature	Undisturbed	High	Byrne 1971, Brumley and Willis 1976, 1977	Cairn, >200 rings, lithics
EcOp-20	Prehistoric	Stone Feature	Undisturbed	Moderate	Byrne 1975, Brumley and Willis 1976, 1977	15 rings
EcOp-21	Prehistoric	Stone Feature	Undisturbed	Moderate	Byrne '71 Brumley and Willis 1976, 1977	15 rings
EcOp-22	Prehistoric	Stone Feature	Undisturbed	High	Byrne 1975, Brumley and Willis 1976, 1977	70 rings in clusters
EcOp-24	Prehistoric	Campsite	Undisturbed	Low	Byrne'71, Brumley and Willis 1976, 1977	
EcOp-28	Prehistoric	Stone Feature	Undisturbed	Moderate	Byrne 1975 Brumley and Willis 1976, 1977	3 rings
EcOp-32	Prehistoric	Stone Feature	Undisturbed	Moderate	Byrne 1975 Brumley and Willis 1976, 1977	10 rings
EcOp-33	Prehistoric	Stone Feature	Undisturbed	Moderate	Byrne 1975 Brumley and Willis 1976, 1977	10 rings
EcOp-34	Prehistoric	Stone Feature	Undisturbed	Moderate	Byrne 1975 Brumley and Willis 1976, 1977	3 rings
EcOp-35	Prehistoric	Stone Feature	Undisturbed	Low	Byrne 1975 Brumley and Willis 1976, 1977	1 ring
EcOp-36	Prehistoric	Campsite	Undisturbed	Low	Byrne 1975 Brumley and Willis 1976, 1977	
EcOp-37	Prehistoric	Stone Feature	Undisturbed	Low	Byrne 1975 Brumley and Willis 1976, 1977	1 ring
EcOp-40	Prehistoric	Stone Feature	Undisturbed	Moderate	Byrne 1975 Brumley and Willis 1976, 1977	4 rings
EcOp-41	Prehistoric	Stone Feature	Undisturbed	Moderate	Byrne 1975 Brumley and Willis 1976, 1977	3 rings, 2 cairns
EcOp-45	Prehistoric	Stone Feature	Undisturbed	Moderate	Byrne 1975 Brumley and Willis 1976, 1977	20 rings
EcOp-48	Prehistoric	Lithic Scatter	Undisturbed	Low	Saylor 1983 Brumley and Willis 1976, 1977	
EcOp-49	Prehistoric	Stone Feature	Undisturbed	Low	Saylor 1983 Brumley and Willis 1976, 1977	
EcOp-50	Prehistoric	Campsite	Undisturbed	Low	Brumley 1972 Brumley and Willis 1976, 1977	
EcOp-70	Prehistoric	Stone Feature	Undisturbed	Low	Brumley and Willis 1977	
EcOp-73	Prehistoric	Campsite/Stone Feature	Undisturbed	Moderate	Brumley 1978	Besant, ring, cairn, lithics
EcOp-74	Prehistoric	Campsite/Stone Feature	Undisturbed	Moderate	Brumley 1978	2 rings, 3 cairns, lithics
EcOp-82	Prehistoric	Stone Feature	Undisturbed	Low	Brumley 1972 Brumley and Willis 1976, 1977	

Borden Number	Class	Type	Condition	Significance	Reference	Comments
EcOp-83	Prehistoric	Stone Feature	Undisturbed	Moderate	Brumley 1972 Brumley and Willis 1976, 1977	5 rings, lithics
EcOp-100	Prehistoric	Campsite/Workshop	Undisturbed	Moderate	Brumley and Dau 1980	Lithics, faunal
EcOp-104	Prehistoric	Stone Feature	Undisturbed	Low	Brumley, and Dau 1980	
EcOp-141	Prehistoric	Lithic Scatter	Undisturbed	Low	McCullough 1989	
EdOn-3	Prehistoric	Workshop	Undisturbed	Moderate	Brumley 1972	Lithics, point base
EdOn-11	Prehistoric	Stone Feature/Workshop	Partially Disturbed	High	Lifeways 1976, Brumley and Willis 1977	>110 rings, 5 cairns, lithics
EdOn-12	Prehistoric	Campsite/Stone Feature	Partially Disturbed	High	Lifeways 1976, Brumley and Willis 1977	60 rings, 5 cairns
EdOo-12	Prehistoric	Lithic Scatter	Partially Disturbed	Low	Brumley 1972	
EdOo-13	Prehistoric	Lithic Scatter	Partially Disturbed	Low	Brumley 1972	
EdOo-18	Prehistoric	Stone Feature	Partially Disturbed	Low	Brumley 1972	10 rings, 1 cairn (disturbed)
EdOo-20	Prehistoric	Stone Feature	Undisturbed	Moderate	Brumley 1972	10 rings
EdOo-23	Prehistoric	Stone Feature	Partially Disturbed	Low	Brumley 1972	>10 rings
EdOo-24	Prehistoric	Stone Feature	Partially Disturbed	Low	Brumley 1972	>8 rings
EdOo-25	Prehistoric	Stone Feature	Partially Disturbed	Low	Brumley 1972	Cairn, ring
EdOo-27	Prehistoric	Campsite	Undisturbed	Moderate	Brumley 1972	Hearth, 2 possible components
EeOm-4	Prehistoric	Stone Feature	Partially Disturbed	Moderate	McCullough 1991	Hearth, lithics, faunal
EeOm-5	Paleontological	Fossil Remains	Undisturbed	Unknown	McCullough 1991	
EeOm-12	Prehistoric	Campsite	Disturbed	Low	Lifeways 1977	Besant, site destroyed
EeOm-33	Prehistoric	Stone Feature/Workshop	Disturbed	Low	Head 1992a	Ring, lithics (points) faunal
EeOm-37	Prehistoric	Stone Feature	Undisturbed	Low	Amundsen, 1995	
EeOm-39	Prehistoric	Stone Feature	Undisturbed	Low	Head 1997	
EeOm-40	Prehistoric	Lithic Scatter	Disturbed	Low	Head 1997	
EeOm-45	Prehistoric	Isolated Find	Disturbed	Low	Wondrosek 1999	
EeOm-50	Historic	Homestead/Trail	Disturbed	Low	Kozakavich 2000, Unfreed 2001	
EeOm-51	Prehistoric	Campsite/Stone Feature	Disturbed	Moderate	Kozakavich 2000, Unfreed 2001	
EfOm-4	Prehistoric	Stone Feature	Undisturbed	Low	Adams 1976	
EfOm-5	Prehistoric	Stone Feature	Partially Disturbed	Low	E Adams 1976	
EfOm-6	Prehistoric	Stone Feature	Undisturbed	Low	Adams 1976	
EfOm-9	Prehistoric	Stone Feature	Undisturbed	Low	Adams 1976	
EfOm-54	Prehistoric	Lithic Scatter	Disturbed	Moderate	Archaeological Society Project Past 1989-1990	Multicomponent cultivated

Borden Number	Class	Type	Condition	Significance	Reference	Comments
						field

Of these 85 sites, one is palaeontological in character, six are historic period homesteads or settlements that would be considered largely of value for their archaeological rather than structural remains, and the remainder represent use of the area by Native peoples during prehistoric times. The 77 prehistoric sites include: 38 stone feature sites that consist principally of tipi rings and associated occupational remnants; 14 campsites, which contain the evidence of landscape use and domestic activities; two workshops, where stone tools were manufactured; ten lithic scatters representing small stone tool use areas, and two isolated finds of a single artifact each. Several of the sites represent combinations of these types of occupation: seven are campsites with stone features, three are workshops that also contain stone features and one is a campsite/workshop. A single possible bison jump and campsite complex has also been identified. One site contains both a historic and a prehistoric component.

In terms of significance, six are considered to rate a high ranking, 31 are ranked as having moderate significance and 45 are likely to be of low value. Three sites were considered to be of unknown value. The high value sites include the Cactus Flower Site (EbOp-16), which has been designated as a Provincial Historical Resource and would require the approval of the Minister of Alberta Community Development before any alteration could take place. A possible bison jump and campsite complex (EcOo-1) is also included in the highly ranked sites. The remaining four sites are large tipi ring encampments consisting of between 60 and greater than 200 rings each. The moderate value sites consist of a wide range of types that occur in undisturbed or partially disturbed circumstances. Low value sites tend to consist of lithic scatters, isolated finds or other site types that occur in disturbed circumstances. However, considerable degree of variation exists in these respects.

The potential for additional archaeological sites to occur within possible disturbance zones is considered extremely high. The South Saskatchewan River represents the most important source of water and a major travel corridor in this region. It would have been a key constraining factor affecting animal movement patterns throughout the entire span of post-glacial history. As such it would have been a key element of prehistoric land use patterns in this part of the bison-rich plains. Undoubtedly, its terraces, fords and abandoned channels will be the location of a rich

record of prehistoric human use. The steep canyon walls may have provided rock shelters for early occupants and potential exists for prehistoric art to be located on vertical rock faces. Flooding, slope wash and other depositional processes have also undoubtedly buried much of the prehistoric record of this area making discovery difficult. Few of the previous studies have included deep testing programs and none has been undertaken in any extensive fashion. It is predicted that numerous multiple component, deeply stratified sites will be discovered during a comprehensive Historical Resources Impact Assessment of the development area. Some of these will be highly significant as a result of age, good preservation factors and potential to address provincial or nationally important research questions.

5.9.1.3 Historic Period Resources

Historic Period resources generally represent the structural remains of Euro-Canadian occupation of the region. The region surrounding the potential Meridian Reservoir development area is considered of interest for its settlement and military history as well as history as a transportation route. Resources relating to occupation in this region span a period between the arrival of the Northwest Mounted Police in 1874 and the present day. Building on the grazing potential of the surrounding landscape, ranching was the principal focus of early settlement and dates back as far as the late 1880s. The area surrounding the potential Meridian Reservoir has long been the location of numerous ranching operations.

A province-wide inventory of historic periods resources is also maintained by ACD. This inventory is largely the result of research undertaken by Alberta government personnel and interested community groups, but its focus has been principally on built heritage in urban and rural communities. Because of the distance from major settlement areas, the area potentially affected by development of the Meridian Reservoir has seen limited historic period use and few sites are on record in the provincial registry. Five sites are listed in ACD's inventory for the areas surrounding the potential Meridian Reservoir. Table 5.9-7 lists these sites and their locations are illustrated in Figure 5.9-1.

The Sandy Point Bridge and campsite represent locally significant sites that reflect the focussed transportation and recreational needs of the surrounding communities. Inventory records do not contain any information relating to the significance of these sites on a provincial scale.

Undoubtedly they are of historical interest to local community members. This interest has been identified in the table above.

Table 5.9-7 Historic Period Resources within the Potential Meridian Reservoir Development Zone

Site	Name	Historical Resource Value
1	Sandy Point Bridge (1961)	Local
2	Sandy Point Campsite	Local
3	Coal Mine # 236	Unknown
4	Coal Mine # 336	Unknown
5	Coal Mine # 1107	Unknown

The remaining three sites are coal mines that likely date to the period after the arrival of the railway in 1884, and the establishment of coal mines in the Redcliff area, and before the widespread adoption of natural gas as the principal fuel for both industrial and domestic use, around 1904. The mining of coal seams exposed in river valleys of southern Alberta represents a distinct historical theme in the development of Southern Alberta economies. However, mining of this type in the Drumheller and Lethbridge regions had more significant and lasting impact in terms of Alberta's historical development. In fact, it is reported that the coal obtained in this region had a tendency to reduce to powder if kept more that six months and, during the early period of coal use, it was shipped down-river by boat from Lethbridge to supply local demands (Morrow 1923). Nevertheless, these mines represent one of the earliest industrial uses of the area and are of significance in understanding the history of the Medicine Hat area. It is likely that if their remains were to be affected by the potential development, that mitigation consisting of detailed recording, possible collection, archival research and interpretation would be required in advance of reservoir development.

The potential for additional sites and areas of historical significance are moderate to high along the valley of the South Saskatchewan River north of Medicine Hat. Comprehensive on-site inspection and documentary research would be required to identify and assess such sites. It is expected that, given the long history of ranching in this area, structures associated with this use of the landscape will occur, especially around good points of access for watering herds and near

fords. The Brush Flats/Old Channel Lake and Drowning Ford areas would have particular potential in this regard.

The South Saskatchewan River was once a major transportation route tying the western provinces. In the early 1880s attempts were made to use steam-driven river boats to bring goods down river to Saskatoon from the rail terminal at Medicine Hat. Bob Louden, a local homesteader, piloted the “Northcote” this distance in 1885 shortly after the “Lily” had been stranded on a sandbar near the Drowning Ford the previous year (Morrow 1923). The remains of the Lily are said to have been embalmed in the sand and may be discoverable.

The Suffield Military Reserve began as the Suffield Experimental Station in 1941. It is a unique facility with an important history of use. Most of the facilities and residences associated with the DND use of this area centre around Suffield and Ralston. However, military use may have left significant remains in proximity to the potential reservoir. In addition, documents maintained by DND may contain important contextual information for use of the area and any sites that may be present. This possibility warrants investigation prior to reservoir development and may require mitigative procedures should the project be approved.

5.9.2 Potential Impacts of the Project

5.9.2.1 Palaeontological Resources

<u>Mezozoic Era Fossils</u>

Development of the Meridian Reservoir will likely have negative effects on palaeontological resources during both construction and operations stages. Mesozoic Era fossils are contained within bedrock formations that are exposed along the valley walls throughout large portions of the inundation zone. Any activity that is likely to affect bedrock will affect these resources.

Areas immediately impacted by dam construction, and subsequent filling are of obvious importance. These include the dam site itself, locations where bedrock is excavated in order to build the dam structure, diversion canals, new access roads and river crossings. These activities will completely remove any fossils that may be associated with the affected sections. During initial flooding and subsequent operation, fossils may be affected through saturation and loss of

mineral constituents. In the case of areas that may erode or slump, fossils will be lost entirely. One of the most significant negative effects of reservoir filling is the preclusion of future access for recording, collection and interpretation for research purposes. There is also potential for unregulated collection of specimens as a result of increased recreational use of the reservoir and boat access to previously inaccessible bedrock exposures.

Given the provincially recognized sensitivity of the formations exposed along the South Saskatchewan River valley and the nationally recognized importance of the Alberta Mesozoic Era fossil record, it is anticipated that these effects may be highly significant. The effects may be offset to some degree by institution of a comprehensive mitigation program which would recover, process, store and interpret specimens and associated materials prior to development of the project. It would also include on-going monitoring and recovery programs over the operational life of the reservoir. Implementation of such programs would provide some positive effects as new finds are made, preserved and interpreted for both the scientific community and the public. ACD, in conjunction with Saskatchewan Municipal Affairs and Housing, would determine whether implementation of such a program would be sufficient to permit development of the reservoir to proceed.

<u>Quaternary Sections and Faunal Remains</u>

As with the Mesozoic Era resources, Quaternary palaeontological resources would likely be negatively affected by construction and operation of the Meridian Reservoir. These resources occur in poorly consolidated deposits that are more susceptible to erosion and slumping than the bedrock formations that contain the earlier fossilized materials.

The largest reservoir scenario (Scenario 3) may affect four of the seven Quaternary sections/collection locales previously defined for the South Saskatchewan River north of Medicine Hat. The following sections lie within or adjacent flood zones as currently considered:

- None would be affected at the 621.8 m (2040 ft) interval
- At the 621.8 m (2,040 ft) reservoir level, Mitchell Bluff lies adjacent to the terminal portion of the lake
- At the 635.5 m (2085 ft) level and Mitchell, Island, Low, Scouts Falls, Evilsmelling and Lindoe Bluffs, and the Twin Cliffs occur within or adjacent to the possible lake.

For the three proposed reservoir scenarios, the effects of reservoir development and operation on these sites are predicted to be relatively minor, except to the extent that some undercutting may occur. This could result in displacement of sediments or possible slumping and in degradation of faunal elements through the effects of inundation as well as displacement and alteration of the previously recorded section. This risk does not exist the under inundation Scenario 1. The risk is almost negligible under Scenario 2 and would have moderate potential under Scenario 3. If an on-going monitoring and recovery program were implemented as part of the mitigation program, these effects may have a positive outcome if significant new faunal finds are made and analyzed and reported.

Similar sediments appear to exist in at least two other localities, the Brush Flats/Old Channel Lake and Drowning Ford areas. The former location would be affected to some degree under Scenario 3 and 2 but not 1, while the latter would be affected by all three scenarios. It is anticipated that significant quaternary specimens may be present in these areas and possibly elsewhere in the potential reservoir. The effects of reservoir filling and operation would increase in intensity with proximity to the dam site. In addition, preclusion of future access to any significant quaternary deposits situated in the permanent pool may be a significant negative effect of reservoir development. There is also potential for unregulated collection of specimens as a result of increased recreational use of the reservoir.

Another potentially severe effect may be felt if any of the sensitive quaternary deposits were selected as a source of granular material for construction purposes, such as in the dam structure itself or as fill for roads and bridge abutments. These effects would not necessarily be confined to the reservoir area and would be difficult to offset with mitigation programs. Advance knowledge of the potential sources of granular material necessary for project development would be a key element of effective historical resource management procedures adopted for the project.

5.9.2.2 Archaeological Resources

Archaeological resources occur on surface or are buried in fine grained sediments near the surface. They are generally primary deposits and contain a wide variety of associated organic and inorganic contextual material as well as cultural objects. They are especially sensitive to land surface disturbance and can suffer significant degradation under water-saturated conditions.

Negative effects to archaeological resources could occur during both the construction and operations stages of the reservoir and may not be limited to the reservoir alone. Some of these potential negative effects can be as follows:

Construction

- Dam site disturbances.
- Access road development, including a perimeter road.
- Auxiliary facilities such as construction camps, materials storage areas, power lines, etc.
- Borrow source development.
- Topsoil removal necessary to avoid increased mercury levels in the waterbody.
- Construction of recreational facilities.
- Mitigation programs such as creation of revegetation plots, runoff catchment facilities, and improved fisheries habitat augmentation.

Operation

- Inundation effects.
- Erosion and slumping of valley walls.
- Construction of irrigation facilities.
- New breaking of native grasslands in irrigation areas.
- Recreational facility use.
- Potential vandalism and unregulated collection due to increased use patterns.

Because of the potentially widespread nature of the impacts both within and adjacent to the potential reservoir it is difficult to predict the numbers of archaeological resources that might be affected by development of the Meridian Reservoir. This uncertainty is further complicated by the high potential for additional finds in this area. Section 5.9.1 listed 85 sites within or along the margins of the potential reservoir. Each of the three proposed reservoir scenarios would different direct effects on archaeological resources as a result of reservoir construction and operation. These differential effects would be most significant in the upper portions of the reservoir where the extent of flooding will be most pronounced. For example, under Scenario 1, 23 of the 85 listed sites appear to lie well above the flood zone, while only three lie above the Scenario 2 flood

zone. This analysis has not attempted to quantify the effects of development of new irrigation plots on archaeological resources. However, it can be expected that a number of archaeological sites would be affected in this process. Currently, agricultural developments are not regulated under either of the historical resources management systems in effect in Alberta or Saskatchewan.

Full definition of the effects of the reservoir on archaeological resources would require a comprehensive Historical Resources Impact Assessment prior to development of the reservoir, as well as a complex program of mitigative studies. These studies would likely entail pre-development material and information recovery as well as on-going monitoring throughout the operating life of the reservoir. Given the high levels of significance assigned to the sites already known and the fact that one of these is a designated Provincial Historical Resource, ACD would be required to make a determination in conjunction with SMAH as to whether mitigative studies would be sufficient to offset the effects of the project.

5.9.2.3 Historic Period Resources

Historic Period resources generally occur on existing land surfaces and are highly susceptible to any kind of surface disturbance. The effects of reservoir construction and operations are virtually identical to those predicted for archaeological resources (see above). It should be noted, however, that the existing database for historic period resources indicates there is a significantly lower level of concern for these resources than for either palaeontological or archaeological resources discussed previously. This reflects the fewer number of resources known in the development area, as well as the fact that an important component of a resource's value resides in the documentary records which provide the essential context for interpretation. Nevertheless, a comprehensive Historical Resources Impact Assessment that incorporates in-field studies focusing on identification and recording as well as documentary research would be required. It is predicted that new finds would occur.

5.9.3 Issues and Uncertainties

5.9.3.1 Palaeontological Resources

Mesozoic Era Fossils

Data indicate that while several investigations have taken place within the South Saskatchewan River valley, a comprehensive inventory and collection program associated with potential fossil bearing formations in the vicinity of the potential Meridian Reservoir has yet to be completed. Consequently, a full inventory of the palaeontological resources of the impact zone represents a significant uncertainty in predicting the palaeontological effects of the project and the costs that might be associated with any mitigation program that might be designed to offset its effects.

The mitigation requirements for this class of resource would be established by ACD and SMAH. The extent of these requirements would be based on the results of predevelopment studies and may be influenced by federal government input. These requirements represent an uncertainty and may entail commitments for programming and material storage throughout the life of the reservoir.

No other comparable situation to that anticipated for the Meridian Reservoir has been previously experienced in Alberta as the Meridian Reservoir is planned for one of the most highly sensitive areas in the province. For example, the Oldman River reservoir was planned in an area where only one palaeontologically sensitive area had previously been identified. The costs for conducting mitigative studies were relatively modest. The cost for implementing a program of the scale anticipated for the Meridian Reservoir cannot be predicted at this time.

Quaternary Sections and Fauna

Uncertainties related to quaternary palaeontological resources can be identified in several areas. One relates to whether additional information on previously known sites can be found in unpublished or manuscript form, or in collections. A considerable degree of uncertainty also exists with regard to the existence of additional significant deposits as well as the dgeree of mitigative programming that might be required to offset these effects. As with Mesozoic fossil remains, a commitment to ongoing programming may be required.

5.9.3.2 Archaeological Resources

A comprehensive inventory does not exist of archaeological resources within the reservoir or associated development that may occur outside the potential flood zone. Consequently, a significant uncertainty exists in relation to the number and significance of archaeological resources that might be affected by the project. Current information suggests that that the negative archaeological effects of the potential project would be substantial and that a large-scale mitigation program would be required. Decisions relating to the nature of these requirements and whether they would be considered sufficient to allow the project to proceed under existing legislation will be made by ACD and SMAH. The extent of these requirements would be based on the results of predevelopment studies and may be influenced by federal government input. These requirements represent a considerable uncertainty.

One of the sites which would be inundated under all of the scenarios considered, Cactus Flower, is designated as a Provincial Historical resource. This designation provides the maximum degree of protection that can be afforded under the Alberta Historical Resources Act. The minister of Community Development would be required to consider whether or not the type of potential impacts can be permitted.

Other sites that may qualify for designation, may be identified in the course of the HRIA studies that would be required in advance of project approval. This represents a significant uncertainty and would complicate the decision making process required by ACD and SMAH. These sites would also be a major influence on possible mitigation strategies. In addition, an archaeological site, of cultural or ceremonial value to nearby First Nations communities may be identified. This would likely have a major influence on the outcome of any public hearing into the benefits of the project, as federal fiduciary responsibilities would be considered in any decision made by a joint federal/provincial review panel.

5.9.3.3 Historic Period Resources

Data indicate that Historic Period resource issues with respect to reservoir development would likely be relatively modest in comparison to the other types of historical resources discussed here. However, uncertainties exist in relation the number of sites that would be affected and their

significance. No thorough inventory of historic period structural remains within the potential reservoir exists. Should significant structural remains relating to early ranching history, or the remains the late nineteenth century river boat be encountered, these would be considered historically important. To address these uncertainties, a comprehensive HRIA that includes a historical component would undoubtedly be required in advance of project approval. The requirements established by ACD and SMAH for the conduct of this study, and the funding necessary to comply with these requirements, also represent an uncertainty.

While the effects of reservoir development on historic period resources would be negative, these can likely be offset by implementation of standard mitigative procedures. If a site that qualifies for designation is identified, additional management considerations as discussed above will be necessary. Although negative historic period impacts are expected to be modest, they would have an additive effect on considerations for the overall historical resources effects of the project.

5.9.4 Mitigation Works

Mitigation represents the final stage of the historical resource management process administered in both provincial jurisdictions and is determined by regulatory review of the results of Historical Resources Impact Assessment. Until HRIAs are completed and most accessible historical resources have been identified and evaluated, it is not possible to specify the nature of the mitigation program that may be necessary to offset the negative effects of development of the Meridian Reservoir. Decisions as to the nature of the program required and whether those programs would be sufficient to allow the development to proceed would be made by ACD in Alberta and SMAH in Saskatchewan. To date, ACD has not taken the position that historical resource impacts with respect to a major development proposed in Alberta could not be mitigated. For purposes of the following discussion, a similar regulatory position will be assumed.

In comparison, the Oldman River Reservoir was determined to negatively affect more than 170 historical resource sites, of which only 45 were known prior to the HRIA. Although several of the affected sites were highly significant, the reservoir was allowed to proceed with a long term and extensive mitigation program. However, no provincially “designated” sites were affected and the palaeontological concerns associated with the project would be considered minor in comparison to the potential Meridian Reservoir. The Meridian reservoir would hold two to six

times the water impounded by the Oldman reservoir and would flood a comparably greater amount of major river valley where historical resources typically occur in concentration. Although the South Saskatchewan River valley is less accessible that the Oldman and fewer suitable landforms for historic occupation occur, it would seem reasonable to predict a greater number and diversity of resources.

Mitigative options for historical resources can involve a wide variety of options, but most of these can be grouped as either avoidance or implementation of comprehensive scientific materials and information recovery and interpretation programs. Given the nature of reservoir development, avoidance options are limited except in relation to auxiliary facilities such as roads, borrow sources, campsites and so forth. Successful avoidance may entail special procedures such as site capping or laying down of protective materials but these cannot be predicted in advance. The types of mitigative programming that might be anticipated for the potential Meridian Reservoir would likely involve a number of key elements as follows:

- Detailed mapping of archaeological and palaeontological resource locations, including as found recording of historic structural remains;
- Controlled collection of materials exposed on surface;
- Detailed excavation of archaeological and palaeontological sites;
- Detailed documentary research to establish the context for interpretation of historic period sites;
- Review of existing collections to provide a comparative body of information for interpretation of palaeontological materials ;
- Laboratory preparation, conservation, analysis and interpretation of recovered materials and information;
- Presentation of all findings in detailed final reports that make the information available for professional, scientific, and historical review;
- On-going periodic monitoring of the status of remaining sensitive resources within and around the perimeter of the reservoir along with appropriate collection analysis and reporting of findings; and
- Possible public interpretation of the results of the program.

Historical resources mitigation programs are time and labor intensive and require substantial funding. For comparative purposes, the Oldman River Dam mitigation program required in excess of $3 million to complete in 1988-1990 dollars. It is expected that historical resource mitigation costs for the Meridian Reservoir would exceed these substantially, perhaps by an order of magnitude. For purposes of this study, mitigation costs are estimated at $3-15 million.

5.9.5 Data Gaps and Study Needs

To address the uncertainties identified above, an HRIA would be required before mitigation needs could be established. Communication from ACD has outlined some of the expected components of such a study and has indicated that the results of such a program may result in significant concerns and in strong opposition to the project. Historical Resources Impact Assessments are generally conducted in stages and consist of pre-field planning, in-field investigation, analysis, and interpretation and reporting stages. The general objectives of this stage of the study are to:

- Design a program of investigation that will provide through coverage of potential impact zones;
- Complete appropriate levels of inspection for all areas of high and moderate potential and areas adjacent to known historical resources;
- Identify previously recorded historical resource sites in the vicinity of the potential development;
- Identify and record any new historical resource sites in the vicinity of the potential development;
- Evaluate the significance of the historical resources identified;
- Evaluate the potential impacts to historical resource sites that could result from potential development of the Meridian Reservoir; and
- Recommend conservation strategies appropriate for offsetting potential impacts.

6 ADDITIONAL IMPACTS

6.1 Infrastructure

The local and provincial roadway network is illustrated in Figure 6.1-1. The approximate flooded reservoir area for Scenario 3 is shown at a full supply level of roughly 646 m. The affected area is approximately 150 km^2. A buffer zone (490 km^2) is also shown which includes additional area adjacent to the reservoir to the top of valley walls. Infrastructure in this buffer will not be flooded, but may potentially be negatively affected by reservoir development and valley wall instability resulting from reservoir flooding.

A concern has been raised regarding the possibility additional flooding of low-lying areas north of the reservoir. Preliminary review of available information indicates there may in fact be a hydrogeologic divide between the reservoir and these areas, however this has not been confirmed and there exists the possibility of a connection between the two. As discussed in Section 5.7, further studies would be needed to determine hydrogeological connectivity and thus potential for flooding. For the purposes of this study, the cost of relocating and abandoning infrastructure in the low-lying areas has not been addressed.

6.1.1 Roads and Utilities

Table 6.1.1 summarizes the type and length of existing roadway within the flooded reservoir area and the buffer area. Due to realignments, the required replacement road length may exceed the original length. It is also possible that not all local roads would need to be replaced as alternative routes could connect to existing roadways, or the roads may no longer be required to provide access to abandoned facilities. Consequently, the replacement cost for local roads may be significantly less than the present value of all roads within the delineated areas.

Representatives of various organizations were contacted regarding expected costs associated with remediation, relocation, or abandonment of roads and utilities. These parties and the information provided are summarized in Table 6.1-2.

Figure 6.1-1 New Road Alignment

Table 6.1-1
Characteristics of Roads Potentially Affected by the Meridian Dam

Type of Road	Length within reservoir area	Length within Buffer	Length Bypassed	Replacement Length
Alberta Highway	5 km	12 km	22 km	38
Alberta Local Road	53 km	133 km	not determined	not determined
Saskatchewan Local Road		4 km	not determined	not determined

Table 6.1-2
Available Information on Roads and Utilities in the Meridian Area

Organization	Information Provided	Comments
Alberta 1 Call	All registered underground utilities within reservoir area to be flooded	Very few facilities other than oil and gas pipelines were identified.
Alberta Transportation	Cost for highway re-alignment	Construction cost $400,000 to $700,000 (1998 dollars) per km, depending on road standard. Amount excludes land acquisition. Road reclamation $300,000 to $500,000.
	Cost of stockpiling gravel deposits (quantity of gravel may be in the range of 1-2 million tonnes)	$4 per tonne in 1980's
	Salvage costs for removal of Highway 41 bridge	$1 Million (??)
Saskatchwan Highways and Transportation	Review of proposed Highway 41 re-alignment	A formal cost-share agreement would be required between Alberta and Saskatchewan governments.
Cypress County	Cost for construction of local roads and other anticipated impacts	Costs average $40,000 to $50,000 per mile, and are higher in hilly (valley) areas. However, most county roads near river valley are private. Estimated replacement cost of Sandy Point Municipal Park is $200,000.
Town of Redcliff	Expected impacts	Impacts expected to be minimal. However, further assessment of changes to floodplain would be required.
City of Medicine Hat	Expected impacts	Response pending at time of writing.
CFB Suffield	Impacts to infrastructure on Federal lands	Most infrastructure is related to AEC facilities. No costs to CFB, except submergence of 65 to 70 km of federal lands along the river.

As shown above, the cost for construction of local roads is generally in the range of $75,000 per kilometre (pers. comm Brian Whitson, County of Cypress), and a replacement of Highway 41 is estimated to cost $1 million per kilometre (pers. comm Michael Bradley, Alberta Transportation).

No detailed information was obtained regarding costs for utilities such as telephone and electrical facilities, although very few facilities were identified through Alberta 1-Call.

Estimated costs to abandon, modify and/or replace existing roads and utilities are provided in Table 6.1-3.

Table 6.1-3
Estimated Costs Associated with Roads and Utilities Relocation for Scenario 3

Facility	Quantity	Unit Cost	Total
Reclaim Inundated Roadway			
Alberta Highway	5 km	$400,000/km	$2,000,000
Alberta Local Road	53 km	$55,000/km	$2,900,000
Replace Roadway			
Alberta Highway	38 km	$550,000/km	$21,000,000
Alberta Local Road	53 km	$75,000/km	$4,000,000
Replace Utilities			
10 % of road replacement			$2,500,000
Stockpile Gravel	1.5 million tonnes	$5/tonne	$7,500,000
Replace Recreational Facilities			
Municipal Park	1 park	$200,000	$200,000
Total			**$40,000,000**

The requirements for roads and utilities relocation would be similar for all three scenarios due to the aereal disturbance of the potential project. For the purposes of this study, the associated costs of approximately $40 million are assumed to be the same for Scenarios 1, 2, and 3. The following assumptions were made in the above estimate:

- Only inundated local roads will require reclamation and replacement.
- Highway length will be reclaimed in inundated areas only, and replacement length is roughly 38 km as shown on Figure 6.1-1.
- Costs of land acquisition for roads is not included (see Section 7.4 for land costs).
- In the absence of detailed information, the value of electrical and telephone utilities are assumed to be 10% percent of roadway costs.
- The cost of sewer and water facilites are not included as they are site-specific, and correspond to the location of private residences or farms.

- Inflation (since 1990) for gravel stockpiling is 25%.

As evident in the above assumptions and the level of detail available, more detailed consideration would be needed to quantify accurate costs of roads and utility relocations. It is expected that this would be completed in future phases of more detailed project consideration.

6.1.2 Oil and Gas Wells and Pipelines

Figure 6.1-2 illustrates the location and present ownership composition of oil and gas wells and pipelines in the region.

The type and quantity of wells within the approximate flooded area and buffer area are provided in Table 6.1-4. Similarly, the size and length of pipeline within the area is shown in Table 6.l-5.

Table 6.1-4 Number of Wells Within the Meridian Area

Well Type	Number of Wells Within Reservoir	Number of Wells Within Buffer
Spudded	0	3
Licenced	9	29
Farm Gas	1	4
Dry Hole	7	31
Susp. Gas Well	1	7
Standing	15	64
Abandoned Gas	6	14
Gas Producer	98	459
Flowing Oil	1	1
Commingled Gas	31	78
Dual Comp. Gas Well	77	351
Total	**246**	**1041**

Figure 6.1-2 Oil and Gas Facilities Arrangement Map

Table 6.1-5 Pipeline Lengths Within theMeridian Area

Pipe Diameter	Length Within Reservoir	Length Within Buffer
0 - 100 mm	93.9 km	445.2 km
100 - 200 mm	16.2 km	112.4 km
200 – 400 mm	12.8 km	40.6 km
400 – 800 mm	9.2 km	15.9 km
800 – 1600 mm	7.0 km	29.6 km
Total	**139.1**	**643.7 km**

Additional information regarding wells and pipelines by operators is summarized in Table 6.1-6 and Table 6.1-7.

Table 6.1-6 Well Operators

Well Operator	Quantity Within Reservoir	Quantity Within Buffer
Alberta Energy Company	71	296
Direct Energy Marketing	103	280
The City of Medicine Hat	4	85
Petro-Canada	0	61
Tetreau and Associates	7	28
Other	61	291
Total	**246**	**1041**

Table 6.1-7 Pipeline Operators

Pipeline Operator	Length Within Reservoir	Length Within Buffer
Alberta Energy Company	58.4 km	148.9 km
Direct Energy Marketing	56.7 km	205.6 km
The City of Medicine Hat	3.4 km	3.4 km
Petro-Canada	0.7 km	33.6 km
Tetreau and Associates	1.0 km	19.8 km
TransCanada Pipeline (Nova Gas)	6.7	29.9 km
Foothills Pipeline	.9 km	4.8 km
Other	18 km	227.6 km
Total	**139.1**	**643.7 km**

Representatives of various organizations were contacted to inquire about expected costs associated with remediation, relocation, or abandonment of wells and pipelines. Feedback from those contacted is summarized in Table 6.1-8:

Table 6.1-8 Available Information on Wells and Pipelines in the Meridian Area

Organization	Information Provided	Comments
Alberta 1 Call	All registered underground utilities within reservoir area	Some oil and gas pipelines were identified. However, the listing was incomplete in comparison to the industry database of facilities shown on Figure 6.1-2.
Cypress County	Lost revenue from well	Response Pending at time of writing.
	Value of assessments and municipal tax revenue	Average assessed value $14,814/well; $20,681/km pipeline; combined municipal and school tax $160/well, $224/km
City of Medicine Hat	Expected impacts and costs	Response pending at time of writing.
Alberta Energy Company	Expected impacts and costs for 760 wells and associated facilities[1]	Cost of reclamation $20 million. Present value $1.1 billion, over 20 years lost resource and property; $65 million refitting + O&M. Local employment, spending, taxes, royalties $160 million.
Direct Energy Company	Expected impacts and costs	Response pending at time of writing.
Petro-Canada	Expected impacts and costs	35 sections (70 existing wells and 70 future locations). Gross value $80 million +/- 50% recoverable reserves. $100-150,000/km for 50 mm pipe realignment.
TransCanada Pipeline	Expected impacts and costs	Modifications $2 million per kilometre for large diameter pipelines at river crossings $1 million to dismantle pipeline bridge; $100,000/submerged well reclamation cost.

[1] The 760 impacted wells and facilities represent infrastructure in the flooded area and buffer zone (as shown in Figure 6.1-2). The number also includes infrastructure within a large low-lying area north of the potential reservoir that is shown as flooded by the Digital Elevation Model (DEM) developed by Environment Canada.

The following considerations were highlighted by industry:

- The primary resource represented by the above activities is shallow natural gas, which cannot be exploited by means of directional drilling.
- Abandoning of wells also requires abandonment of the underlying resource, without possibility of recovery using presently available technology (this would apply only to flooded areas, although other affected wells may become less economical).

- Approximate cost of retro-fitting large diameter (800mm +) pipes is in the range of $1,000,000 per kilometre.
- Gas prices have recently been extremely volatile, which increases the uncertainty in valuation of the resource.

From the available information summarized above, the following assumptions were derived to estimate costs of relocating and abandoning oil and gas infrastructure:

- Cost of well reclamation is approximately $100,000 per well (TransCanada Pipeline)
- Costs associated with pipelines are based on size where pipelines:
- >800 mm in diameter cost $1,000,000 per kilometre
- 200-800 mm in diameter cost $600,000 per kilometre
- <200 mm in diameter cost $150,000 per kilometre
- The average value of abandoned resource is $1,000,000 per well

It was also assumed that all submerged wells and pipelines would have to be abandoned and reclaimed, as well as 50% of the infrastructure located in a buffer area that was estimated to cover a width of approximately 1 km on each side of the reservoir. The associated costs are highly dependent on current gas prices which have been extremely volatile in the recent past and on the assumption of how many facilities in the buffer zone will in fact be impacted by the reservoir development. These costs for reservoir impacts are uncertain as they are based on preliminary assessments by operators without independent verification and because the size of buffer zone was roughly estimated. As mentioned previously, infrastructure located in low-lying areas were not considered. The cost to abandon, modify and/or replace existing well sites and all associated facilities (including pipeline and compressor, etc.) is estimated as $960 million for Scenario 3 as shown in Table 6.1-9. Estimates for Scenarios 1 and 2 are $440 million and $700 million, respectively, based on the relative amount of flooded areas.

Table 6.1-9 Estimated Costs Associated with Impacts on Wells and Pipelines for Scenario 3

Item		Quantity[1]	Unit Cost	Total
Abandonment and reclamation of wells		770 wells	$100,000/well	$77,000,000
Associated pipeline costs	Large (>800 mm dia.)	22 km	$1,000,000/km	$22,000,000
	Medium (200-800 mm dia.)	50 km	$600,000/km	$30,000,000
	Small (<200 mm dia.)	390 km	$150,000/km	$58,000,000
Abandonment of resource		770 wells	$1,000,000/well	$770,000,000
Total				**$1,110,000,000**

[1] Includes 100% of infrastructure in flooded area plus 50% of infrastructure in buffer zone.

Table 6.1-10 Estimated Costs Associated with Impacts on Wells and Pipelines[1] for Scenarios 1,2, and 3

Item	Scenario 1	Scenario 2	Scenario 3
Abandonment and reclamation of wells	$35,400,000	$56,000,000	$77,000,000
Associated pipeline costs	$50,500,000	$80,000,000	$110,000,000
Abandonment of resource	$354,000,000	$560,000,000	$770,000,000
Total	**$440,000,000**	**$696,000,000**	**$1,110,000,000**

[1] Includes 100% of infrastructure in flooded area plus 50% of infrastructure in buffer zone.

6.1.3 Municipal Water Supply

The effects of the Meridian Dam on downstream municipal water supplies are discussed in Section 6.2.1.

6.2 Effect on Stream Flows and Water Uses in Saskatchewan

The following section focuses on the potential effects that Meridian Dam would have on stream flows, water uses and water levels in Saskatchewan. For simplicity, these discussions refer to and compare only two scenarios. The first represents the baseline and is referred to as the "Current Scenario". It represents the current level of water use and development in Alberta. The second case is Scenario 3, that of the largest reservoir capacity (3,700,000 dam^3) and largest area of irrigation use being considered (240,000 ha). At a pre-feasibility level, it is adequate to interpolate the downstream effects of the smallest and intermediate capacity reservoirs from the Current Scenario and Scenario 3. Effects on stream flows and water uses in Saskatchewan were evaluated by SaskWater using the available water resources management model (WRMM) which

includes the lower reaches of the South Saskatchewan River basin. Inputs to the system included the Meridian Dam outflows as modelled by Alberta Environment.

The following discussion on downstream effects is broken down into five sections: South Saskatchewan River upstream of Lake Diefenbaker, Lake Diefenbaker water levels, Lake Diefenbaker water uses, flows downstream of Lake Diefenbaker, and hydropower production.

6.2.1 South Saskatchewan River Upstream of Lake Diefenbaker

Development of the potential Meridian Dam would have impacts on the South Saskatchewan River upstream of Lake Diefenbaker as described below.

6.2.1.1 Average Annual Volume

The most obvious effect of the Meridian Dam on stream flows into Saskatchewan is that the long-term average annual river flow would be reduced due to withdrawals from the Meridian reservoir and due to evaporation from the reservoir surface. The simulated flows show that for infrastructure currently in place, the average annual flow into Saskatchewan below the Red Deer River would have been 187 m^3/s over the entire 1928 to 1995 simulation period. With the addition of the Meridian Dam and its associated uses, the long-term average annual river flow would be reduced by 16 percent, or 30 m^3/s, to 157 m^3/s.

6.2.1.2 Annual Flow and Apportionment

The annual flow is not uniformly reduced by 30 m^3/s in each of the 68 years of the simulation period. The greatest reductions in annual flow due to the Meridian Dam would be in above-average flow years, with little to no reduction to annual flows in years with low runoff. Figure 6.2-1 compares annual flows during the 68 years period of simulation. The same information is presented in Figure 6.2-2, except that the annual flows have been sorted from largest to smallest and assigned a probability (i.e. out of 68).

In 1969, the three prairie provinces and the federal government agreed on how flows of eastward flowing interprovincial streams should be shared (1969 Master Agreement on Apportionment).

In all but extreme low flow years, Alberta must pass at least one-half of the combined natural flow of the Red Deer and South Saskatchewan rivers (in extremely low runoff years, special provisions in the agreement allow Alberta to take more than 50% of the natural flow). In all the scenarios examined in this study, the annual apportionment flow obligation to Saskatchewan is met based on river flows alone. In the scenarios evaluated, an additional portion of flow is also passed to Saskatchewan as irrigation water from the reservoir.

Over the 68 year simulation period, Alberta passed an average of 65% of the natural flow at the Alberta/Saskatchewan boundary with the current level of development. Under Scenario 3, Alberta passed an average of 55% of the natural flow, as river flows. Including irrigation water allocated to Saskatchewan (an annual average of 13 m^3/s), the percentage of natural flows passed to Saskatchewan is roughly 60%.

6.2.1.3 Minimum Flow - Frequency at 42.5 m^3/s

An additional provision of the 1969 Master Agreement on Apportionment is that, except for the situation where the natural flow drops below 85 m^3/s at the Alberta-Saskatchewan boundary, Alberta must maintain a flow of at least 42.5 m^3/s at the confluence of the Red Deer and South Saskatchewan rivers (downstream of the confluence). A natural flow of less than 85 m^3/s occurs only in extremely dry years such as in 2001. In all the scenarios examined for this study, the weekly average flows were in excess of 42.5 m^3/s.

6.2.1.4 Distribution of Monthly Flow

The Meridian Dam will have the effect of altering the distribution of the annual flow throughout the year. Figures 6.2-3 and 6.2-4 show the monthly average and median flows respectively. These flows represent the South Saskatchewan River at the Alberta-Saskatchewan border, including flows from the Red Deer River. From these figures, it appears that Meridian Dam would not radically shift flows from one season into another. The figures indicate that there will be a significant reduction of flows in July and August. Flows in September through December may be slightly increased but will be largely unaffected, while there will be modest flow reductions in the months of January through May.

Figure 6.2-1 Annual Flow at the Alberta-Saskatchewan Boundary

Figure 6.2-2 Average Annual Flow at the Alberta-Saskatchewan Boundary - Exceedence

Figure 6.2-3 Monthly Average flow at the Alberta-Saskatchewan Boundary

Figure 6.2-4 Monthly Median Flow at the Alberta-Saskatchewan Boundary

6.2.1.5 Ferry Operation and Winter Ice Crossing Roads

During the open water season, ferry operations at Estuary, Lemsford, and Lancer can be affected by low flows, high flows, and by rapid changes in flows. During the winter, ice crossings at these three sites can also be affected by changes in flow rates.

With the current level of development, flow rates into Saskatchewan vary throughout the open water season but the existing works in Alberta are able to regulate them to a large degree. In most years, ferry operations are largely unhindered by flows, or are able to adjust their operations in response to forecasts of low flows or of high flows. In the case of rapid flow changes such as when a large rainfall occurs in the headwaters areas (e.g., June 1995), ferry operations may be disrupted for one or more weeks. In extreme low flow years such as 2001, the ferries either have to limit their loads or cease operations altogether.

The effect of the Meridian Dam on ferry operations along the river upstream of Lake Diefenbaker would depend largely on the installed hydropower capacity, any hydropower peaking operations, and use of the reservoir for seasonal flow modification for hydro-electric operations. The greatest potential effect would be at the closest ferry location, the Estuary Ferry. Large rainfall-runoff events in the Red Deer River watershed will continue to have the potential to disrupt ferry operations, however, it will likely be possible to reduce outflow from the Meridian Dam during passage of the Red Deer River peak flow, thus moderating any large impacts.

6.2.1.6 Municipal Intake works

Four communities in southwestern Saskatchewan have developed municipal water supplies from the South Saskatchewan River upstream of Lake Diefenbaker. These include the communities of Eston, Kindersley, Prelate and Leader, with a combined population of about 3,200 people. Eston and Kindersley share a common water intake and pump station at the river.

Municipal intakes are generally designed to accommodate the maximum range of expected flows, and are not likely to be affected by upstream developments unless that range of flows were altered. However, problems were encountered during the summer of 2001 at the Eston/Kindersley intake due to low river levels associated with the low flow rate in the river.

This occurred despite Alberta continuing to meet the 42.5 m^3/s flow rate objective throughout the summer.

With the development of the Meridian Dam, one might expect more frequent occurrences of flows approaching the 42.5 m^3/s guideline. Examination of the weekly flow arrays indicates that for the current level of development, there would be only one week in the 68 year simulation period with a weekly average flow of less than 50 m^3/s. With the largest size Meridian Dam, however, the frequency of weekly average flows less than 50 m^3/s increases to 29 occurrences (out of 3,536 weeks in 68 years).

A long-term effect of the development of Meridian Dam may be on the sediment load carried by the river and on the geomorphology of the riverbed as discussed in Section 5.1. Changes in these aspects of the river may affect municipal intakes.

6.2.1.7 Irrigation Intake Works

There are two basic types of irrigation intake works in southern Saskatchewan: permanent intakes and portable works that can be moved within short distances of the water's edge. Group irrigation projects tend to have permanent intakes, while individual irrigators have portable works.

The effects of Meridian Dam on permanent irrigation intakes would be similar to those discussed for municipal intakes. The only difference being that irrigation works are only needed during the summer irrigation season, typically May through September, whereas municipal works must be functional year-round. The only permanent irrigation intake upstream of Lake Diefenbaker is for the Chesterfield Water Users District in section 8-23-27-W3.

The operators of portable irrigation intakes are able to relocate their works to accommodate a range of water levels without the higher capital cost of a permanent intake. Typically the works consist of a portable pump powered by a diesel or gasoline engine delivering water through aluminum irrigation pipe to a permanent pipe system on the river bank. At normal and high water levels, the pump can be located on the river bank. At low water levels, the pump is moved to the water's edge and irrigation pipe laid back to the bank. In this situation, the operator has two

concerns. The first is delivering fuel to the pump. The operator either locates the tank by the pump and refuels the tank by driving out to the site with a truck to deliver fuel, or the tank is situated on the river bank and a long fuel hose is extended to the pump. Each option has operational and/or environmental risks. The second concern is that a rapid increase in river level may flood the pump site and/or cut off access to the pump site.

6.2.1.8 Cattle Access and Containment

There are a number of sites along the river where cattle have access to the river. During times of normal or high flows, the cattle can generally be contained by the river bank and on-shore fencing. However, during periods of low flow, the cattle descend the bank to the water's edge and temporary fencing is extended to the water's edge to provide containment. If flows rapidly increase, the cattle may become stranded on sand bars or islands. Retrieving the cattle then becomes a problem and in extreme cases the cattle may be lost. If the operation of Meridian Dam results in more frequent occurrences of high flows following periods of low flow, the frequency of cattle becoming stranded or lost may also increase. This has not been assessed in detail.

6.2.1.9 High Flows and Flood Damages

In general, the development of a major reservoir results in an enhanced ability to reduce flood peaks during extreme events. As discussed in Section 4.4, this is likely the case with Meridian Dam. For example, the simulated maximum weekly flow for the flood in 1995 was simulated at 2,297 m^3/s under the current level of development. With the largest size dam in place, the simulated flow is reduced by 32 percent to 1,556 m^3/s. It should be noted that during the flood event of 1995 there were no reports of extensive flood damages along the river upstream of Lake Diefenbaker. Figure 6.2-5 shows that, except for the extreme high flow years and extreme low flow years, maximum annual weekly flows would be reduced by Meridian Dam.

Additional discussion and an analysis of flood control benefits is presented in Section 4.4.

Figure 6.2-5 Weekly Maximum Flow at the Alberta-Saskatchewan Boundary – Exceedence

6.2.1.10 River Morphology

As discussed in Section 5.1, construction of a large dam on a river affects not only the flow of water carried by the river, but also the sediment load carried by the river. Sediment is trapped in the upstream end of the reservoir and relatively clear water is passed on downstream. This water may pick up sediment from the streambed and carry it downstream in a process known as bed degradation due to an increase in sediment-carrying capacity. In the case of the Meridian Dam, the analysis of this effect would be complicated by the flows and sediment loads contributed a short distance downstream by the Red Deer River.

A second effect of a large dam on the downstream river discussed in Section 5.1, is change to sediment transport and deposition during flood events. It is largely during floods that sand bars shift location and river banks erode or built up by deposition. By reducing the frequency and magnitude of flood peaks, dams generally have the effect of slowing down these processes. This could have implications on shoreline and sand bar vegetation and habitats.

6.2.1.11 Winter Ice Formation and Break-up

The construction of a large reservoir alters the thermal regime in a river, particularly where the outlet works draw water off the lower portion of the reservoir. Heat stored in the reservoir over the summer will be passed as warmer water into the fall months. This may delay freeze-up of the river for some distance downstream from what is currently experienced.

As mentioned previously, operations of Meridian Dam have not been optimized for hydro-electric generation. If hydro-electric peaking operations were to occur, however, this may delay formation of a winter ice cover by repeatedly breaking up the initial cover while it is still weak. As a result of this phenomenon, plants are typically operated during the freeze-up period to ensure a smooth, stable ice cover is formed. Spring break-up of the ice cover may also be affected by Meridian Dam. This issue would require more investigation.

6.2.2 Lake Diefenbaker Water Levels

Lake Diefenbaker operates on an annual cycle. The large reservoir redistributes the seasonal pattern of inflows in such a way as to ensure water supply to authorized users. It also provides flood protection downstream, maximizes hydro-electric power production at the Coteau Creek station as well as at the two stations downstream on the Saskatchewan River, and allows for recreational use of the reservoir. Figure 6.2-6 shows the historic median month-end water levels over the period 1969-2000. Also shown are the historic month-end maximum and minimum levels. The figure shows the annual minimum level typically occurs in March. The reservoir then typically refills over the spring months, reaching annual maximums during the summer. In years with low runoff, such as 1977, 1984, and 1988, the reservoir did not fill to 552.0 m during the summer months.

The winter and early spring month-end minimums of less than 549.0 m all occurred in the first 13 years of operation of the reservoir. Figure 6.2-7 shows the historic annual minimum levels over time. The figure shows that there is clearly an upwards shift in the minimum level from the earlier years. This shift is the result of increased operating experience with the reservoir. Figure 6.2-7 shows that since about 1983 the annual minimums have been within the three metre range of 549.0 m to 552.0 m. The variance in annual minimums is influenced by two factors, the reservoir level of the previous fall, and the observed snowpack accumulation in the Rocky Mountains and foothills of southern Alberta. A large snowpack will lead to a lower minimum level while a below normal snowpack generally results in a restricted reservoir drawdown and a higher minimum level.

6.2.2.1 Modelling Results

The effects of Meridian Dam on Lake Diefenbaker levels, water uses from the lake, and flows downstream were analyzed using the WRM Model software developed by Alberta Environment (1999). The South Saskatchewan River system into Saskatchewan was previously modeled for the 1991 Canada-Saskatchewan South Saskatchewan River Basin Study. The same model was used in this analysis, although it was updated to reflect both current level of demands and operating practices. The input data arrays of precipitation, evaporation and inflow were also updated to be concurrent with the 1928 to 1995 simulation period.

The original model of the South Saskatchewan River system operated on monthly time steps. For this analysis, the monthly time step was retained as there was no apparent advantage to switching to a weekly time step. To do so would have required a significant effort in reworking the database. The weekly average simulated inflow data to Saskatchewan provided by Alberta Environment was converted to monthly averages and entered into the model database.

The WRM Model of the South Saskatchewan River system did not have the ability to replicate the variation in spring runoff minimums as the model cannot incorporate forecasts of spring inflow volumes. As a result, a March 31 target level of 551.0 m was established in the model. Figure 6.2-8 shows the median month-end simulated levels over the 68 year study period from 1928 to 1995. Figure 6.2-9 compares the historic median month-end levels with the medians simulated for the current level of development over the 68 year study period. The January through March simulated medians reflect the 551.0 m target. Over the spring and summer months, the two traces are very similar, with the simulated trace remaining somewhat higher into October and November in order to maximize winter hydro-electric generation from Lake Diefenbaker.

Also shown on Figure 6.2-8, are the maximum and minimum month-end levels during the simulation period. The trace of minimum levels approaches the 551.0 March 31 target through January, February and March. The trace remains at that level for the balance of the year due to the combination of higher summer downstream flow demands than observed historically, and the inclusion of additional low flow years in the simulation such as 1931, 1937, 1941, and 1949 as opposed to the historic record which dates back only to 1969.

Figure 6.2-10 compares the historic maximum month-end levels with the maximum month-end levels simulated for the current level of development over the 68 year study period. The November through March simulated maximums reflect the 551.0 m March 31 target. The simulated April and May month end levels reflect the high spring runoff years of 1952 and 1948 respectively, which are not part of the historic record of Lake Diefenbaker levels.

Figure 6.2-6 Lake Diefenbaker Historic Month End Level Distribution

Figure 6.2-7 Lake Diefenbaker Historic Spring Minimum Levels

Figure 6.2-8 Lake Diefenbaker Current Simulation – Month End Levels

Figure 6.2-9 Lake Diefenbaker Median Month End Levels

Figure 6.2-10 Lake Diefenbaker Maximum Month End Levels

Figure 6.2-11 Lake Diefenbaker Current Level of Development

Figure 6.2-12 Lake Diefenbaker Scenario 3

Figure 6.2-13 Lake Diefenbaker Median Month End Levels

Figure 6.2-14 Lake Diefenbaker Maximum Month End Levels

Figure 6.2-15 Lake Diefenbaker Minimum Month End Levels

The historic month-end maximums for November through March shown on Figure 6.2-10 reflect the operations of 1999/00. In November and December 1999, record or near record inflows were recorded due to abnormally high temperatures in Alberta which resulted in melting of the accumulated snowpack. As the winter progressed into 2000, the normal snowpack did not re-develop and outflows were reduced through February and March to ensure the reservoir refilled in the spring. The historic maximum month-end levels for April and May reflect the reservoir operation of 1993 when low snowpack accumulations were observed in the headwater areas and the reservoir drawdown was curtailed at elevation 551.61 (see Figure 6.2-7).

If the current level of water development and water use in the river basin had been in place over the entire period 1928-1995, the simulated levels of Lake Diefenbaker would have been as shown in Figure 6.2-11. As noted previously, the model consistently reaches the March 31 drawdown target of 551.0 m. The trace of month-end levels also reflects the years of high inflow and of low inflow as shown on Figure 6.2-1. In high inflow years, the reservoir would have exceeded elevation 556.0 m. In years of low inflow, the reservoir may not reach elevation 552.0 m.

In general, the reduced annual flows to Saskatchewan due to the development of the Meridian Dam and its associated water uses would affect water levels on Lake Diefenbaker. Extreme low flow years will be less affected because Alberta is required to pass the apportionment flow. Some high flow years are also largely unaffected because in those years Lake Diefenbaker fills to capacity and there is excess water, even with the Meridian Dam. In the simulation of Lake Diefenbaker for the largest size of the Meridian reservoir (Scenario 3), the March 31 drawdown target was raised to 551.5 m to compensate for the reduced average annual inflow. The simulated reservoir levels are shown in Figure 6.2-12 and can be compared with those simulated for the current condition. It is evident that summer levels will be lowered by the Meridian Dam in many years.

Figures 6.2-13 through 6.2-15 compare the median, maximum, and minimum month-end levels for the Current Scenario and Scenario 3. Figure 6.2-13 shows the higher winter drawdown target of 551.5 m. With the reduced inflow primarily occurring in the spring and summer months (see Figures 6.2-3 and 6.2-4), the simulated median summer levels are significantly lower with the Meridian Dam than they are without the Dam. Figure 6.2-14 shows that the Meridian Dam will not significantly affect the maximum month end levels achieved by Lake Diefenbaker. Again,

the 551.5 m March 31 target affects the simulated winter month end levels. Figure 6.2-15 shows the minimum simulated month end levels. With the raising of the March 31 target, the summer minimums are also raised. However, winter minimums end up slightly lower than under the Current Scenario due to a few low flow years in which winter flow from Alberta is reduced.

6.2.2.2 Irrigation

Water levels of Lake Diefenbaker have two direct implications for irrigation projects, (group or private) which withdraw water directly from the reservoir. The first implication is that at low reservoir levels, some project intakes may not be able to access the volume of water required by the project. The WRM Model incorporated a minimum irrigation elevation target of 551.0 m from May 1 through to September 30. However, operating experience in early June 2001 indicated the Miry Creek irrigation project has reduced capacity to draw water into their wet well at reservoir elevations below 551.7 m. When levels increased to above 552.0 m later in the month, the concerns were reduced, however, intake capacity was still limited and not all pivots on the project could be operated simultaneously throughout the remainder of the irrigation season. The month-end elevations for April 30 through September 30 indicate that there were no simulated occurrences of levels less than 551.0 m for either the Current Scenario or for Scenario 3. One reason for this result was the selection of the 551.0 m March 31 target for the Current Scenario and the 551.5 m target for Scenario 3. These were chosen in part to ensure that the 551.0 irrigation minimum would not be violated.

The second implication of reservoir levels on irrigation projects around Lake Diefenbaker is that of pumping cost. As discussed above, the effect of Meridian Dam will be to lower the summer reservoir levels (Figure 6.2-13). Lower levels will have the effect of increasing the energy required to pump water up to the irrigation projects, and hence increase the pumping cost. At this pre-feasibility study level, the energy cost of lower reservoir water elevations over the irrigation season due to the Meridian Dam has not been assessed.

6.2.2.3 Recreation Levels

The 1991 South Saskatchewan River Basin Study (SSRBS) recommended an elevation target of 552.0 m by May 15 and throughout the open water recreational season. At this level boat launch

and marina facilities around the reservoir are fully operable. Table 6.2-1 outlines the number of occurrences when simulated month-end levels were to be below 552.0 m.

Table 6.2-1 Occurences of Month End Levels Below 552.0 m (out of 68 years)

Month	May	June	July	August	September	October
Current	19	8	8	8	7	5
Scenario 3	12	3	3	3	3	1

The SSRBS also found that the preferred elevation range on Lake Diefenbaker for summer recreation was 554.0 m to 556.0 m. Table 6.2-2 outlines the frequency that these limits were met.

Table 6.2-2 Frequency of Lake Diefenbaker Levels at 554 m and 556 m

Month	June	July	August	September
Frequency of Month End Levels Below 554.0 m (% of years)				
Current	37	25	22	22
Scenario 3	42	38	34	33
Frequency of Month End Levels Above 556.0 m (% of years)				
Current	19	43	46	49
Scenario 3	11	33	27	25
Frequency of Month End Levels Between 554.0 m and 556.0 m (% of years)				
Current	44	32	32	29
Scenario 3	47	29	39	42

A quick study of the table shows that the Meridian Dam would significantly increase the frequency of water levels not reaching the lower end of the preferred range (elevation 554.0 m). The recreational impact of levels below 554.0 m include increased distance to water's edge, exposed mud flats and blowing sand on beaches, and poor access to water for boating, docks etc. The table also shows that Meridian Dam will reduce the frequency of summer water levels above 556.0 m. When water levels are above 556.0 m, beach width is reduced and erosion of shoreline bluffs is accelerated.

When taken together, the reduced frequency of being above 556.0 m more than offsets the increased frequency of being below 554.0 m. Thus, the frequency of being within the preferred range will increase with the development of Meridian Dam and its associated water uses.

6.2.2.4 Piping Plover Habitat

In recent discussions with Sask Water, Environment Canada and Saskatchewan Environment and Resource Management (SERM) have proposed that Lake Diefenbaker should have a target of being no higher than 555.0 m before July 1. The contention is that this would allow sufficiently wide and open beach habitat above the 555.0 m level to allow increased survival of fledged Piping Plover chicks against predators foraging on the beaches.

An assessment of the recorded Lake Diefenbaker June 30 levels from 1969 to 2000 indicates that historically the 555.0 m July 1 target level has been exceeded 52 percent of the time. In the Current Scenario, the 555.0 m target is exceeded 41 percent of the time. In Scenario 3, the exceedence rate is reduced slightly to 38 percent of the time.

6.2.2.5 Riverhurst Ferry and Winter Ice Crossing

The Riverhurst Ferry is designed to operate at all expected water levels during the open water season. Since water levels are not allowed to exceed the Lake Diefenbaker Full Supply Level (FSL) of 556.87 m, and Figure 6.2-15 suggests that the open water season minimum levels will increase with Meridian Dam, the Ferry operation will not be affected by the Dam.

Unless winter temperatures are unusually mild, a winter crossing is provided at the Riverhurst Ferry site once the ice is sufficiently thick. With the development of the Meridian Dam and its associated water uses, the winter drawdown of Lake Diefenbaker will generally be reduced. Thus, there should be no negative impacts on the provision of the winter ice crossing at Riverhurst due to Meridian Dam.

6.2.3 Lake Diefenbaker Water Uses

6.2.3.1 Qu'Appelle Dam Releases

Releases are made from Lake Diefenbaker to the Qu'Appelle River system via the Qu'Appelle Dam. These releases supply municipal, irrigation, industrial and waterfowl project uses and support summer recreational levels on eight lakes along the Qu'Appelle River in Saskatchewan. At the current level of development along the Qu'Appelle, the average annual release is 97,700 dam^3.

Sask Water recently completed a study of the Qu'Appelle system using the WRM Model. Simulated monthly Qu'Appelle Dam releases from that model for the current level of development were used as a water demand in the South Saskatchewan River WRMM. In both the Current Scenario and Scenario 3, there were no simulated shortages in releases to the Qu'Appelle River system.

6.2.3.2 SSRID and SSEWS

The South Saskatchewan River Irrigation District (SSRID) is located north of Lake Diefenbaker on the east side of the river. The East Side Pump Station, located at the east end of Gardiner Dam, lifts water from Lake Diefenbaker into a canal that carries water to Broderick Reservoir. From there the water is distributed to the SSRID. The irrigation district was simulated in the WRMM with an irrigated area of 13,790 ha. The simulated annual irrigation water demand for the district was 56,200 dam^3.

From Broderick Reservoir the Saskatoon Southeast Water Supply (SSEWS) system, a series of canals, five reservoirs, pump stations and pipelines, extends for over 150 kilometres, terminating at the town of Lanigan. The system supplies water for irrigation, industrial, municipal and waterfowl project uses, and supports the levels of the five reservoirs and one lake for recreational use. The SSEWS system was simulated in the WRMM and the average annual water demands totalled 68,900 dam^3. The SSEWS system demands were not reviewed in detail for this study. It was assumed that the projected year 2000 demands used in the SSRBS adequately represented the current level of municipal, irrigation and industrial demand.

In both the Current Scenario and Scenario 3, there were no simulated shortages in deliveries to either the SSRID or the demands along the SSEWS system. However, as discussed previously, lower levels on Lake Diefenbaker will result in higher energy costs at the East Side Pump Station.

6.2.3.3 Municipal and Irrigation Use

There are a number of irrigation projects and municipalities that take water directly from Lake Diefenbaker. The irrigation demand was reviewed and updated for this study while it was assumed that the projected year 2000 demands used in the SSRBS adequately represented the current level of municipal demand. The total direct annual demand on Lake Diefenbaker at the current level of development is 75,500 dam^3. In both the Current Scenario and Scenario 3, there were no simulated shortages in deliveries to the direct demands out of Lake Diefenbaker.

6.2.4 Flows Downstream of Lake Diefenbaker

Since there is no change in the amount of water supplied from Lake Diefenbaker to the Qu'Appelle, SSRID, SSEWS, or direct users, and there is no change in the evaporation loss from the reservoir, the reduction in average annual flow into the reservoir of 30 m^3/s due to Meridian Dam is passed entirely downstream through Saskatoon and to the Saskatchewan River.

6.2.4.1 Through Saskatoon

The simulated average annual flow through Saskatoon under the current level of development is 168 m^3/s over the 1928 to 1995 simulation period. With the Meridian Dam, the average annual flow would be reduced to 137 m^3/s, a reduction of 18 percent. Figure 6.2-16 shows the series of average annual flows over the study period. Similar to the pattern shown in Figure 6.2-1, the reduction in annual flow tends to be larger in years of high flow and smaller in years of low flow. This pattern is also shown on the annual flow duration curves in Figure 6.2-17.

Figure 6.2-16 Annual Flow Through Saskatoon

Figure 6.2-17 Annual Flow Through Saskatoon - Exceedence

Figure 6.2-18 Monthly Average Flow Through Saskatoon

Figure 6.2-19 Monthly Median Flow Through Saskatoon

Figure 6.2-20 1995 Monthly Hydrograph Current Scenario

The operation of Lake Diefenbaker will alter the monthly distribution of outflow from the distribution of inflow. The redistribution of flows is to allow for additional hydro-electric generation through the winter months and to try to keep summer flow rates through Saskatoon within the preferred range. The SSRBS recommended summer flows through Saskatoon be kept between 60 m^3/s and 150 m^3/s. Also recognized in the SSRBS was the year-round minimum flow target through Saskatoon of 42.5 m^3/s. Other objectives of redistributing the flows are to avoid spilling water from Lake Diefenbaker in order to maximize power generation from the available flow, and to reduce the risk of downstream flood damage. The maximum discharge capacity of the Coteau Creek generating station is 425 m^3/s.

The simulated distribution of monthly average flows is shown on Figure 6.2-18. The effect of Lake Diefenbaker can be seen by comparing 6.2-18 with Figure 6.2-3. Whereas inflows into Lake Diefenbaker peak in June, outflows are highest in December and January. Whereas inflows are lowest in January and February, the lowest average outflows occur in August, September and October. Figure 6.2-18 also shows that the Meridian Dam would cause reductions in average flows in each month of the year, with the greatest average reduction in October.

Figure 6.2-19 shows the monthly median flows through Saskatoon. This figure also demonstrates the effect of Lake Diefenbaker operation when compared to the median monthly inflows shown on Figure 6.2-4. Figure 6.2-19 shows that median summer flows through Saskatoon will be maintained at 60 m^3/s, the lower end of the preferred flow range. Most of the annual flow reduction due to the Meridian Dam will be made up by reduced flows during the spring months of March and April, and during the fall and into December.

In the WRM Model, as in practice, the policy is to provide summer flows of at least 60 m^3/s through Saskatoon if Lake Diefenbaker is above elevation 552.0 m. If the reservoir level falls below 552.0 m, the outflow will also be reduced. Table 6.2-3 outlines the frequency that simulated monthly average flows equaled 42.5 m^3/s. The table shows that the effect of raising the minimum drawdown at Lake Diefenbaker in response to the reduced flows to Saskatchewan is to reduce the overall frequency that flows through Saskatoon will be at the 42.5 m^3/s lower limit. In both scenarios the frequency of flows at 42.5 m^3/s decreases through the summer and in most of the low flow years the level of Lake Diefenbaker slowly rises. In the model, once the water level reaches 552.0 m, the level will be held at 552.0 m and the flow will slowly increase above

42.5 m^3/s. The zero frequencies through the fall and winter months reflect the higher flows due to hydro-electric generation even though Lake Diefenbaker may be below 552.0 m for some of those months.

Table 6.2-3 Percent of Time That Monthly Average Flows Through Saskatoon are Less than 42.5 m^3/s

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Current	0	0	0	0	16	22	13	12	10	0	0	0
Scenario 3	0	0	0	6	12	21	12	4	4	0	0	0

Table 6.2-4 gives the frequency that summer flows are below, within, or above the preferred range of 60 m^3/s to 150 m^3/s. Again, the frequency of flows less than 60 m^3/s declines through the summer for the same reason that the frequency of occurrences at 42.5 m^3/s declines as discussed above. The table also shows that the frequency of flows exceeding 150 m^3/s also declines as the summer progresses. This is because the highest inflows to Lake Diefenbaker occur in June and July and declines through August and September (see Figure 6.2-3). Similarly, in high flow years, the outflows from Lake Diefenbaker generally decline over the summer as inflows and or reservoir levels decline. As an example of a high flow year, Figure 6.2-20 shows Lake Diefenbaker inflows, outflows, and levels for 1995 under the Current Scenario. A heavy rainfall in early June in Alberta coincided with the snowmelt and resulted in a very high inflow to Lake Diefenbaker. The reservoir level rose to FSL with outflows increased to plant capacity. As inflows declined through the summer, outflows were also reduced so that by September, they were less than 150 m^3/s. The effect of storage at Meridian Dam would be to reduce peak summer inflows (see Figure 6.2-3). Hence in Scenario 3 the frequency of summer flows in excess of 150 m^3/s is lower than in the Current Scenario.

As shown in Table 6.2-4, the net effect in both scenarios of reduced frequency of flows less than 60 m^3/s and greater than 150 m^3/s over the course of the summer is the increased frequency of flows within the preferred range as the summer progresses. For the reasons discussed above, the development of Meridian Dam and adjustments to Lake Diefenbaker operation will result in summer flows through Saskatoon being more frequently in the preferred range.

Table 6.2-4 Frequency of Flows Through Saskatoon Between 60 and 150 m^3/s

Month	Jun	Jul	Aug	Sep
Percent of time that monthly average flows are less than 60 m^3/s				
Current	26	13	12	10
Scenario 3	21	18	9	9
Percent of time that monthly average flows are greater than 150 m^3/s				
Current	35	31	24	7
Scenario 3	21	21	12	6
Percent of time that monthly average flows are between 60 m^3/s and 150 m^3/s				
Current	39	56	64	83
Scenario 3	58	61	79	85

As mentioned previously, the plant discharge capacity at Coteau Creek is 425 m^3/s. In analyzing the results from the WRM Model, it was assumed that spill would be avoided if monthly average flows were below 410 m^3/s. Table 6.2-5 gives the frequency of months with flows in excess of 410 m^3/s. As expected, the development of additional storage upstream with Meridian Dam will reduce the frequency of spill events at Lake Diefenbaker and of monthly flows in excess of 410 m^3/s through Saskatoon.

Table 6.2-5 Frequency That Monthly Average Lake Diefenbaker Outflows Exceed 410 m^3/s

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Current	0	0	0	0	1	9	9	3	3	1	0	0
Scenario 3	0	0	0	6	1	7	3	1	3	1	0	0

6.2.4.2 Below Tobin Lake

SaskPower is required to maintain a daily average flow of 150 m^3/s below Tobin Lake. This requirement originated from concerns over low levels at Cumberland Lake and water supply to Cumberland House. With storage in Tobin Lake, SaskPower is able to manage flows around this requirement on a daily and weekly basis. In the rare situations when low flows out of Lake

Diefenbaker coincide with extended periods of low flows on the North Saskatchewan River, water may be required out of Lake Diefenbaker storage to augment flows into Tobin Lake and support the 150 m^3/s requirement. For this analysis it was assumed that if the monthly average flow was less than 170 m^3/s, that SaskWater would increase Diefenbaker releases to Tobin Lake. In the Current Scenario, there were four months with simulated Tobin Lake outflows less than 170 m^3/s. In Scenario 3, there were five months with simulated Tobin Lake outflows less than 170 m^3/s.

6.2.4.3 To Manitoba

Just as Alberta has an obligation to pass certain flows to Saskatchewan under the 1969 Master Agreement on Apportionment, Saskatchewan has an obligation to pass certain flows to Manitoba on the Saskatchewan River. The general principle is that Alberta must pass 50 percent of the natural flow of the North Saskatchewan, South Saskatchewan and Battle rivers. Saskatchewan is entitled to use one-half of the flow that Alberta passes to Saskatchewan, allowing the other half to pass to Manitoba. In addition, Saskatchewan is entitled to use one-half of the natural flow originating within Saskatchewan and must pass the other half on to Manitoba. Thus, on the Saskatchewan River, Manitoba is entitled to one-quarter of the natural flow of the flow arising from Alberta and one-half of the flow arising from Saskatchewan.

Estimates of monthly flow to which Manitoba is entitled have not been calculated over the entire 1928 to 1995 study period. However, since Alberta consumes no more than its share and Saskatchewan does not consume its full share of the flow from Alberta, and Saskatchewan does not consume its one-half share of flow arising within the province, it is safe to assume that the flow obligation to Manitoba is fully met under both scenarios.

6.2.5 Hydro Power Production

In Saskatchewan there are three hydroelectric power stations located downstream of the proposed Meridian Dam. The Coteau Creek generating station has an installed capacity of 186 MW and is located at Lake Diefenbaker. The Nipawin generating station is located 80 km dowstream of the confluence of the North and South Saskatchewan Rivers and has an installed capacity of 255 MW. The E.B. Campbell generating station is located immediately downstream of the Nipawin

station and has an installed capacity of 288 MW. These three stations provide, on average, a total of 2,800 GWh of electrical energy per year to the Province of Saskatchewan, or approximately 16% of demand.

Development of the Meridian Dam would result in an average annual flow reduction of 30 m^3/s. Flows from the WRMM simulations indicate that this would reduce hydroelectric energy production in Saskatchewan by approximately 250 GWh annually. This lost generation would need to be replaced by either gas-fired generation and/or imported electricity from other jurisdictions which, at a current energy replacement cost of about $50/MWh, would increase electrical generation costs in Saskatchewan by about $12.5M annually.

6.2.5.1 Manitoba

Manitoba has six hydroelectric stations which utilize the flows of the Saskatchewan River. Power production at each of these plants will be reduced by the reduction of average annual flow of 30 m^3/s due to the development of Meridian Dam and its associated water uses.

6.2.6 Saskatchewan Irrigation - General

Using the WRM model simulated flows from Alberta for Scenario 3 (3M Ac-ft and 600,000 ac irrigation), determined that summer flow in excess of 42.5 m^3/s could support approximately 37,000 ha (91,000 ac) of irrigation on a firm basis if 1928-95 can be assumed to represent future hydrologic conditions.

The most noticeable impact of Saskatchewan Irrigation out of Meridian would be reduced flows of up to 12.2 m^3/s between the boundary and Lake Diefenbaker during the irrigation season compared to simulated flows under Scenario 3. With an irrigation depth of 0.3048 m, 37,000 ha would consume 113,000 dam^3 annually. This represents an average annual flow of about 3.6 m^3/s. Adjustments can be made in Lake Diefenbaker operation to ensure that existing water uses continue to be fully met and that the flow regime through Saskatoon is no worse than under current conditions.

6.2.7 Summary

The development of Meridian Dam and associated water uses (Scenario 3) would have a number of impacts on Saskatchewan:

- Under Scenario 3, the Meridian Dam would reduce the average annual riverflow at the Alberta-Saskatchewan border by 30 m^3/s which is equivalent to 16% of the mean annual flow. Currently, Alberta passes an average of about 65% of the combined natural flows of the South Saskatchewan and Red Deer rivers to Saskatchewan. With development of the potential Meridian Dam, Alberta would pass an average of 55% of the combined natural flows as flows in the South Saskatchewan River. Including irrigation water from the reservoir allocated to Saskatchewan (roughly 13 m^3/s annual average for Scenario 3), the percentage of natural flows crossing the Alberta-Saskatchewan border would be approximately 60%.

- Potential impacts upstream of Lake Diefenbaker include effects on ferries and winter ice crossings, municipal and irrigation intakes, and river morphology, etc. The Meridian Dam would help mitigate large flow volumes from heavy rainfall events that could disrupt ferry service, but may also result in lower flow volumes associated with limitations on ferry loads. Some intakes may not function properly due to inefficiencies at the lower end of the acceptable water level range, and pumping costs may rise due to increase heads. The risk of flooding will likely be removed, however this would also affect riparian vegetation and habitat.

- The average annual inflow into Lake Diefenbaker would be reduced by 30 m^3/s (16 %) due to the Meridian Dam. In most years, the effect of the flow reductions on reservoir levels could be mitigated by adjusting the operation of the reservoir. However, levels would on average be lower over the summer months. The frequency of summer levels being above the preferred range of 554.0 m to 556.0 m would be reduced, but the frequency of summer levels being below 554.0 m would also be increased.

- Water uses supplied by Lake Diefenbaker including releases to the Qu'Appelle River, the SSRID, the SSEWS system, and municipal and irrigation projects sourced directly from the reservoir, will not be affected by the Meridian Dam due to the adjustments that can be made at Lake Diefenbaker.

- Average annual flow through Saskatoon will be reduced by 30 m^3/s, or 18% of the mean annual flow, however the adjustments that can be made at Lake Diefenbaker will improve the frequency that summer flows are within the preferred range and will reduce the frequency of high flow events through Saskatoon.

- Flow reductions downstream of the potential Meridian Dam would likely reduce hydroelectric energy production in Saskatchewan by approximately 250 GWh annually. Replacing this lost generation, at a current energy cost of about $50/MWh, would increase electrical generation costs in Saskatchewan by about $12.5M annually.

6.3 Socio-Economic Issues

This review of social and economic issues associated with the proposed Meridian Dam is based on census data, studies of other irrigation and dam projects, information available through published secondary sources, and phone interviews with key local and regional agencies. The most recent census data available for the majority off the study area dates from 1996 and is currently 5 years old. More recent data are available at the provincial economy level, as well as for the City of Medicine Hat. The following sections discuss the socio-economic profile of the region, characteristics of the area including population and land use, and the social implications of the potential Meridian Development. The identification of potential social impacts, both positive and negative, includes consideration of impacts identified by the public in the consultations held in relation to this pre-feasibility study (see Section 1.4).

6.3.1 Socio-Economic Profile of the Region

The Alberta economy has been the fastest growing provincial economy over the last 5 years. Socio-economic indicators are amongst the strongest in the country and the unemployment rate

was second lowest in Canada in 2000 (5%). The province also had the highest investment per capita over the past 5 years as well as rapid growth in the manufacturing sector (Alberta Treasury, 2001). By September 2001, unemployment had fallen to 4% and average weekly earnings were at $689.00 (Statistics Canada, 2001). The GDP of Alberta grew at an average annual rate of 3.8% between 1995 and 1999, and was worth $91 billion in 1999.

By contrast, Saskatchewan's economy is smaller. The province had a GDP of $23.9 billion in 1999 as a result of an average 3.4% annual increase from 1992 to 1999, the third highest rate in the country. Since then, however, the annual increase rate has dropped and the forecasted growth for 2001 is only 1.8% (www.gov.sk.ca). In September 2001, unemployment was slightly increased at 5.8% and average weekly earnings were $603.00 (www.statcan.ca/english/econoind/sk.htm).

Alberta and Saskatchewan economies are relatively dependent on the primary sector which contributes 21% and 21.8% to the respective provincial GDPs. Table 6.3-1 compares the economies of Alberta and Saskatchewan by sector. Compared to other provinces, both Albeta and Saskatchewan have relatively small manufacturing sectors as a percentage of GDP (9 and 6.3%) compared to other provinces. However, in 2001 shipments in Alberta's manufacturing sector were valued at $3,664 million (with chemicals and chemical products being the biggest manufacturing industry, followed by food), whereas the value of shipments from Saskatchewan's manufacturing sector was only $573 million.

Table 6.3-1 Sector Comparison (as percent of GDP)

Sector	Alberta[1]	Saskatchewan[2]	Canada[3]
Primary industries	21%	21.8	9
Communications, transportation and trade	22.3	25.6	
Manufacturing and construction	17.8	12.2	24
Finance and other services	38.9	40.6	67

[1] 1995 – 1999 averages. Source: Alberta Treasury, Office of Budget and Management, March 14, 2001.
[2] 1999, Source: www.gov.sk.ca/econdev/the_saskatchewan_economy
[3] Statistics Canada, 2000.

6.3.2 Characteristics of The Study Area

For the purposes of the socio-economic component of the study, the study area has been defined as those communities and political districts directly affected by construction of the dam and associated facilities or by the potential for irrigation.

The area along the potential reservoir and affected by irrigation potential in Alberta lies within two political divisions: Census Division 1, which includes the City of Medicine Hat and Cypress Municipal District (MD), and Special Areas #2, which lies north of CFB Suffield and south of the Red Deer River. Included in the data for Cypress MD and Special Areas #2 are the unincorporated communities of Bowmanton, Schuler, Hilda, Vale, McNeil, Altee, Bindloss, Buffalo, and Cavendish. On the Alberta side of the study area, only Medicine Hat and the village of Empress have specific census data. The entire study area in Alberta belongs to the Federal Electoral District of Medicine Hat.

In Saskatchewan, the potential irrigation blocks have been located in the Rural Municipalities (RMs) of Enterprise, Fox Valley, Deer Forks, and Happyland. The census data for these RMs include the unincorporated communities of Horsham, Linacre, Estuary, Gascoigne, Johnsborough, Liebenthal, Mendham and Westerham. Specific census data are available for the incorporated hamlets and villages of Leader, Richmound, Fox Valley and Burstall. This area belongs to the Cypress Hills Federal Electoral District.

6.3.2.1 Population and Demographic Change

The total population of the study area in 1996 was 58,150, with 11,367 (19.5%) outside of the City of Medicine Hat. Of the rural population, 8,070 resided in Alberta and 3,297 in Saskatchewan. In general the study area supports a very low population density.

As shown in Table 6.3-2, there are significant demographic differences between the Alberta and Saskatchewan populations. The Alberta communities, with the exception of the village of Empress, experienced positive rates of population growth in the inter-census period 1991 – 1996, with both Cypress MD and Medicine Hat growing at rates faster than Alberta as a whole (7.9% and 7.6%, respectively, compared to 5.9% for Alberta). Special Area #2 experienced a rate of

positive population growth (1.6%), however it was considerably lower than that of Cypress MD or Alberta as a whole.

Table 6.3-2 Population of the Study Area

AREA[1]	Population 1991	Population 1996	% Change	Area km2	1996 Population Density pers/km[2]	Potential irrigation[2] (ha)
ALBERTA:	**2,545,553**	**2,696,826**	**5.9**			
MD Cypress #1	4962	5353	7.9	13181	0.41	62,000
Bowmanton, Schuler						
Hilda, Vale, McNeil						
Special Areas 2	2490	2531	1.6	4279	0.59	58,700
Atlee, Bindloss						
Buffalo, Cavendish						
Empress	189	186	-1.6			
Medicine Hat (City)	43625	46783	7.2			
Total in Alberta Study Area excluding MH	**7641**	**8070**	**5.6**			
SASKATCHEWAN:	**988,928**	**990,237**	**0.1**			
RM Enterprise #142	299	265	-11.4	988	0.27	25,500
Horsham						
Richmound	236	203	-14.0			
RM Fox Valley #171	400	387	-3.3	1250	0.31	10,000
Fox Valley	360	359	-0.3			
Linacre						
RM Deerforks #232	258	242	-6.2	731	0.33	33,500
Estuary, Gascoigne						
Burstall	451	426	-5.5			
RM Happyland #231	457	432	-5.5	1256	0.34	60,000
Johnsborough, Mendham						
Liebenthal, Westerham						
Leader (town)	999	983	-1.6			
TOTAL AREA	54726	58150	6.3	21685	0.52	249,700
Excl. City of Medicine Hat	11101	11367	2.4			

Source: Statistics Canada, Community Profiles
[1] Bold = Incorporated; all other locations are under the jurisdiction of the respective MD/RM's.
[2] Approximate hectares only based on Scenario 3

In Saskatchewan, the study area population declined on average by 4.7%, which is considerably lower than the Province's overall slightly positive growth rate (0.1% growth).

Medicine Hat has had positive population growth for the last decade, and grew 7.2% from 1996 – 2000 when the population topped 50,000. The city has an older population than the surrounding area, with an average age of 36.9 years as compared to an average age of 31 to 32 years in rural areas. This is consistent with the reputation of Medicine Hat as a city that attracts retirees because of the climate and relative low cost of living.

6.3.2.2 Land Use

The potential Meridian development would affect a large extent of land in both southeastern Alberta and southwestern Saskatchewan. There are on the order of about 1.6 million acres of farm and ranch land in the greater region. All of this is dryland except for about 1,010 ha (2,500 ac) of irrigation in RM Deerforks and RM Happyland, and a few isolated pivots in Alberta.

Nearly 40% of the land is native pasture and about 60% is cultivated, half of which is with annual crops. Approximately 80% of the cropland is wheat or fallowed, and the remainder is perennial pasture. Other crops include canola, flax, barley and oats. Specialty crops include corn, carrots, safflower, sunflowers and beans. In addition, the Medicine Hat - Redcliff area is known as the "Greenhouse Centre of Western Canada", with 70 acres under glass in 1999. The cattle industry is also a major component of the agricultural sector around Medicine Hat, and food processing is described as one of the most important economic development opportunities in southern Alberta (ref.)

Developing between 162,000 ha (400,000 ac) and 243,000 ha (600,000 ac) of irrigation in this region would have a profound impact on the existing agricultural landscape. It would involve converting up to 1/3 of all land in the area into intensively-farmed irrigated crop production. As a result of this change it is estimated that the price of impacted land would approximately double. (see Appendix Tables VII-2 and VII-3). Additional details on economic structure and benefit-costs are provided in Section 8.3.

6.3.2.3 Economy of the Study Area

The economy of the study area is mixed, with agriculture, oil and gas, manufacturing, and the service sector all contributing to the economy. There is a clear division, however, between the rural areas and the city and urban fringe around Medicine Hat. In 1996, the City of Medicine Hat had most of its employment in the tertiary sector, with 16.6% in secondary and 8.7% in primary industry. Cypress MD, which surrounds the city, has as much employment in the service sector as in the primary sector. It also has the lowest concentration of employment in the primary sector of all the rural areas. The remainder of the study area depends heavily on employment in the primary sector, specifically both agriculture and oil and gas extraction.

The respective sector contributions to GDP are perhaps more indicative of what drives the Meridian area economy (exclusive of Medicine Hat): agriculture contributes 71% and the oil and gas contribution is 14%. All other sectors of the local economy generate only 15% of regional GDP. At the same time, personal income estimates suggest that on the Alberta side of the border average income levels are only slightly below the Alberta average. On the Saskatchewan side, per capita incomes are considerably above the Saskatchewan average. Interestingly, outside of Medicine Hat, labour participation rates also tend to be relatively high while unemployment rates are relatively low. These characteristics are not normally associated with a disadvantaged region.

The City of Medicine Hat is the principal business center for the area, and it therefore has strong retail trade activity. Natural gas was discovered there at the turn of the century, and has been an important part of the local economy since then. Medicine Hat has developed its own generation facilities, and as a consequence has attracted energy-intensive manufacturing due to low energy costs. The manufacturing sector produces tires for automobiles and heavy equipment, methanol, anhydrous ammonia and granulated urea for fertilizers, clay brick and refractories, thermal carbon black, and equipment, and also includes food processing and commercial printing.

The oil and gas industry is also active in Saskatchewan. New exploration activities are taking place in the Burstall area as well as pipeline construction. Mera Petroleum Inc. cites $5 million in investments in the Leader area in the recent past (Mera Petroleum Inc, 2001).

Diversification of the economy has also come through the presence of CFB Suffield. This training area is located 56 km north of Medicine Hat and is also used by the British Army Training Unit [BATUS]. CFB Suffield is one of the largest testing areas for advanced weapons technology and military robotics applications. The City of Medicine Hat's Economic Development Office estimates that the presence of the base contributes $80 million per year to the area's economy through payrolls in military and civilian staff, as well as local purchases of goods and services (Albertafirst Profile, 2001).

Table 6.3-3 Percent of Labour Force by Sector, 1996

AREA	Percent of Labour Force by Sector (%)		
	Primary	Secondary (Manufacturing And Construction)	Tertiary (Finance And Other Services)
ALBERTA			
Medicine Hat City	8.7	16.6	74.6
Cypress MD	42	11	47.3
Special Areas #2	61	3.4	36
SASKATCHEWAN			
Happyland RM	67	6	28
Deer Forks RM	68	0	32
Enterprise RM	79	0	21
Fox Valley RM	52	9	39

Source: Basic data from Statistics Canada, Statistical Profile:Municipal Income and Work Statistics Population Census, 1996.

As can be seen in Table 6.3-3, the primary sector is important but not dominant except in Enterprise RM. The tertiary sector is important in all of the rural areas, and the secondary sector is by far the smallest in the study area as a whole. Table 6.3-4 provides more detailed information for the study area on labor force participation, income and GDP by sector.

Construction of the Meridian Dam and the subsequent irrigation development would have a profound impact on the regional economy (including Medicine Hat). Based on experience related to previous development projects, it is estimated that short and long-term regional employment would probably climb about 3% while regional GDP would immediately jump about 10%. In the longer-term, the regional GDP would likely expand an additional 10% as irrigation development gradually takes place (ref: Special areas study). These changes are general orders of magnitude.

6.3.2.4 Agriculture Profile

There are approximately 900 farms or ranches in the surrounding Meridian area with an average size of 730 ha (1,800 ac). About 60% of the area is typically cultivated while 40% is native pasture. Farm size characteristics are provided in Table 6.3-5 and land use characteristics are shown in Table 6.3-6.

Table 6.3-4 Socio-Economic Profile of the Meridian Area, 1996

	ALBERTA			SASKATCHEWAN					Total
	20% MD Cypress #1	Medicine Hat	10% Special Area #2	RM #142 Enterprise	RM#171 Fox Valley	RM#232 Deer Forks	RM#231 Happyland	Total AREA	Area w/o Medi. Hat
POPULATION	1071	46783	253	265	387	242	432	49433	2650
LABOUR FORCE									
Agriculture[1]	224	1772	77	132	77	81	153	2514	742
Natural Resources[2]	39	313	14	23	14	14	27	444	131
Manufacturing/Construction	70	3965	5	0	15	0	15	4070	105
Trans./Commun./Utilities	48	2850	8	6	11	7	12	2943	93
Trade-Wholesale/Retail	81	4809	14	11	19	12	20	4966	157
Services[3]	141	8371	25	19	33	21	35	8644	274
Public Administration	30	1781	5	4	7	5	8	1839	58
TOTAL ALL INDUSTRIES	633	23860	148	195	175	140	270	25420	1560
GDP									
Agriculture[1]	$59,205	469361	20260	34893	20260	21386	40520	665885	196524
Natural Resources[2]	$11,296	89550	3865	6657	3865	4080	7731	127045	37495
Manufacturing/Construction	$4,346	246171	310	0	931	0	931	252690	6519
Trans./Commun./Utilities	$3,781	225193	670	506	885	569	948	232552	7359
Trade-Wholesale/Retail	$3,138	186892	556	420	735	472	787	193000	6107
Services[3]	$5,351	318731	948	716	1253	805	1342	329146	10416
Public Administration	$1,682	100188	298	225	394	253	422	103462	3274
ALL INDUSTRIES	$88,798	1636086	26909	43416	28323	27566	52682	1903779	267694
Average Income/Employee[4]	$24,622	$23,682	$25,187	$25,697	$25,139	$26,114	$27,505	$23,929	$25,014
1996 Unemployment Rate	3.1	7.7	2.0	0	0	0.0	0.0	6.7	2.4
1996 Participation Rate	81.4	66.3	79.1	100	71.4	80.6	81.8	69.0	81.1

(1) Ranching and Farming

(2) Oil and gas, mining, forestry, and fishing/trapping.

(3) Includes health, education & social services. Also includes Financial & R.E. services

(4) Alberta average = $26,138/annum; Saskatchewan average - $22,541/annum; Deer Forks average = average incomes for RM's 142, 171, and 231.

Sources: Basic data from Statistics Canada, Statistical Profile: Municipal Income and Work Statistics

Population Census, 1996

GDP estimates derived by using sector Wate/Employee and GDP/Wage Ratios from Alberta Treasury.

Table 6.3-5 Farm Size Characteristics, Meridian Area, 1996

Item	ALBERTA		SASKATCHEWAN				TOTAL AREA (acres)	TOTAL AREA (percent)
	20% MD Cypress #1	10% Special Areas #2	RM #142 Enterprise	RM#171 Fox Valley	RM#232 Deer Forks	RM#231 Happyland		
Total Area of Farms	467,116	223,252	236,502	243,789	163,711	317,081	1,651,451	
Owned	196,425	90,535	150,243	156,155	90,680	210,255	894,293	54.2
Leased	270,691	132,716	86,259	87,634	73,031	106,826	757,158	45.8
Number of Farms	209	60	120	160	95	270	914	
Average Size of Farm	2,233	3,709	1,971	1,524	1,723	1,174	1806	
Existing Irrigation[1]	14,370	1,549	N/a	n.a.	1,971	647	18,537	
Number of Farms with Irrigation	73	6	N/a	2	10	9	101	

[1] Special Areas estimate. Hanna, 2000.
Sources: AAFRD, 1996 Census of Agriculture for Alberta: I.D., M.D., and County Data, by Region, Edmonton, 1997.

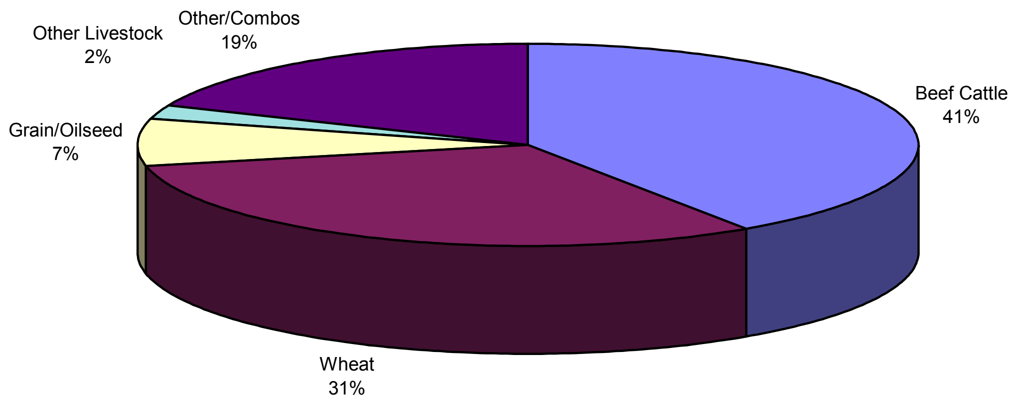
Table 6.3-6 Land Use Characteristics, Meridian Area, 1996

Item	ALBERTA		SASKATCHEWAN				TOTAL AREA (acres)	TOTAL AREA (percent)
	20% MD Cypress #1	10% Special Areas #2	RM #142 Enterprise	RM#171 Fox Valley	RM#232 Deer Forks	RM#231 Happyland		
Crops								
Wheat (total)	*48,196*	*14,352*	*96,221*	88,101	47,068	134,797	428,735	
Oats	*2,076*	*4,494*	*520*	*1,132*	*695*	*1,252*	*10,169*	
Barley	*6,023*	*3,524*	*1,790*	*4,410*	*1,247*	*3,311*	*20,305*	
Rye	*607*	*1,106*	*n.a.*	*2,415*	*6,699*	*4,285*	*15,112*	
Mixed Grain	*480*	*458*	*n.a.*	*.a.*	*n.a.*	*0*	*938*	
Alfalfa/Mixtures	*9,693*	*6,163*	*391*	*480*	*607*	*949*	*18,283*	
Other Tame Hay/Fodders	*3,494*	*2,593*	*680*	*1,862*	*472*	*812*	*9,913*	
Canola	*3,709*	*2,363*	*0*	*n.a.*	*0*	*545*	*6,617*	
Mustard	*314*	*692*	*0*	*n.a.*	*0*	*380*	*1,386*	
Dry Field Peas	*95*	*68*	*0*	*n.a.*	*n.a.*	*n.a.*	*163*	
Canary Seed	*118*	*221*	*0*	*1,420*	*n.a.*	*2,075*	*3,834*	
Triticale	*1,255*	*135*	*337*	*1,003*	*475*	*1,415*	*4,620*	
Forage Seed			*0*	*0*	*0*	*n.a.*		
All Other	*2,019*	*267*	*333*	*728*	*1,614*	*675*	*5,636*	
Crops (total)	78,081	36,432	100,272	101,551	58,877	150,496	525,709	**31.8**
Summer Fallow	31,652	15,341	88,057	74,696	45,298	124,088	379,131	**23.0**
Tame/Seeded Pasture	25,209	15,936	5,483	10,176	4,337	6,601	67,742	**4.1**
Native Pasture	318,168	152,404	36,028	52,092	41,669	29,154	629,515	**38.1**
Other Land	14,007	3,139	6,662	5,274	13,530	6,742	49,354	**3.0**
TOTAL ALL LAND	467,116	223,252	236,502	243,789	163,711	317,081	1,651,451	**100.0**

Source: Saskatchewan Agriculture & Food/Statistics Branch, **1996 Census of Agriculture,** Regina, November 2001. (Courtesy of Mr. Jason Johns. Basic data from Statistics Canada.)

As illustrated in Figure 6.3-1, wheat farms and beef cattle ranches predominate. Crop production characteristics are profiled in detail in Appendix Table VII-3. In terms of ranching, beef producers have an average herd size of about 150 head.

Figure 6.3-1 Commercial Farm Types, Meridian Area, 1996



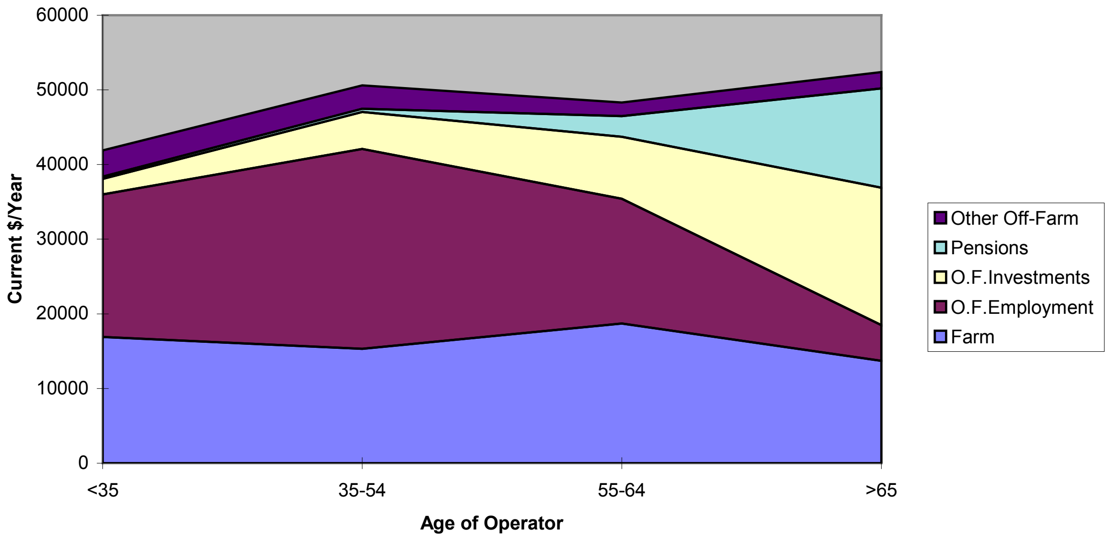
Typical capital values per farm are as follows:

Land and Buildings	$527,000
Farm Machinery/Equip.	153,000
Livestock & Poultry	45,000
TOTAL	$725,000

The total of $725,000 is about 75% of the average farm value in Alberta (AAFRD 1996).

Farm families usually have both farm and non-farm income sources. The net income from farming frequently makes up a relatively small part of that total (as shown in Figure 6.3-2). Direct impacts of the potential Meridian Dam development on the local agricultural community are analyzed in detail in Section 8.3.1.

Figure 6.3-2 Income Composition, by Age of Operator, Alberta, 1999



6.3.3 Social Assessment and Irrigation

The development of irrigation is generally associated with increased agricultural production and higher gross farm income, which in turn is spent on increased productive inputs, goods, and services. Socio-economic studies of the impacts of irrigation on prairie communities have found a correlation between the presence of irrigation and higher population density in rural areas, as well as greater population stability over time relative to dryland farming areas. Higher population density is in turn associated with better infrastructure and social services (UMA, 1988).

6.3.3.1 Dams, Irrigation and Social Change

Due to the dry and unpredictable precipitation in the area, irrigation development began early in the area known as the Palliser Triangle. A number of private irrigation initiatives were underway at the turn of the last century, with government support and financial assistance. The Provinces of Alberta and Saskatchewan gained control of their water resources in the 1930's after which irrigation expanded rapidly in Alberta, but less quickly in Saskatchewan. By 1952, Alberta had 223,000 ha (550,000 ac) under irrigation and Saskatchewan had only 23,300 ha (57,500 ac) (SSRP pg. 314).

The development of irrigation has proceeded historically with the contribution of significant public investment. The settlement of the region, and later the social and economic recovery from drought, provided for general social acceptance that public investment to support private sector agricultural production in arid lands was justified. As the population has become less rural and less dependent on agriculture economically, other changes in social and political values have also occurred such that decisions about public investment in dams and irrigation infrastructure have become politically contentious.

6.3.3.2 Adoption of Irrigation

The adoption of irrigation is an important factor in determining the benefit-cost of a potential project. A number of studies have been conducted to assess the socio-economic impacts of recently constructed dams, as well as to review the adoption of irrigation historically.

In the 1988 assessment of social impacts from the South Saskatchewan River Project (SSRP), UMA Engineering reviewed 4 studies on factors influencing adoption of irrigation by farmers in the SSRP area. A number of factors contribute to the adoption of irrigation by farmers, including economic conditions and technical factors such as initial capital cost and complexity of the technology, diversity of farming activities, and government policies (presence of subsidies for adoption, and other incentives, etc.). Additional factors include education, farming experience, family size, age of farmer, status in the community, and decision-making process within the economic enterprise. In other words, there is a complex range of factors that contribute to whether or not farmers will make the decision to adopt irrigation once it becomes available (UMA 1988).

One of the studies reviewed assessed the adoption of irrigation from the Gardner Dam in the South Saskatchewan River Irrigation District #1 (SSRID#1) for the period 1968-1985. Table 6.3 -6 shows some of the characteristics of irrigators and non-irrigators. This study concluded that the on-farm economics of production dominate farmers' decision-making regarding irrigation. There are many factors that contribute to this process, but farmers perceptions of the profitability of irrigation was the largest constraint to adoption (UMA, 1988). After construction of the Gardner Dam, adoption was relatively slow, and government subsidies were employed to increase the rate of adoption (Erickson, 2001).

Table 6.3-6 Selected Characteristics of Irrigators and Non-irrigators,SSRID #1 Sample, 1987

Characteristic	Unit	Irrigators	Non-irrigators	Test of Hypothesis of Difference
Farm Size	Acres	1,089	835	*
Rented Area	Acres	305	300	-
Gross Sales	$	85,333	42,632	**
Net Worth	$1,000	298	207	*
Assets Owned	%	60	84	-
Age	Years	41.8	52.3	**
Years Farming	Years	19.6	29.1	*
Education:				
Grade 12 Comp.	%	87	67	*
Post-Secondary	%	49	30	**

- No significant difference
* signficantly different at = 0.05
** Significantly different at = 0.01

Source: UMA Engineering Ltd. 1988.

For the potential Meridian Dam project, social and economic benefits predicted from potential irrigation should be assessed on the basis of a detailed analysis of how likely farmers in the study area will adopt irrigation.

6.3.4 Potential Positive Social Impacts

The potential direct social benefits (positive impacts) from development of the dam are of two kinds, the direct benefits from expenditure on the dam and infrastructure development, and indirect benefits from creation of the reservoir and the irrigation potential, which in turn has a number of potential indirect social impacts. Economic impacts from construction of the dam and associated facilities are temporary, while irrigation's social impacts, while not permanent, are considered to be long-term.

Construction Stage Impacts

The capital expenditure on the dam would provide significant economic stimulus, some of which will accrue to the regional and local economies. The distribution of direct and indirect (multiplier effects of increased economic flow-through) benefits from the capital expenditure will depend on the awarding of contracts and how much of the money is spent directly in the region. For construction of the Gardner Dam, less than 20% of capital expenditure on construction was spent within Saskatchewan, resulting in the majority of the economic benefits being realized outside of the project area (UMA, 1988). The greater size and diversity of the Alberta economy suggests

that Alberta at least would be able to retain a greater percentage of the capital expenditures than Saskatchewan did for the Gardner Dam construction.

Positive Impacts from the Adoption of Irrigation

In the rural areas the potential impacts from development are: increased gross incomes for farms, agricultural diversification, population stabilization, and the maintenance or improvement in quality of life as measured through access to services and infrastructure. Of the potential irrigation blocks identified, approximately half are in Alberta and the other half in Saskatchewan. The potential social impacts are close to equal between the provinces, though the rate of adoption of irrigation may differ, and it would be slightly less for Scenario 1 where the majority of irrigation potential lies in Alberta.

The entire study area, much of which is not identified for potential irrigation, had a population of only 11,400 in 1996. Based on the findings of previous studies, the development of irrigation in the area, if widely adopted, would likely improve population stability and the social well-being of small communities.

An important factor in determining the economic benefit, and therefore the positive social impacts from irrigation, however, is the capital cost incurred by farmers who do not already have irrigation. Most of the area of irrigation potential for the Meridian Dam would require significant capital investments. The area has a long history of dryland farming, in which the logic of the operation is to maintain low cost of inputs. The traditional third and fourth generation dryland farmers and ranchers are not the only population in the study area, however. The Hutterites are large users of irrigation in Saskatchewan, and there is at least one colony in Deer Forks RM. The recent expansion of Hutterite colonies into both Empress and Fox Valley RMs could potentially increase the likelihood of irrigation uptake, as they are non-traditional farmers (Bohrson, 2001).

The expansion of irrigated specialty crops, offering better economic opportunities for farmers than traditional crops, could enhance the socio-economic benefits of irrigation. Agricultural extension specialists in southwest Saskatchewan consider recent expansion of irrigated potato production (4 to 5 individual producers or consortiums) as a speciality crop to be both successful and able to expand. A limiting factor to crop innovation in the area is lack of water (Bohrson, Robertshaw, 2001). It is also important to note that in 1988 many farmers (71.2%) in the SSRID

#1 study identified the marketing of specialty crops (peas, vegetables) as an important constraint to the adoption of irrigation. Specialty crops frequently require processing before storage, or are destined to markets easily saturated, leading to price volatility (UMA 1988). Both the Outlook, SK area and Lethbridge-Medicine Hat, AB have expanded specialty crops in recent years, however, it is not known to what extent that experience is considered transferable to the study area.

6.3.5 Potential Negative Social Impacts

The discussion of potential negative impacts covers both those issues identified in this review, as well as a number of concerns raised by the public in consultations or by local contacts during interviews.

Identified Negative Impacts

A potential negative socio-economic impact is the disruption or loss of various economic activities due to creation of the reservoir. Two potentially significant disruptions are:

- A reduction in royalties or expenditures in the Medicine Hat area from closure of operating gas wells owned by AEC and other changes to their facilities and operations. The scale of these impacts and estimated financial cost is addressed in Section 6.3.
- Changed use of CFB Suffield if the flooding of the river interferes with Suffield's MOU with the UK government. A submission by CFB Suffield states that it is possible the base would no longer be used for UK training, however, a final determination of that has not been made by the base authorities.

It is not anticipated that the actual construction activities or changes to other infrastructure would result in any significant social impacts. Review of available maps of the region do not indicate a need for resettlement, however, the maps are outdated and new structures may exist. A study of the impacts of a dam in the area in 1969 identified 4 sets of farm structures at the upstream end requiring relocation (PFRA, 1969) but it is not clear whether they remain and/or require relocation for reservoir levels below 646.2 m (full supply level of Scenario 3). Until detailed land acquisition data are available it will not be possible to determine whether resettlement may result

from the impacts rendering any properties uneconomical due to the flooding, but it is considered unlikely given what is currently known about land ownership.

Additional concerns were raised in public hearings about potential negative social impacts resulting from downstream water reduction. Of particular concern was potential impact to the remaining ferries below the confluence of the South Saskatchewan and Red Deer Rivers, at Estuary, Lemsford and Lancer. Also of concern are the impacts on the Chesterfield irrigation system, the municipal water supplies of Kindersley and Eston which draw from the river, impacts on the town of Cabri if the regional park were affected, and concerns regarding the impact on the tourism and summer festivals in Saskatoon if the river flow is reduced. These concerns are addressed in Section 6.2, which assesses potential impacts on downstream flows and shows that high flows are reduced and that low flows are maintained.

The recent past history of social conflict over the development of dams (Oldman River Dam in particular) suggests that the costs of building the Meridian Dam should include the cost of social conflict as some groups are likely to oppose it.

6.3.6 Additional Studies Required

To accurately assess the likelihood of the adoption of irrigation by farmers in the study area, further work is required. This should include a detailed survey of farmers' attitudes towards irrigation, farm-level socio-economic analysis, an updated review of the economics of irrigation under current and predicted market conditions, and evaluation of the potential additional costs from government subsidies to support irrigation adoption.

7 PROJECT IMPLEMENTATION

7.1 Aboriginal Issues

The area surrounding the potential Meridian Reservoir is an open plains environment along one of the most significant transportation corridors in the region. Prior to the arrival of European explorers, traders and settlers, this area was the seasonal home of vast bison herds and of the nomadic groups whose lives focused on the movement of this prolific food source. After the arrival of the horse in the early 1700s, the mobility of these groups and their ability to intercept bison herds on their seasonal movement patterns increased significantly.

Euro-Canadian influences beginning in the later 1700s brought dramatic changes to the Native cultures of the Plains. Perhaps the most devastating of these were effects of several disease epidemics, which reduced populations in many groups by more than 50% and resulted in large scale population movement, and the decimation of the bison herds during the latter part of the nineteenth century. In addition, the economic competition for trade goods and the introduction of firearms resulted in a greater incidence of conflict. Consequently, when the earliest written records of aboriginal inhabitants of the area were made, the cultural circumstances observed were considerably different than may have been the case prehistorically.

Historic and ethnographic evidence suggests that the member groups of the original Blackfoot Confederacy (Siksika Blood and Peigan) occupied this region at approximately A.D. 1750 (Kidd 1986, Magne 1987). Anthony Henday was one of the first Europeans to meet with the Blackfoot in the autumn of 1754 near present-day Red Deer (Kidd 1986: 9) and noted their intimate ties with the plains of southern Alberta. Also present were Plains Cree, with whom the Blackfoot frequently had conflict. Other groups frequenting the region included the Assiniboine, a group of which known as the Stoney now inhabit the region west of Calgary, the Gros Ventre who are now centred in Montana, the Dakota, the Sioux, and possibly at an early time, the Hidatsa and an enigmatic group referred to as the Snake. With the extirpation of the bison, by the time Treaties were signed in 1874 (Treaty 4) and 1877 (Treaty 7; Dempsey 1988), only the Blackfoot in Alberta and the Cree and Assiniboine in Saskatchewan were considered to be locally resident Aboriginal groups.

Between 1850 and 1870 sizeable groups of Metis became a key element of the fur trade, conducting large-scale bison hunts to provide robes to meet local and national demand and to supply dried meet to provision northern trading posts. These nomadic groups moved throughout much of southern Alberta and Saskatchewan and frequented the vicinity of the potential project area.

The nearest defined aboriginal communities to the project area are the Blood, Siksika, and Peigan of the Blackfoot Confederacy in Alberta and the Cree speaking Nekaneet in Saskatchewan. An Assiniboine group, the Carry the Kettle Band, has recently made claim for Treaty Entitlement in the area, and, Metis people reside throughout the region.

7.1.1 Stakeholder Identification

To identify stakeholder groups for the potential Meridian Reservoir, a review of existing documentation on the potential Meridian Reservoir was conducted and contact was made with the Department of Aboriginal Affairs and Northern Development in Alberta, and with the Department of Intergovernmental and Aboriginal Affairs in Saskatchewan. In addition, contact was made with the Treaty Seven Tribal Council in Alberta, the Treaty Four Governance Centre in Saskatchewan and the Zone II Regional Office of the Metis Nation of Alberta Association. As a result of these consultative efforts six stakeholder groups with potential interest in the project were identified.

Blackfoot Confederacy

The three member tribes of the original Blackfoot confederacy, the Siksika, the Blood and the Peigan, were originally considered to be a single group that split into three to guard the frontiers of their territory (Grinnell 1892, Dempsy 1988). All three tribes speak a single language, have close interfamily ties and participate in membership within pan-tribal societies. At the time of the arrival of the first European traders, the Blackfoot confederacy occupied a vast area bounded on the west by the Rocky Mountains, on the north by the North Saskatchewan River, on the south by the Missouri River and on the east by the present Alberta-Saskatchewan border (Demsey 1988). Initially, home territories for each of the three groups were somewhat north of their present locations. By about 1815, the Peigan controlled hunting grounds south of the Bow River and into Montana within 200 miles of the Mountains, the Blood were situated in the Lethbridge area and

ranged south east to the Sweet Grass Hills, and the Siksika controlled the area between the Red Deer and Bow Rivers. All three groups are known to have frequented the area proposed for the Meridian Reservoir from time to time in the historic period.

After the arrival of the Northwest Mounted police in 1874, settlers began to enter the region. Recognition of the difficulties this influx posed resulted in the Blackfoot petitioning the Canadian Government to enter into Treaty negotiation. In 1877 Treaty Seven was signed by members of all three Blackfoot Bands and by the Stony and the Tsuu T'ina, who had allied themselves with the Blackfoot. The Bands selected Reserves in areas that comprised their wintering grounds, to which it was expected the bison would regularly return. However these do not reflect the traditional range of the three groups and all three branches of the Confederacy undoubtedly have interest in the Meridian Reservoir Project. Because their stated traditional lands encompass the project area each of the members of the confederacy are considered stakeholders in the consultative process.

<u>Cree</u>

Although the Plains Cree were generally considered to occupy territory north and east of that occupied by the Blackfoot Confederacy, there was considerable fluidity in prehistoric times and individual bands often clashed in the area surrounding the proposed Meridian Reservoir. The Cree are of the same Algonkian linguistic stock but speak considerably different language from Blackfoot and have quite different cultural traditions. Unlike their northern cousins, the Plains division developed a lifestyle almost completely dependent on the bison. The Cree acted as middlemen in the fur trade, selling European goods to groups more distant from Hudson Bay and buying furs for transport to British posts. Expansion from their homeland in northern Manitoba and northeastern Saskatchewan was already underway prior to European arrival but accelerated with their role in the fur trade.

Bands of Plains Cree often moved with Assiniboine groups and frequented a territory that extended from central Alberta throughout much of southern Saskatchewan. Unlike the Blackfoot, the Cree organization was relatively decentralized with bands being largely independent family-related groups unified by language and common traditions.

Perhaps one of the southwesternmost areas of their occupancy was the flanks of the Cypress Hills. When Treaty Four was signed in 1874 at Fort Qu'Appelle, one of the listed individuals under Kahkewistahaw was "Foremost Man" or Ne-can-ete, the leader of a band that was not present at the signing. When the Buffalo were gone Ne-can-ete and his people survived by hunting small game in the Cypress Hills, chopping wood, and selling horses. Another Cree/Assiniboine group that had moved to the Cypress Hills area with the demise of the bison was the Young Dog band led by Piapot. In the eyes of the Canadian government they were notorious raiders and horse thieves. Piapot signed an adhesion to Treaty Four on the condition changes be made and an economic base provided for the Cree peoples. These requests were never fulfilled, and Piapot spent the rest of his life resisting government policies and protecting his traditions (OTC 2001).

Around 1881 the Cree people were induced to go north to take reserves, but Ne-can-ete stayed even though did not receive any Treaty benefits or government assistance. Ne-can-ete died in 1897 in the Cypress Hills, without receiving a reserve (OTC 2001). In 1913, his successor, Crooked Legs, obtained a land grant near Maple Creek, but the First Nation was not paid Treaty benefits until 1975.

The Nekaneet Reserves are situated approximately 120 km south east of the proposed Meridian Reservoir development area. Given their historical presence in the area the Nekaneet First Nation are considered potential stakeholders with interest in the potential development of the Meridian Reservoir.

The Assiniboine

The Assiniboine speak a Siouxan language but are thought to have separated from the main branch of the Sioux sometime before 1640 (Denig 1988). In the mid 1700's the Assiniboine were divided into two branches the Strong Woods and the Swampy Grounds. The former is said to have been the branch that practiced a plains lifestyle, dependent on the bison. These plains Assiniboine were allied with the Cree and expanded into the area along the Saskatchewan River during the fur trade period and occupied "an uninhabited country on or near the Saskatchewan and Assiniboine Rivers" (Denig 1930:395). Although they often traveled with the Cree and a certain degree of intermarriage took place, the Assiniboine maintained their own identity.

The Reserve of the Assiniboine people is currently located in the southeastern segment of Saskatchewan approximately 100 kilometres east of Regina. This reserve status came about after Chief Cuwkencaayu signed an adhesion to Treaty Four on September 25, 1877 (Carry the Kettle 2001). Prior to this event the tribes of Cuwekencaayu and Long Lodge resided in the Cypress Hills along with other Cree tribes of Piapot and Little Pine. The Assiniboines then moved from the Cypress Hills and settled in the area around Indian Head. They relocated in 1891 to the present location after Chief Cegakin's appointment as Chief following the death of his brother Cuwkencaayu.

Due to historical ties to the Cypress Hills area, the Carry the Kettle First Nation is considered a potential stakeholder in the review process that would be instituted for further consideration of the potential Meridian Reservoir.

Metis

The core of Metis activity and settlement currently focuses along the north Saskatchewan River and in the Lakeland District. However, early evidence indicates that Metis buffalo-hunting groups were common throughout an area that is bounded by the junction of the Red Deer and South Saskatchewan Rivers in the east, both north and south of these Rivers, as far as the Cypress Hills and west toward the Bow River junction (see Magne 1987). Metis settlement in the Medicine Hat area began at least as early as 1867 when Pierre and Joseph Girard formerly of the Red River area moved to this region (Garneau 2001).

Currently, Metis Local #8 in Medicine Hat represents the Metis community of the region and people of Metis origin reside throughout the area. Because of historic ties to this region of the province and the presence of an active community, the Metis people residing in the vicinity of the potential project are considered to represent an identifiable Aboriginal stakeholder group for purposes of future consultation related to the Meridian Reservoir.

7.1.2 Status of Existing Claims

Three of the above groups have made specific application for claims with the Indian Claims Commission (ICC) of the Government of Canada as follows:

7.1.2.1 Blood Tribe/Kainaiwa [Akers Surrender 1889**,** July 1998 (ICC 2000a)]

This claim involved a clerical error that led to the surrender of 440 acres of land from the Blood Reserve in southern Alberta which, the First Nation alleged, the Government of Canada failed in its fiduciary obligation to correct.

Response: In April 1998, mid-inquiry, the Blood Tribe/Kainaiwa and the federal government agreed to enter negotiations and the claim is now in mediation with the Commission. As agreed to by both parties, the Commission is now co-ordinating several land appraisal and loss-of-use studies by independent researchers, (ICC 2000d).

This claim does not appear to have a direct bearing on issues surrounding the potential Meridian Reservoir.

7.1.2.2 Nekaneet First Nation Inquiry Report 1987 (ICC 2000b)

In February 1987, the Nekaneet First Nation submitted a specific claim to the Minister of Indian Affairs and Northern Development seeking compensation under Treaty 4 for outstanding provisions of agricultural benefits, programs and services, annual payments to band members and damages for failure to provide a reserve at the time of the Treaty's signing in 1874. In 1998 the First Nation requested the ICC to conduct an inquiry after waiting almost 10 years for Canada to respond to the claim submitted in 1987.

Response: On October 23, 1998, Canada accepted the claim for negotiation. In March 1999, the Government of Canada agreed mid-inquiry that it has an outstanding obligation under Treaty 4 to provide the First Nation with livestock, farm implements, and tools (ICC 2000e).

The Nekaneet First Nation has received funding to purchase lands and support agricultural development for its members, under the Treaty Land Entitlement process jointly administered by the Government of Canada and the Province of Saskatchewan.

This claim and its acceptance indicates the Nekaneet First Nation should be considered a stakeholder in future review conducted for the potential Meridian Reservoir. However, this claim does not appear to have a direct bearing on issues surrounding approval of the project.

7.1.2.3 Carry the Kettle First Nation Inquiry Cypress Hills Claim (ICC 2000c)

The First Nation alleges that a 340-square-mile block of land north of the Cypress Hills was established as a reserve for the Band, but that the land was then taken by the Government of Canada without following the surrender provisions of the Indian Act. Community sessions were held in May and October 1997 and in February 1988. Canada supplied additional research and the Band undertook its own research. In May 1999 oral sessions were completed in Regina and a report is now being drafted.

In addition to this enquiry, the Carry the Kettle First Nation has received a settlement under the under the Treaty Land Entitlement process jointly administered by the Government of Canada and the Province of Saskatchewan. This has enabled land purchase in the Cypress Hills, wherein twenty, one-quarter sections of land adjacent to the West Block of Cypress Hills Provincial Park has been obtained for the Band. These issues indicate that Carry the Kettle First Nation should be considered a stakeholder in the review process of future studies related to the Meridian Reservoir but neither would have a direct bearing on issues surrounding approval of the project.

7.1.3 Public Meeting Commentary

Public consultation meetings regarding the potential project were held in July and August 2001 at five locations in Alberta and Saskatchewan (see Section 1.4). No issues related to First Nations concerns or interest were raised at these meetings.

A forum was also held at the Medicine Hat College in Medicine Hat, AB, sponsored by the Society for Grassland Naturalists. At the Meridian Dam Forum a letter was presented from the Blackfoot Nation citing opposition to the Meridian Dam without prior consultation and consent. Concerns include the impacts that the potential dam would have on the surrounding ecosystem, as well as on the South Saskatchewan River itself.

7.1.4 Issues and Uncertainties

As part of this study, verbal and/or written requests for information relating to issues and concerns for the potential project were submitted to of the following First Nations and Tribal agencies:

- Treaty Seven Tribal Council
- Blood Tribal Council
- Siksika Council
- Peigan Nation Council
- Treaty Four Governance Centre
- Nekaneet First Nation
- Carry the Kettle First Nation

Upon request, information packages on the potential Meridian Development were sent to the Treaty Seven Tribal Council, the Blood Tribe, Siksika Nation, Peigan Nation and the Nekaneet First Nation. A conversation with Elsie Kootchicum, the Treaty Land Entitlement Officer for the Carry the Kettle First Nation, indicated that there was limited concern for the project in that community, given their reserve is currently located east of Regina and no members reside in their recently acquired Cypress Hills holdings. Consequently, although Carry the Kettle First Nation would like to be kept informed of the development, the impression given was that the group currently has no significant interest in the project. Conversely, Janette Hansen representing the Metis Nation of Alberta (Zone II), Medicine Hat Local #8, indicated that her group has considerable interest in the project. Although the Metis community was familiar with the reservoir proposal and did not immediately require an information package, on-going consultation would be considered appropriate.

Although interest in the potential project was indicated by the other groups receiving packages, and intentions were expressed that written commentary would be provided, to-date only one formal expression of issues or concerns has been received. This expression of interest by Chief Larry Oakes has been forwarded on behalf of the Nekaneet First Nation and the 33 Treaty Four signatory First Nations. The submission outlines the basis for these parties' interest in the project

and discusses some of the particulars of this interest. This submission has been included in its entirety as Appendix VI of this report and is summarized as follows:

> The Nekaneet and other Treaty Four First Nations formally affirm their historic rights and traditional ties to the area encompassed by the Treaty. Concern is expressed about both the upstream and downstream impacts of the project and interests are specifically outlined in relation to:
>
> - Rights to natural resources.
> - The legally enshrined requirement to consult with First Nations and to mitigate negative effects on their rights and interests.
> - A participatory role with respect to an EIA, identification and conservation of historical. spiritual, heritage and cultural sites, traditional land use studies, and contemporary use studies.
> - Sharing in the socio-economic benefits of the project.
> - Protection and application of First Nation rights in relation to the project.

Formal responses have yet be received from Alberta First Nations however, a conversation with Reg. Crowshoe of the Peigan Nation provided an indication of the general tone of the issues that might be raised in formal responses from Treaty Seven First Nations. The concerns expressed in this conversation can be summarized as follows (R. Crowshoe, pers. comm.):

- Historical resource sites represent the heritage of First Nations people.
- Certain types of historical resources such as effigies and rock art are highly significant and represent spiritual ties with the landscape.
- Sources of paint that could be used in important ceremonies may occur in the reservoir.
- Plants used as medicine may occur in this area.
- Natural and culturally significant materials that would be important for bundle renewal may be present.
- Cultural materials (e.g. eagles, etc.) that may occur in the potential development area may legitimize current oral practices that are important to the spiritual life of the community, including the transfer of rights for these practices.

- The geography of the area may be essential for legitimizing oral practices of decision making (stories, songs etc.).

These concerns relate to both the preservation of evidence of past aboriginal use of the landscape as well as to cultural practices that are unique to the First Nations cultures of the region and are vital for the on-going practice of that culture. The connection First Nations people have with the landscape, is an essential part of their identity and as these communities struggle with the changes brought about by the dominant culture, a strong sense of identify and pride in one's heritage will be important for community health. In addition, as First Nations communities move toward self governance, preservation of decision making practices, and other aspects of the oral tradition that have evolved in the context of those cultures will be important for the success of these efforts.

In a brief conversation with Janette Hansen, of Metis Local #8, Medicine Hat, it was indicated that the local Metis community strongly opposes the potential project. Issues and concerns raised included:

- Metis people have strong historic and cultural ties to the land and the environment and consider it wrong to alter it in such a drastic fashion.
- It is believed that the proposed reservoir will create a natural imbalance that will have far reaching negative environmental effects.
- The ecosystem impacts will be so severe that it would not be possible to mitigate the losses expected.
- The South Saskatchewan River valley has a rich natural and cultural heritage with which the community has close ties. It is felt that the impacts to this heritage resulting from the reservoir cannot be adequately mitigated. Ms. Hansen indicates that she has anecdotal information from local informants that human burials are present somewhere along the east valley walls.
- The Metis community currently operates an ecotourism business in partnership with the Medicine Hat Interpretive Centre that would be impossible to continue if the reservoir proceeds.
- It is felt that other alternatives should be explored to meet the water needs of the surrounding area. These might include exploitation of underground water sources and use of smaller storage basins in the region.

Some of these issues will be raised in the formal responses anticipated from other communities contacted during the consultation process. It is also anticipated that issues beyond those identified will be raised.

7.1.5 Consultation Needs

Formal identification of the issues of concern to First Nations communities in relation to the potential Meridian Reservoir project has yet to be received. This is not surprising considering the history of effort to consult with aboriginal communities regarding previous reservoir projects completed in Alberta. Consultation with aboriginal communities is a process that requires time and effort on behalf of the proponents and their agents. It must be conducted in an atmosphere of mutual respect and must be engaged in at the earliest possible opportunity. Effective consultation depends on development of good working relations and will require the direct participation of those in ultimate authority for the planning and development of the project.

The relevant aboriginal stakeholder groups have been identified above, and it is recommended that should the project proceed to more detailed planning stages, that these organizations and communities be contacted as soon as possible so that channels of communications can be established. As planning proceeds, other aboriginal communities may also indicate an interest in the project and it is recommended that consultation be extended to these communities if a desire is expressed. Consideration should also be given to the establishment of advisory committees within consulted communities to ensure a consistency of voice and effective lines of communication for members, especially for elders, who may not directly participate in community administration and may not be comfortable expressing their views in public. Within-community liaison officers or other forms of direct community participation may be appropriate. Project proponents should adopt a flexible approach and rely on the advice of the community to establish effective communication strategies that are suited to each of the individual communities.

7.2 Regulatory and Legal Issues

7.2.1 Background

The potential Meridian Dam project would be subject to both Provincial (Alberta and Saskatchewan) and Federal legislation. The following provides an initial overview of the legislation that would cover assessment, approval, and permitting associated with the project.

7.2.2 Provincial Regulations

7.2.2.1 Alberta

Environmental Protection and Enhancement Act

Alberta Environment, created in 1971, is the provincial government ministry responsible for a range of environmental legislation including the Environmental Protection and Enhancement Act (EPEA). The EPEA became law on June 26, 1992 and went into force on September 1, 1993. This Act replaces and combines previous acts into one legal framework and takes an integrated approach to the protection of air, land and water.

The EPEA establishes a legislated environmental assessment process to ensure that economic development occurs in an environmentally responsible manner with the opportunity for full public participation. There are four stages under the Environmental Assessment Process:

- Stage 1 – Initial Review
- Stage 2 – Screening
- Stage 3 – Preparation of an Environmental Assessment Report
- Stage 4 – Final Review

Certain projects such as pulp mills, oil refineries, and large dams are always subject to the environmental assessment process according to the EPEA Mandatory and Exempted Activities Regulation. Other projects, which do not meet any mandatory thresholds or that warrant further consideration, are referred to the Director responsible for environmental assessment for a decision regarding review and reporting requirements.

The Meridian Dam project would qualify as a "mandatory activity" requiring the preparation of an environmental impact assessment report (Section 3(c) and 3(e) EPEA Mandatory and Exempted Activities Regulation).

Hydro and Electric Energy Act

If hydroelectric power generation were included as a component of the Meridian development then the Hydro and Electric Energy Act would apply. The Hydro and Electric Energy Act (HEA*)* is administered under the Alberta Energy and Utilities Board (EUB). The Meridian project would fall under Section 7 of HEA because the project is a new stand-alone facility that is not appended to an existing structure (e.g., an irrigation dam). The HEA was initially intended to ensure that new hydroelectric projects were given adequate review and consideration by the Alberta Legislature by requiring a bill be passed in the legislature before a new hydroelectric project could proceed. The Meridian project may require acceptance of a bill in the legislature in order for the project to be built. There is, however, provision in the HEA (paragraph 3(1)(b)) for the EUB to pass a regulation which would exempt the project from Section 7.

Because the project is reviewable by Alberta Environment, it meets the threshold for review by the Alberta Natural Resources Conservation Board (NRCB). It is likely that the NRCB will review the project jointly with the EUB.

Water Act

Alberta's Water Act came into force on January 1, 1999. Under the Water Act, the Minister of Environment must establish a framework for water management planning and a strategy for the protection of the aquatic environment. Part 6 of the Water Act deals with dam and canal safety, which would apply to the project.

Other Legislation

There are numerous other pieces of legislation and legal requirement that would be pertinent to the potential Meridian Dam project. These include the following:

- Wildlife Act
- Wilderness Areas, Ecological Reserves, and Natural Areas Act

- Historical Resources Act
- Natural Resources Conservation Board Act
- Expropriations Act

7.2.2.2 Saskatchewan

Environmental Assessment Act

The Environmental Assessment Act is of primary importance in terms of development of water and resources within the Province of Saskatchewan. It outlines the powers and duties of the Minister when a development which may substantially alter the environment is being planned or proposed. While the Meridian Dam project may be subject to a variety of other legislation, the Environmental Assessment Act provides the basis for provincial review and decision making.

Definitions of pollution and contamination are broader in the Environmental Assessment Act than in the Environmental Management and Protection Act, and highlight the Environmental Assessment Branch's broader scope of interests.

The legislation widely defines development as any project, operation, activity, or alteration or expansion of a project, operation or activity, which is likely to:

- Have an effect on any unique, rare or endangered feature of the environment;
- Substantially utilize any provincial resource and in so doing pre-empt the use, or potential use, of that resource for any other purpose;
- Cause the emission of any pollutants or create by-products, residue or waste products which require handling and disposal in a manner that is not regulated by any other Act or regulation;
- Cause widespread public concern because of potential environmental changes;
- Involve a new technology that is concerned with resource utilization and that may induce significant environmental change, or;
- Have a significant impact on the environment or necessitate a further development, which is likely to have a significant impact on the environment.

Notwithstanding any other Act, regulation or by-law, a proponent must obtain ministerial approval before proceeding with any development. The conditions pursuant to this legislation

prevail where a conflict exists between a condition of any other license, permit, approval, etc., granted under any other Act, regulation or by-law and a condition of ministerial approval.

Other Legislation and Regulations

- Water Corporation Act
- Irrigation Act, 1996
- Reservoir Development Regulations

7.2.3 Federal Regulations

Department of the Environment Act

The Department of the Environment Act (1970) (DOE Act) provides Environment Canada with general responsibility for environmental management and protection within the federal government. Its obligations extend to and include all matters over which Parliament has jurisdiction, and have not by law been assigned to any other department, board, or agency of the Government of Canada related to:

- Preservation and enhancement of the quality of the natural environment (e.g., water, air, soil);
- Renewable resources including migratory birds and other non-domestic flora and fauna;
- Water;
- Meteorology;
- Coordination of policies and programs respecting preservation and enhancement of the quality of the natural environment.

The DOE Act also states the Environment Canada has a mandated responsibility to advise heads of federal departments, boards and agencies on matters pertaining to the preservation and enhancement of the quality of the natural environment and to make environmental information available to all Canadians. This responsibility is also reinforced as per subsection 12(3) of the Canadian Environmental Assessment Act (CEAA), which states that federal departments must

provide specialist and expert information or knowledge to other federal departments or review panels.

Canadian Environmental Assessment Act

The government of Canada enacted the Canadian Environmental Assessment Act (CEAA), which establishes a process to assess the environmental effects of projects requiring federal action or decisions. Under CEAA, projects receive an appropriate degree of assessment depending on the scale and complexity of the likely effects of the project. Consequently, there are four types of environmental assessment: screening, comprehensive study, mediation, and panel review. A project is referred to a panel for review only when it may cause significant adverse environmental effects or public concerns warrant it.

The Meridian Dam project is expected to trigger a review under CEAA since it will require a permit under the Navigable Water Protection Act and an authorization under the Fisheries Act. The size of the reservoir requires that a Comprehensive Study level assessment be prepared.

Canada Water Act

The Canada Water Act enables Environment Canada to enter into agreements with other jurisdictions and to carry out research and surveys regarding water quantity and quality issues. This also enables Environment Canada to support the implementation of the Federal Water Policy (1987) and Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines.

Navigable Waters Protection Act

The potential Meridian project would require permitting under Section 5(1) of the Navigable Waters Protection Act (NWPA).

Fisheries Act and Migratory Birds Convention Act

Should the Meridian Dam project proceed, the statutory or regulatory provisions of the Fisheries Act and the Migratory Birds Convention Act would be binding on the proponent. These include the pollution prevention and control provisions of the Fisheries Act, which are administered by Environment Canada on behalf of the Minister of Fisheries and Oceans. The provisions prohibit

the deposition of deleterious substances into waters frequented by fish (Section 36). The project would require authorization under Section 32 and/or 36 of the Fisheries Act. As well, the migratory Birds Convention Act and Regulations deal with the protection of migratory birds and the conservation of their habitat, under Sections 6 and 35 of the regulations of the Migratory Birds Convention Act.

Species at Risk Act

This Act is currently before the standing committee.

7.2.4 Joint Provincial/Federal Review

The Department of Fisheries and Oceans Canada (DFO) would likely be the federal Responsible Authority for the Meridian Dam project. However, the province of Alberta would probably take the lead role in the project review, which would proceed in the spirit of the Canada-Alberta Agreement for Environmental Assessment Cooperation (June 1999). This agreement is intended to streamline communications and information sharing between the two governments and provides a framework to coordinate the provincial AEPEA and the federal CEAA processes. The Agreement thereby promotes effective, efficient, consistent and cooperative environmental assessment by the governments of Canada and Alberta, including the avoidance of uncertainty and duplication.

7.2.5 Federal and Provincial Programs

South Saskatchewan River Basin Study

The South Saskatchewan River Basin Study (SSRBS) was a scientific study program initiated in 1980 to establish a sound water management plan for the basin. The SSRBS was directed by a multi-stakeholder Study Board. At the conclusion of the program, the Study Board put forward a number of recommendations to guide the management of the natural resources in the basin. Some of the data generated through the research conducted for the SSRBS were used by the Project Team for this assessment.

Kyoto Protocol

The Kyoto Protocol may be applicable in relation to the way the project may assist in reducing greenhouse gas emissions. Hydropower production does not produce greenhouse gases, as do power plants that burn fossil fuels.

7.2.6 Permits, Licenses and Miscellaneous Agreements

In order to construct and operate the Meridian Dam project, a number of permits, licenses and agreements would be required. Aside from those approvals discussed in previous sections, the following list identifies additional approvals that may be required:

- EUB Approval for a Power Generation Plant under the HEA;
- EUB Approval for development of a power line;
- Land and lease holder agreements;
- Water license Permit to withdraw or use water in a stream;
- Energization Certificate is required from ESBI (transmission administrator);
- Power Pool notification of a New Plant is required;
- Agreement required to tie into ATCO Power's line; and
- Municipal District Development Permits to build structures (buildings) and roads, and remove timber.

7.3 Environmental Impact Assessment

7.3.1 Background

The following section outlines the key elements of the EIA process for the potential Meridian Dam project. Given the likelihood of a joint Federal-Provincial review, a variety of regulatory requirements would need to be addressed as part of both the issues identification and the scope of work related to the EIA (see Section 7.2). Guidelines for conducting the EIA are suggested. These follow a multi-stakeholder input protocol and thus permits cross-referencing of regulatory compliance and key issues raised during the public consultation process. An issue scoping exercise is discussed as part of the EIA process along with the identification of the general scope of work (including spatial and temporal boundaries). A preliminary cost estimate is provided to

conduct the EIA, as well as approximate costs likely to be associated with suggested mitigation measures.

7.3.2 EIA Process Guidelines

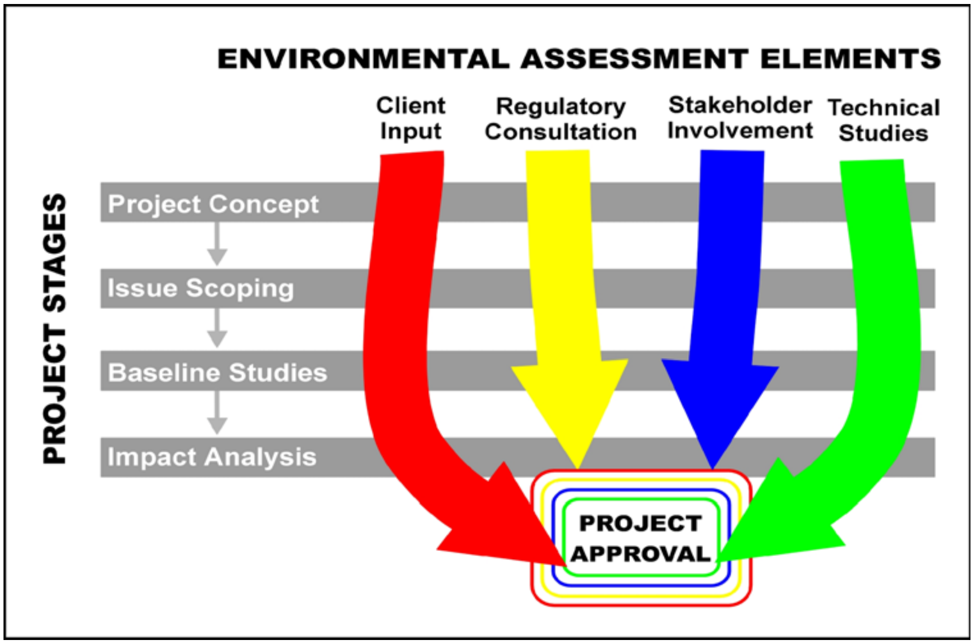
If the potential Meridian Dam project proceeds to further phases of investigation, the associated environmental impact assessment would involve a process that integrates consultation, technical assessment, and documentation. This environmental assessment should incorporate a balanced approach involving:

- input from the project proponent;
- consultation with regulatory agencies;
- consultation with stakeholders; and
- consideration of technical requirements for the assessment.

The following tasks would form the EIA Process for the Meridian Dam:

- Develop a clear framework for the steps of the Meridian Dam EIA that identifies the linkages between the engineering/design team, regulators, environmental specialists and stakeholders throughout the project planning process (Figure 7.3-1).
- Design and conduct a public consultation program that provides information about the environmental aspects of the project, provides opportunities for meaningful stakeholder involvement in the project planning and implementation, and ensures that stakeholder concerns are communicated to the project team for consideration in the EIA.
- Review existing environmental baseline information (i.e., air, surface water quality, fisheries, terrain and soils, vegetation and wildlife) to assess the suitability of the data to support an impact analysis and EIA submission.
- If required, conduct additional baseline surveys and literature reviews to ensure an adequate information base for the EIA and mitigation planning.

Figure 7.3-1 Environmental Assessment Elements



- Work with legal/regulatory advisors and regulatory agencies to ensure that environmental requirements for permitting are understood and a define terms of reference for the EIA. This will guide the submission of a scientifically credible EIA that is consistent with legislative requirements.
- Ensure that the engineering/design teams and environmental specialists communicate at appropriate stages of the design process to ensure that the project design responds to environmental concerns, and that the proposed environmental impact mitigations make sense from an engineering perspective.
- Develop an EIA methodology that responds to regulatory requirements.
- Conduct a preliminary assessment of the project's likely environmental impacts.
- Formulate mitigation concepts in consultation with environmental and engineering/design teams to determine suitable design, construction, or operational practices that could reduce impacts.
- Develop mitigation plans as components of the final project design and operating plans that will form the basis of the EIA submission.
- Apply an EIA methodology and prepare quality reports suitable for regulatory review.
- Participate at regulatory hearings.

7.3.3 Preliminary EIA Cost Estimate

Key data gaps for each of the environmental components were identified in Section 5 of this report. Cost estimates to complete required studies and the EIA investigations were also provided. The overall cost estimate for completing an EIA for the potential Meridian Dam is roughly $5-8 million based on the major components as discussed below.

To enable a thorough impact assessment to be completed for fisheries issues, the following information would be required: basic information on the fish fauna and their habitat in this region of the South Saskatchewn River, and possibly the lower reach of the Red Deer River; information on the physical and chemical environments that would exist in the reservoir; and a multi-discipline instream flow needs study of the South Saskatchewan River, from the dam site possibly as far downstream as Lake Diefenbaker. The estimate to complete such studies is approximately $2.0 to $2.5 million.

The main data gaps and EIA tasks related to native grasslands and protected areas issues included: complete issue scoping and literature review, biophysical field programs and mapping, and analysis of impacts. Costs estimates for these studies are approximately $1.0 million.

Recognizing the level of wildlife biodiversity in the region, the nature of the habitat, and the high number of listed and sensitive species that would require study and consideration in the impact assessment and mitigation process, the cost for wildlife studies would be considerable. The final cost would also depend on the value ecological components (VECs) that were ultimately selected. It is estimated that the cost of determining the VECs (including public participation), collecting, processing and evaluating habitat data, and completing the environmental impact assessment and mitigation planning could be in the range of $1 million to $2 million.

A Historical Resources Impact Assessment (HRIA) would also be required for the Meridian Dam project. The final cost of such an assessment is highly dependent on the number and quality of sites encountered during the studies. It is expected that an HRIA would cost on the order of $1 to $2 million.

Other EIA costs include, among others, hydrologic and water quality modelling, detailed hydrogeologic investigations, and an assessment of air quality impacts.

7.3.4 Preliminary Mitigation Cost Estimate

The environmental components associated with the potential Meridian Dam were discussed in Section 5 of this report. Significant mitigation measures included: fish habitat compensation, allowances for fish passage, a multi-level outlet for releases from the dam, purchase of native grassland, wildlife habitat compensation, wildlife habitat enhancement or creation, avoidance of historical resources, and recovery and interpretation of historical resources, etc.

Estimates of mitigation costs associated with each of the components were provided based on experience and on information available from other large reservoir projects in southern Alberta. Due to the lack of detailed information related specifically to the Meridian project, particularly with respect to historical resources, it is not possible to provide a highly accurate estimate of potential mitigation costs. The summary of mitigation costs shown in Table 7.3-1 is intended to provide an indication of the order of magnitude investment that may be required should the Meridian Dam be developed.

Table 7.3-1 Summary of Estimated Mitigation Costs ($ million)

Component	Mitigation
Fisheries[1]	16-22
Protected Areas[2]	See wildlife
Native Grasslands[2]	See wildlife
Wildlife	10-15
Water Quality[3]	As for fisheries
Historical Resources	5-15
Total	31-52

[1] Fisheries mitigation includes $8-12 million for fisheries compensation and approximately $8-10 million for inclusion of a multi-level outlet for the dam.
[2] Protected areas and native grassland mitigation are included in wildlife mitigation costs.
[3] Water quality mitigation includes a multi-level dam outlet as for fisheries mitigation.

7.4 Project Review and Approval

As noted in Section 7.2.2.1, an application to construct and operate the Meridian dam project will have to be submitted to both the Alberta Energy and Utilities Board and the Natural Resources Conservation Board. Both Boards have jurisdiction and would be required to determine whether

the project is in the public interest, having regard to environmental, social and economic effects, and would be responsible for identifying appropriate terms and conditions if the project is approved. Based on recent experience with the proposed Dunvegan Hydroelectric Project, the Boards would conduct a joint review of the project using a panel that consists of representatives from both Boards.

Since an approval would also be required from DFO and a public review may be required under CEAA, a joint federal-provincial review process might also occur. A joint review is also consistent with the Canada-Alberta Agreement for Environmental Assessment Cooperation (June 1999) and has been employed in reviewing two previous water management projects in Alberta, the Pine Coulee Project and the Little Bow Project/Highwood Diversion Plan. In the case of joint reviews, the panel makes a decision on matters of provincial jurisdiction but only makes recommendations to the Federal Government.

A joint review process could take six to 12 months to complete, depending on the number of issues raised by interveners and the adequacy of the application. This process will have a number of cost implications. First, the applications to the Boards will require more than just the EIA since the Boards must consider the public interest and may require additional information on social and economic impacts. Furthermore, the EUB will require information on how the proposed hydroelectric facility will be linked into the provincial grid, including and environmental assessment of any proposed transmission lines.

Second, since the review process requires that all interveners be given access to the application and all supporting documents, printing costs can be substantial. It is likely that the Boards would require full sets of information be made available in all major communities in the region, typically in municipal government offices or libraries, and the CEAA would likely establish a Federal registry in one community. The applicants are also expected to pay the costs of all public notices.

Third, the Boards will likely hold a pre-hearing conference to allow interveners to learn more about the project and to identify the key issues that need to be addressed at the hearing. There is the possibility that evidence at the pre-hearing conference may identify some deficiencies in the

application that can only be addressed by additional studies, and this can result in some costs as well as a delay in the review process.

Fourth, intervener funding is available from the NRCB, the EUB and CEAA, although the amounts, purposes and sources of funding are slightly different. CEAA typically offers federal support in a predetermined amount to interveners to cover their costs to participate in the hearings. The NRCB and EUB accept and review requests for intervener funding, to be paid by the applicant, and will decide the amounts based on the merits of the request. In some cases where there is uncertainty on some key issues, intervener funding awards can be considerable (over $400 thousand for the Little Bow project).

Fifth, the hearings themselves can result in considerable costs since the technical experts must attend to present evidence and be examined by the interveners. Prior experience at the Pine Coulee review, which took nine days of hearings, and the Little Bow Project, which took 19 days, suggests that the hearings can be quite lengthy depending on the number of interveners and the number of issues. Given the magnitude of the Meridian dam project and the geographical distribution of its effects, it is reasonable to expect that hearings could last from 20 to 30 days.

At this time, one unknown in the project review process is the role of the Government of Saskatchewan. Typically, a joint federal-provincial review process would consider evidence from other parties (such as in the Province of Saskatchewan), so the Government of Saskatchewan would be able to participate as an intervener, submitting evidence and participating in cross-examination of other parties. However, downstream impacts might be better addressed in the decision making process if a joint Canada/Alberta/Saskatchewan review panel were to be established. While there is no precedent for this type of arrangement, there does not appear to be any restrictions which would prevent this from occurring. This area of uncertainty will have to be addressed at a political level if the development of an application for the Meridian Dam is to proceed.

8 ECONOMIC ANALYSIS

8.1 Methodology

8.1.1 Evaluation Criteria

A discounted cash flow analysis compares quantifiable projected benefits with quantifiable projected costs into the foreseeable future. This "benefit-cost" analysis determines if a proposed investment would or would not use financial resources efficiently.

Four criteria are utilized to gauge how (socially) profitable a proposed investment would be. These criteria are described in Table 8.1-1.

Table 8.1-1 Criteria for Evaluating a Proposed Investment

CRITERIA	DESCRIPTION
1. Benefit-Cost Ratio (B/C Ratio)	The ratio of cumulative discounted benefits to cumulative discounted costs over a given time period for a particular interest rate. No units. Measures efficiency ("bang for the buck") but not scale.
2. Net Present Value (NPV) of Incremental Socio-Economic Benefits	Cumulative discounted benefits minus cumulative discounted costs over a given time period for a particular interest rate. Measures the incremental cumulative absolute dollar value over time. Probably the best economic measure when selecting between Investment A and Investment B if both opportunities have a B/C ratio > 1.
3. Internal Rate of Return (IRR)	That interest (i.e. discount) rate where the cumulative discounted benefits are exactly equal to the cumulative discounted costs over a given time period. Preferred by some agencies (e.g. World Bank) because it avoids pre-determining what the most appropriate social discount (i.e. interest) rate should be. However, this still requires establishing a minimum acceptable rate of return.
4. Pay-back Period	The number of years required to recover the capital and on-going discounted cost of a proposed investment.

To be considered economically feasible, the B/C ratio must be greater than one, the NPV must be positive, the IRR must exceed a prescribed minimum annual rate-of-return, and the pay-back period should not exceed a maximum number of years (approximated by 70/interest rate, e.g. at 5% $\Rightarrow$ 14 years). For a single investment proposal, all of these criteria generally provide the economic analyst with the same policy prescription, i.e. go or no-go.

Table 8.1-2 presents a simple example based on an interest rate of 5%.

Table 8.1-2 Example of Criteria Evaluation

Year	Incremental Costs $		Incremental Benefits $		Interest Rate
	Actual	Discounted	Actual	Discounted	5% over 5 yrs.
1	100	95.2	0	0	.9524
2	10	9.1	50	45.4	.9070
3	10	8.6	75	64.8	.8638
4	10	8.2	100	82.3	.8227
5	10	7.8	125	97.9	.7835
Sum		128.9		290.4	
Benefit-Cost Ratio					290.4/128.9= **2.25**
Net Present Value					290.4-128.9 = **$161.5**
Internal Rate of Return					**46%**
Pay-Back Period					**3.0 years**

Discounting future cash flows allows us to compare options on the same basis (i.e.,"apples to apples"). This is necessary as the value of a dollar paid or received today is not the same as a dollar paid or received in five years.

These are all efficiency criteria which entirely ignore equity considerations**.** The rationale for this is that if NPV>0 and B/C>1, then it should always be possible for those who gain from the implementation of a particular investment to compensate those who lose (if, indeed, there are losers). At the same time, this simple calculation does not consider (without further refinements) the possibility that a dollar may be worth more to a relatively poor community than to a relatively wealthy community.

Additionally, it should be emphasized that a provincial benefit-cost analysis is not the same as a regional impact analysis. A regional impact analysis fully considers both the direct and indirect impact of all regional activities generated by a proposed project on the local economy.

8.1.2 Price Levels and Inflation

All costs and prices are presented in terms of current 2001 dollars. The validity of this procedure presumes that future **relative** price levels will remain the same, e.g. one bushel of wheat will

purchase 8 litres of gasoline. This is considered more reliable than speculating about future inflation rates and future technological change.

Various price indices are attached as Appendix Table VII-1. The Canadian Non-Residential Building Construction Index is considered the most appropriate single index for updating previously estimated project costs.

8.1.3 Social Discount Rate

The real social discount rate chosen as the base rate in this appraisal is 5 percent per annum. This approximately reflects long-term annual interest rates minus typical long-term annual rates of inflation. Public investments in Alberta are usually evaluated on this basis. Effects of variations in social discount rates are provided in sensitivity tests shown in Section 8.4.3.

8.1.4 Economic Life of Project

The significant economic life of a project is the time required such that more than 90 percent of the cumulative present value of the benefits and costs are fully considered. The benefit-cost analysis presented in the following sections utilizes a 44 year time-frame, including a 4-year construction period.

8.2 Project Cost Summary[5]

The basic construction costs for the proposed Meridian Dam would include: the earth-filled dam, diversion tunnels, and spillway; and accompanying hydropower installation costs. Related costs would include all other costs in the proposed reservoir area associated with existing recreational opportunities, historical resources, disruption of existing oil and gas production, relocation/remediation of existing infrastructure (roads, power lines, pipelines, water supply systems, and existing recreation facilities), as well as some costs associated with required land purchases. For any irrigation benefits to actually be realized, there would also be very substantial capital and annual operating costs associated with both off-farm ("system") water delivery facilities and on-farm irrigation works.

The three potential development scenarios considered are summarized in Table 8.2-1. Scenario 3 is considered the base case scenario.

Table 8.2-1 Reservoir Scenarios Evaluated

Modelling Scenario	Reservoir Storage Volume		Potential Irrigable Area	
	billion m^3	million ac-ft	hectares	acres
Scenario 1	1.2	1.0	162,000	400,000
Scenario 2	2.4	2.0	202,000	500,000
Scenario 3	3.7	3.0	243,000	600,000

8.2.1 Dam & Outlet Structures

Estimated costs of the earth-filled dam include those associated with the embankment, accompanying earth works, cofferdam construction costs, and Highway #41 realignment approach cuts. This capital cost of between $86 million and $221 million, depending on the scenario, is dependent upon reservoir size. At the same time, the projected capital cost of the accompanying diversion tunnels, spillway structure, excavation, rip-rap, and control building is fairly independent of reservoir size and is projected to range from $719 million to $687 million. The total projected capital costs of the dam and outlet structures, including a 35% contingency, and 20% for engineering costs are summarized in Table 8.2-2 (also Table 3.2-3 and Table 3.3-4).

Table 8.2-2 Summary of Dam & Outlet Structures Costs

Scenario	Dam Embankment	Diversion Tunnels	Spillway	TOTAL
1	$92 M	$376 M	$344 M	$812 M
2	$151 M	$376 M	$323 M	$850 M
3	$237 M	$376 M	$312 M	$925 M

To conduct the economic analysis, it is assumed that the dam and outlet structures would take four years to construct. Subsequent annual operation and maintenance costs (including seepage monitoring) are expected to amount to about 0.5 percent of the initial capital costs per annum. This amounts to between $4.1 and $4.6 million per annum. Additional details are provided in Section 3.2.5.

[5] Costs are negative benefits and vice-versa. There is, however, some professional judgment involved in what is considered a cost and what is considered a benefit. This has some effect on the size of the B/C ratio but no effect on other efficiency criteria.

8.2.2 Hydropower Installation

An installed hydropower station capacity of 80 MW consisting of four turbine units is envisioned for all three scenarios. As shown in Table 3.4-1, this would have the potential to produce between 284 and 359 GWh/year depending on the amount of irrigation. The estimated total cost for the hydropower installation including engineering costs is $101,000,000 in 2001 dollars.

It is expected that hydropower would be constructed concurrently with the dam in Years 1 to 4. Thereafter, annual operation and maintenance costs are expected to be largely independent of both the development scenario chosen or the amount of electricity generated by each scenario. This is estimated to amount to $2.2 million per year in 2001 dollars which is equivalent to about 2.2% of initial capital costs/annum.

8.2.3 Irrigation Water Delivery System

The primary irrigation water delivery system involves two large electric pump stations located on the reservoir. They would provide effective water delivery to all potential irrigation blocks irrespective of reservoir water levels. Pumping is necessary because potential reservoir levels would be far lower than ground levels at the potential irrigated areas. The two main pumps/stations would have to be installed when the dam was under construction and would probably cost between $136 million and $201 million as shown in Table 8.2-3 (also Table 3.5-6).

Table 8.2-3 Summary of Irrigation Pump Station Costs

Scenario	Pump 1	Pump 2	Total
1	$49 M	$87 M	$136 M
2	$49 M	$120 M	$169 M
3	$49 M	$152 M	$201 M

Estimated energy costs, as well as estimated annual operating and maintenance costs are a function of the number of hectares of irrigation that are developed. These are incorporated into associated booster pump costs.

From the main distribution points, water would be conveyed to the respective blocks using both water supply pipelines (likely buried steel) and gravity, lined canals. This is required because of the adverse (hilly) topography near the river valley. The estimated capital cost of these booster pumps/stations, pipelines, and canals (including engineering costs) is summarized in Table 8.2-4 (also Table 3.5-6).

Table 8.2-4 Summary of Irrigation Capital Costs

Scenario	Capital Cost of Pumps, Booster Stations, Pipelines, & Canals	Average Cost per Hectare	Average Cost per Acre
1	$980 M	$6,052	$2,450
2	$1,353 M	$6,684	$2,706
3	$1,748 M	$7,196	$2,913

The corresponding annual operating and maintenance costs for this system (including primary pumping costs) are shown in Table 8.2-5 in 2001 dollars.

Table 8.2-5 Summary of Annual Irrigation Costs

Scenario	Energy Consumption (kW-hr)	Annual Pumping Costs @ .05/kW-hr	Operating & Maintenance Costs/Yr.	Total Primary System O&M per Annum
Total Cost:				
1	294.2 M	$14.7 M	$5.4 M	$20.1 M
2	301.4 M	$15.1 M	$7.4 M	$22.5 M
3	344.9 M	$17.2 M	$9.4 M	$26.6 M
Average/Hectare[1]:				
1	1,817(736)	$91($37)	$33($14)	$124($50)
2	1,489(603)	$74($30)	$36($15)	$111($45)
3	1,420(575)	$71($29)	$39($16)	$110($45)

1 Corresponding per acre estimates indicated in brackets.

Electricity costs are equated to the unit value of electrical sales generated by the proposed hydroelectric facility (see benefits Section 8.3). This is the opportunity cost of the electricity to society, regardless of any possible preferential electrical energy pricing policies for irrigation.

8.2.4 Distribution Within Irrigation Blocks

Within each proposed irrigation block, secondary distribution systems are also required to get the water to the edge of the farmers' field. These cost estimates are shown in Table 8.2-6 (also Table 3.6-2).

Table 8.2-6 Summary of Costs for Distribution within Irrigation Blocks

Scenario	Capital Costs	Operating & Maintenance Costs/Yr.
Total Cost:		
1	$660 M	$3.3 M
2	$817 M	$4.1 M
3	$933 M	$4.7 M
Average/Hectare[1]:		
1	$4,076 ($1,650)	$20 ($8)
2	$4,036 ($1,634)	$20 ($8)
3	$3,841 ($1,555)	$20 ($8)

[1] Per-acre costs indicated in brackets.

8.2.5 On-Farm Development Costs

On-farm irrigation costs include the purchase and annual operation of a pivot or similar system, access to three-phase power, and rural road access.

The preferred irrigation system is most likely to be a ¼ section electrically-operated low-pressure pivot which irrigates 132 acres per unit. These pivots cost about $85,800 per unit installed, as discussed in Section 3.6.2. Purchased by the farmer in the year additional irrigation is developed, these cumulative capital costs would probably be in the range of $260 M to $390 M as indicated in Table 8.2-7. Costs associated with replacing pivots are dealt with as a depreciable item in farm budgets (see Table VII-2).

Table 8.2-7 On-Farm Development Costs

Modelling Scenario	Potential Irrigable Area		Total Capital Cost
	hectares	acres	(cumulative)
Scenario 1	162,000	400,000	$260 M
Scenario 2	202,000	500,000	$325 M
Scenario 3	243,000	600,000	$390 M

Based on an electricity cost of $.05/kW-h, the corresponding annual operating and maintenance cost is estimated to amount to about $77/hectare (or $31/acre). These costs are incorporated in the annual crop budgets estimated in Section 8.2.6 following.

The installation of required power lines and a more extensive road network are related costs which will have to be borne by either the farmer or the public. The cumulative capital cost of this infrastructure at project maturity are shown in Table 8.2-8.

Table 8.2-8 Powerline and Rural Roads Costs

Scenario	3-Phase Power Lines (cumulative)		Rural Roads (cumulative)	
	Kilometres[1]	Total Cost[2]	Kilometres[1]	Total Cost[2]
1	1,288 (800)	$24 M	1,932 (1,200)	$68 M
2	1,610 (1,000)	$30 M	2,415 (1,500)	$85 M
3	1,932 (1,200)	$36 M	2,899 (1,800)	$102 M

*Miles indicated in brackets.
[2] Based on estimated unit costs of $30,000/mile and $60,000/mile for power and roads, respectively.

This translates into about $150/hectare ($60/acre) for the electrical grid and about $420/hectare ($170/acre) for a more extensive rural road network. The economic analysis (Section 8.4) assumes that these expenditures would parallel irrigation pivot installation.

8.2.6 Irrigated Crop Production

Annual irrigated crop budgets indicate the annual costs of production which would be incurred for farm inputs (seed, chemicals, fertilizer, etc.). The estimates include the related annual O&M costs for on-farm irrigation. The incremental annual production costs are equal to the estimated irrigated crop production costs/hectare, less the current dryland production costs/hectare. To obtain a representative average, the respective crops are weighed by their relative importance in actual and project cropping patterns.

Detailed estimates are provided in Appendix Tables VII-2 and VII-3 and indicate an annual incremental cost-of-production as follows:

Irrigation	$615.45/hectare ($249.17/acre)
Dryland	$163.71/hectare ($66.28/acre)
Difference	$451.74/hectare ($182.89/acre)

Extrapolating constant costs (in 2001 dollars) into the future is only valid if it can be assumed that **relative** costs and prices will remained unchanged (e.g. 1 bushel of wheat = 8 litres of gasoline) or that compensating technological change will negate the net affect on profitability of any relative price changes which might arise.

8.2.7 Land Acquisition

Irrespective of land ownership, there are real land costs associated with the proposed development which have not been incorporated into any of the above calculations, e.g. dam construction or infrastructure re-location. These costs include those associated with the reservoir area and set-back, reservoir clearing, and right-of-ways for pipelines, canals, and relocated roads (see Section 3.7).

The total land area required[6] is about 13,500 ha, 19,700 ha, and 24,600 ha for Scenarios 1 to 3, respectively, and the accompanying cost estimates in 2001 dollars are $16.9 M, $24.6 M, and $30.7 M (see Section 3.7).

8.2.8 Flood Control Costs

No incremental costs have been estimated for this cost category.

8.2.9 Recreational Costs

Existing recreation on the South Saskatchewan River in the proposed reservoir area is largely canoeing, boating and some fishing along the rivers length. There is also significant use of Sandy Point Park, an overnight GOA campground along Highway #41 just upstream of the proposed dam. Because of its unique natural physiological and biological features, the area also has considerable potential for future low-density eco-tourism development which may be restricted by reservoir development.

Sandy Point Park would have to be re-located. This Government of Alberta overnight campground has parking stalls, shelters, toilets, and related infrastructure. Excluding the acquisition of other land, it is estimated that moving Sandy Point Park would cost $200,000.

The loss of actual and potential eco-tourism could be more significant. For example, Medicine Hat Metis Local #8, in partnership with the Medicine Hat Interpretive Centre, currently operates

[6] Excludes any land required for rural roads and powerlines to service the respective irrigation blocks.

an eco-toursim business (i.e. river tours) along this reach of the river. From a commercial perspective, this may be worth $100,000 per year with the expectation that it will steadily grow at a rate of perhaps 5 percent per annum.

8.2.10 Environmental Costs

Initial environmental impact assessments are estimated to cost about $6.5 million. These would be pre-project costs but for analytical simplicity they are assumed to arise in project years 1 and 2.

Associated environmental mitigation costs are expected with regard to fisheries, wildlife, and historical resources, among others. The precise cost of the mitigation required to meet the policy of no net loss to the productive capacity of fish habitat is not known. Requirements might include fish ladders, capture-and-haul procedures, and/or a multi-port outlet at the dam site to enable the release of waters from various levels within the reservoir. The multi-level dam outlet is expected to cost about $9 million and, based on the Oldman River Dam experience, it is expected that related fishery costs (including some water quality issues) could well double this basic cost.[7] The economic analysis assumes that most of these expenditures would be required during Years 1 to 9.

The total wildlife cost is also estimated to be about $12 million, mostly for securing other habitat. Again, it is expected that this will be incurred in approximately equal increments throughout project Years 1 to 9.

In addition, there are significant palaeontology concerns regarding this potential reservoir site. Based on experience with the Oldman River Resevoir development, it is estimated that historical resource (HR) mitigation could cost on the order of $10 M; about $2.5 M per year during project Years 1 to 4.

Summary:	Years 1-2	$3.25 M/year for EIA studies
	Years 1-9	$2.1 M/year for fisheries mitigation

[7] Up to 1995, the cost of mitigating the effects of the Oldman River Dam on fish habitat was approximately $5.5 million.

Years 1-9 $1.3 M/year for wildlife mitigation

Years 1-4 $2.5 M/year for HR mitigation

Cumulative total over 9 years: $47 million

8.2.11 Infrastucture

Infrastructure costs include road and utility re-location and oil and gas-related costs.

a) Roads and Utilities

<u>Roads</u>

The major road impacted by the proposed reservoir is Highway #41. About 10 km of road and a modern bridge across the South Saskatchewan would be inundated. Relocation of Highway #41 would involve re-building about 34 km of highway so that it crosses the crest of the dam.

<u>Power Lines</u>

One major power line would have to be re-aligned.

<u>Water Supply Facilities</u>

Three major gas plants just south of the proposed dam site (Pan Canadian, Conoco, and BP), as well as the town of Burstall, presently draw their water directly from the South Saskatchewan. With a reservoir, pumps and inlet facilities would have to be re-located to the reservoir perimeter and water quality might also be negatively impacted. Existing water gauging stations in the proposed reservoir area would also have to be re-located.

Summary

The total capital cost of road and utility re-location is estimated at $40 million for each of the scenarios. The economic analysis assumes that these costs would all be incurred during the initial four-year construction period.

b) Gas & Oil Facilities

Related oil and gas infrastructure costs fall into three major categories: oil and gas well reclamation, pipeline reclamation/retrofitting, and the cumulative cost of completely abandoning a large number of oil and gas wells in and around the proposed reservoir area.

Oil and Gas Well Reclamation

There are approximately 250 wells in the reservoir flooded zone, and an additional 1,000 wells alongside the reservoir in a buffer area that might be at risk due to reservoir development. All submerged wells would have to be reclaimed, and many others in the buffer may be shut down and remediated according to provincial standards. During development years 1 to 4, this would cost an estimated $35.4 M, $56 M, and $77 M for Scenarios 1,2, and 3, respectively.

Pipeline Reclamation/Retrofitting

There is a pump station at Nishamoto Falls, and three major pipelines crossing the South Saskatchewan River. This and related infrastructure would have to be reclaimed and retrofitted during development years 1 to 4 at a projected total cost of $50.5 M, $80 M, and $110 M for Scenarios 1,2, and 3, respectively.

Oil and Gas Reserves

Access to relatively large oil and gas reserves would also be restricted. Over a 20 year period, the total value of these reserves in 2001 dollars is estimated to be $354 M, $566 M, and $770 M for Scenarios 1, 2, and 3, respectively. This translates (in 2001 dollars) into about $17.7 M/year, $28.3 M/year, and $38.5 M/year for development years 1 to 20.

e) Other Infrastructure and CFB Suffield

Some facilities at the (Suffield) Canada Defense Research Establishment about 80 km upstream of the proposed dam site would also be inundated. Situated on some 2000 hectares of the Drowningford flats, these facilities include bunkers, powerlines, and pipelines. In addition, there are a reported seven farmsteads which would also have to be set back from the proposed reservoir. These costs are incorporated into the above estimates.

Non-quantified costs at this point include potential loss of revenue if development of the Meridian dam jeopardizes a contract with the British Army Training unit, and costs associated with clean-up or inundation of unexploded ordinance.

8.2.12 Downstream Hydropower Impacts

As discussed in Section 6.2.5, development of the Meridian Dam would result in lost hydropower production in Saskatchewan of approximately 250 GWh annually. This equates to an annual energy replacement cost of $12.5 million based on $50/MWh.

8.3 Project Benefit Summary[8]

The major benefits of the Meridian Dam would come from irrigated crop development and hydroelectric power generation. Additional benefits might come from dowstream flood control and enhanced high-density recreation in the vicinity of the reservoir. An improved water management capability (especially regarding inter-provincial apportionment) is also cited as a benefit to Alberta (see Section 4.1).

Projected benefits are based on the reservoir size, for Scenarios 1, 2, and 3, same as for projected costs (Section 8.2).

[8] Benefits are negative costs and vice-versa. There is, however, some professional judgment involved in what is considered a cost and what is considered a benefit. This has some affect on the size of the B/C ratio but no affect on other efficiency criteria.

8.3.1 Irrigation Benefits

The potential incremental benefits of irrigation depend upon a large number of variables, particularly: a) irrigation adoption rates; b) irrigation cropping patterns; c) irrigated crop yields; d) relative costs of production and product prices; and e) existing land use patterns.

a) Irrigation Adoption Rates

Irrigation development will be demand-driven and will largely depend upon the initiative of local farmers. Adoption rates are, therefore, highly dependent upon the following: (i) product prices and relative costs-of-production; (ii) social-structural attributes; (iii) product markets; (iv) capacity to invest; (v) and an irrigation "culture". A brief synopsis follows:[9]

- In recent years, crop product prices have generally remained stagnant or, in real terms, have actually fallen. Beef prices have remained more buoyant. At the same time, real costs of production (fuel, fertilizer, machinery, etc.) have continued to climb. This gives rise to "cost-price squeeze" whereby the net return per unit of output continues to decline. Loss of the preferential "Crow" freight rate, subsidized international competition, and the governments' decision to no longer try to neutralize these impacts have generated a growing discontent in the traditional export-based agricultural community.
- The average dryland farm in the Meridian area is 1651 acres in size, about 2/3 of which is cultivated and 1/3 is pasture. Every year, a typical farmer would have about a section (640 acres) of wheat. Most cultivated land is either summerfallowed every second year or every third year. For the 2001 crop year (an extremely dry year), a section of wheat produced as little as 4000 bushels equivalent to about 6 bushels per acre. The average age of farmers is 49 years and he/she is now often considering "getting out" rather than expanding. Pessimism about the future of traditional agricultural production in the agricultural community is increasingly pervasive.
- Product markets are relatively distant and transportation costs tend to be relatively high. Grain is now generally hauled to Medicine Hat, Brooks, or Bassano by tractor

[9] Most of these characteristics are discussed in detail in: MAA, **Agri-Business Management Program Review,** AFC, Nisku, May 2001.

trailers due to elevator consolidation and rail line abandonment. Livestock is generally sold at Brooks or High River (world-class processing facilities). All potential specialty crop processing is equally remote, (e.g. potato processing in the Taber-Lethbridge area). In general, there is a growing sense of isolation in the Meridian area.

- The annual re-investment potential of existing farmers (for irrigation equipment, etc.) is limited. The average total capital value of existing farms is about $650,000 (Section 6.3.2) and the present return on this investment is only perhaps 2% per annum. This equates to only $13,000 per annum. Four centre pivots (for a section) would cost about $343,000 which is about 50% of the entire capital base. Even farmers with larger forms, would probably only purchase a single quarter-section pivot every 2 to 4 years. The increased operating credit requirements (and accompanying risk) could also be a constraint.
- Experience and "know-how" with irrigation in the area is limited. There are only about 2500 acres of existing irrigation on the Saskatchewan side (RM's Deer Forks and Happyland) and most Alberta irrigation is located more than 100 kilometres west. An older (generally risk-averse) dryland farmer may not wish to become an irrigation farmer. Irrigation requires new management skills and new production-marketing skills.

Based on an average farm size of 730 ha (1,800 acres)(Table 6.3-5), the number of farms that could potentially be irrigated ranges from 220 to 330 for Scenarios 1 to 3, respectively. With increased irrigation potential, it is also possible that the number of farmers in the area would increase. Development rates for the Lake Diefenbaker Development Area (LLDA) may be indicative of what might occur in the Meridian area[10]. Although 465,000 acres (188,000 ha) are available for potential irrigation development, this level of development has never been realized. Even with relatively large financial incentives and aggressive technical support services, the entire Lake Diefenbaker Development has only climbed to about 100,000 irrigated acres during the 33 year period from 1968 to 2001. Construction work on West Side canals and distribution

[10] References include: Linsley, J. L., **Irrigation in Saskatchewan (draft)**, Outlook, 2001; SWC, **History of South Sask. River Irrigation Project,** Outlook, July 1987; SWC, **A Look at Lake Diefenbaker,** Moose Jaw, 1998; SWC, **Irrigation Statistics for Saskatchewan (1997)**, Moose Jaw, 1997; and ICDC, **Irrigation Economics and Agronomics, Saskatchewan, 2000,** Outlook, 2001.

works (to service 55,000 more acres) was stopped by the provincial government in 1973. The history of the LDDA suggests a 100-year development trajectory.

The irrigation development rate which would actually be realized in the Meridian area is highly speculative. It could track a traditional S-shaped adoption curve, a curvilinear trajectory which gradually plateaus, or a more linear incremental process. For simplicity, the economic analysis assumes that the irrigated acreage will climb by 15,000 acres (6,073 hectares) per year until project maturity, about 114 pivots per year. This is based on water delivery to the farm gate at little or no cost to the farmer. The implied durations to project maturity (after the construction period) are, therefore:

Scenario 1	400,000 acres	26.7 years
Scenario 2	500,000 acres	33.3 years
Scenario 3	600,000 acres	40 years

b) Irrigated Cropping Patterns

Another important variable is the crop mix under irrigation. The expected cropping pattern is based on three existing developments: Eastern Irrigation District, Ross Creek Irrigation District, and the LDDA. Largely based on the physical and socio-economic similarity of the EID to the Meridian area, a crop mix similar to that of the Eastern Irrigation District is considered most likely, at least on the Alberta side. On the Saskatchewan side, a crop mix similar to that of the LDDA is more likely to evolve. It is therefore expected that a crop mix similar to that shown in Table 8.3-1 would emerge. This crop mix is the mix assumed in the irrigated crop enterprise simulations (Appendix Table VII-2).

Table 8.3-1 Crop Mix for Meridian Area

Crop	Eastern Irrigation District	Lake Diefenbaker Dev. Area	Meridian Prediction
Cereals	26%	47%	40%
Barley Silage	6%		5%
Other Forage[1]	53%	26%	30%
Oilseeds	5%	11%	10%
Specialty Crops[2]	10%	16%	15%
TOTAL	100%	100%	100%

[*]Includes tame pasture.
[2] Primarily alfalfa/grass seed, pulses, sugar beets, horticulture, and herbs/spices.

c) Irrigated Crop Yields

The irrigated crop yields which will actually be realized in the Meridian area are also difficult to project into the future with a high degree of confidence. Considerations include: (i) irrigable land quality and the potential for salinity accumulations; (ii) production technologies employed; (iii) financial-managerial capabilities; (iv) potential for water supply failures.

The average yield estimates employed in the economic analysis reflect actual on-going farm-level irrigated crop yields in Southern Alberta and the LDDA: (/acre)

CPS Wheat	85 bushels
Barley Silage	12 tonnes
Alfalfa/Hay	3.5 tonnes
Canola	50 bushels
Dry Beans	2100 pounds

These yields do not reflect research-station potential. The potential for future yield increases is also ignored because there is a presumption that, net economic margins will remain constant, (i.e. real costs will also increase proportionately).

It is also expected that the irrigation production technologies employed will mirror those already employed in Southern Alberta and the Outlook area. This does not consider the possibility that there may be an initial learning curve for those farmers who adopt irrigation water management.

Implicitly, it is also assumed that there are no on-farm financial constraints which would result in reduced input use.

The possibility of having an irrigation water supply system failure is similarly discounted because this would not become a real possibility until irrigation development was well-advanced (or nearly complete) and because this probability is fairly low even 25 to 40 years into the future.

d) Product Prices

Product prices are subject to considerable variability and are therefore averaged over the 1990's. At this level of analysis, no adjustments have been made for tax or subsidy price distortions. Product prices are also assumed to be the same for both irrigated crops and dryland crops. All of these estimates are incorporated into the irrigated and dryland crop enterprise analyses summarized in accompanying Appendix Tables VII-2 and VII-3.

Extrapolating constant prices into the future is only valid if it can be assumed that relative costs and prices will remained unchanged (e.g. 1 bushel of wheat = 8 litres of gasoline) or that compensating technological change will negate the net affect on profitability of any relative price changes which might arise.

e) Existing Land Use Patterns

Existing dry land use in the Meridian area is generally either low productivity cereal production or low productivity cow-calf production. Approximately a third of all land is cropped every year while about a quarter of all land is fallowed. Over 40% of all land is pasture land, largely native pasture. Additional details are provided in Section 6.3.

In terms of cultivated land (the land which would potentially be irrigated), the breakdown assumed for the economic analysis is as follows:

Spring Wheat	32%
Durum Wheat	12%
Barley/Other	5%

Canola/Other	1%
Alfalfa/Other	10%
Summerfallow	40%
Total	100%

Yields for these particular crops (based on 10-year averages for Special Areas.#2) are (/acre):

Spring Wheat	27 bushels
Durum Wheat	27 bushels
Barley/Other	40 bushels
Canola/Other	19 bushels
Alfalfa/Other	1.2 tonnes

On this basis, a crop enterprise analysis was conducted to determine the average gross margin per hectare per year that might be expected from this composition of dryland agriculture. These calculations are provided in Appendix Table VII-3.

f) Summary of Incremental Gross Revenue

For ease of calculation, revenue estimates are calculated as a weighted average of the actual or expected crop mix on a per-acre (or per-hectare) basis. These estimates for both irrigated and dryland crop production are provided in Appendix Tables VII-2 and VII-3,respectively, and indicate the following:

Irrigation	$856.69/hectare ($346.84/acre)
Dryland	$176.36/hectare ($71.40/acre)
Difference	$680.33/hectare ($275.44/acre)

The projected annual incremental gross revenue in 2001 dollars to the entire irrigation development is then determined by multiplying the per-acre incremental revenue projection by the projected total annual irrigated acreage.

8.3.2 Water Management

Potential benefits of improved water management have not been incorporated into the basic economic analysis.

8.3.3 Hydropower

A complimentary hydroelectric power development would use all of the water not utilized by irrigation. Thus, as the proposed irrigation development matures, the amount of electricity which can be generated is expected to gradually decline. Consistent with the respective irrigation develop scenarios envisioned (Section 8.3.1), these stable generation levels would be established in Years 31, Year 37, and Year 44 for Scenarios 1, 2 and 3, respectively. On the basis of the energy modeling results and an expected 80 MW plant capacity for all three reservoir sizes (Tables 3.4-1 and 3.4-2), hydropower revenue projections can be made as shown in Table 8.3-2.

Table 8.3-2 Estimated Hydropower Revenue

Year	Scenario 1		Scenario 2		Scenario 3	
	Energy (GWh)	Annual Value	Energy (GWh)	Annual Value	Energy (GWh)	Annual Value
Year 5	315	$15.8 M	371	$18.6 M	494	$24.7 M
Year 31	284	$14.2 M	332	$16.6 M	404	$20.0 M
Year 37	284	$14.2 M	323	$16.1 M	384	$19.2 M
Year 44	284	$14.2 M	323	$16.1 M	359	$17.9 M

The estimated market value of this energy is $50/MWh in 2001 dollars for the duration of the project.[11] The gradual inter-year hydropower contraction can be linearly interpolated because the competing irrigation water demand is also expected to expand linearly (Section 8.3.1). This ignores subtle non-linear changes in capacity utilization factors over time.

8.3.4 Flood Control

Periodic flood damage under current conditions (mostly in Saskatchewan) is estimated at $226,200 for a 1:500 flood event. The proposed dam eliminates the potential for downstream

flooding under 1:500 year conditions, which translates into an average annual flood damage benefit of about $22,600. Details of this analysis are provided in Section 4.4.

8.3.5 Recreation

Despite various biophysical/operational limitations (including an expected average seasonal drawdown of about 10 m), there is considerable recreational potential at the proposed Meridian reservoir. This could include the following (see also Section 4.5.3):

- Public day-use facilities including picnic sites, beaches, and boat launches
- Hunting and fishing activity
- Canoing, boating, and sail boarding
- Hiking
- Historic/cultural interpretation centres
- Overnight camping

Reservoirs can be important potential recreation sites in southeast Alberta and southwest Saskatchewan because there are so few natural standing water bodies in the region. Directly comparable alternatives generally only exist outside the region in Montana, the foothills region, and northern Alberta. At the same time, aside from nearby Medicine Hat (population of 50,000), the Meridian area is relatively remote with respect to the more populated centres of Alberta.

Recreational development at Lake Diefenbaker is at least suggestive of what might evolve at the Meridian Dam. Since 1960, three provincial parks have been developed along the banks of Lake Diefenbaker (Danielson, Douglas, and Saskatchewan Landing) and as a result, it now has numerous boat launches, cottages, and beaches. Artificial water bodies in southern Alberta are estimated to be augmenting recreational user-days in the region by about 1 million user-days per year.[12] The time and money that is saved by not having to travel to a similar more distant recreation site represents a net benefit to users.

[11] $50/MWh = $.05/KWh. This price is the same as the assumed cost to farmers.
[12] McNaughton, R. B., **Irrigation Impact Study: Recreation,** Vol. 3, UMA/AIPA, Lethbridge, 1993, Table 4.8.

On this basis, during Years 5 to 14 it might be possible for the Meridian reservoir to eventually generate an additional 500,000 user-days of recreation in the area. The net benefit of this level of recreation development would be approximately as follows:[13]

- Approximate User Days/Year = 500,000 (Yr. 14)
- Average Value/Trip/Person = $4.00
- Site Recreational Benefit = $2 million/year

At this point, eventual use-levels are highly speculative, however the above numbers serve to establish an order-of-magnitude benefit, (e.g. in the order of 10% of hydroelectric benefits).

8.3.6 Other Potential Benefits

Other potential benefits include: “green” hydropower, reduced crop risk, enhanced stockwater availability, enhanced agricultural value-added through additional livestock production, improved domestic and municipal water supplies, and a regional growth stimulus.

a) Environmental Benefits associated with “Green” Hydropower

It is possible that hydropower produced at this facility would be considered “green” energy. If this is so, power could potentially be sold at $70/MWh instead of at $50/MWh, and this would represent an additional net benefit of a$20/MWh. For the purposes of this study, this is assumed to be an environmental benefit valued at roughly $7.2 million annually for Scenario 3 at full irrigation development. Table 8.3-3 shows potential environmental benefits associated with “green” hydropower for the three scenarios.

[13] Unit values assumed to be about twice the value (to reflect twice the distance) calculated in: Planning Division/Alberta Environment, **Little Bow Project/Highwood Diversion Plan: Impacts on Recreation**, Appendix O, in: **Environmental Impact Assessment: Proposed Little Bow Project/Highwood Diversion Plan, Vol. 9,** Alberta Public Works/Supply and Services, Edmonton, 1995.

Table 8.3-3 Estimated Environmental Benefit due to "Green" Hydropower

Year	Scenario 1		Scenario 2		Scenario 3	
	Energy (GWh)	Annual Value	Energy (GWh)	Annual Value	Energy (GWh)	Annual Value
Year 5	315	$6.3 M	371	$7.4 M	494	$9.9 M
Year 31	284	$5.7 M	332	$6.6 M	404	$8.1 M
Year 37	284	$5.7 M	323	$6.5 M	384	$7.7 M
Year 44	284	$5.7 M	323	$6.5 M	359	$7.2 M

b) Reduced Crop Risk

Without widespread irrigation, the Meridian area will remain a relatively high risk farming area. AAFRD estimates that the risk of not covering all costs on dryland operations in central and southern Alberta is in the vicinity of 10 to 30 percent.[14] In approximately one in five years, production drops to about half of its long-term average and this is magnified in terms of farm cash income. Estimates indicate that instead of making an average $30/cultivated acre/year, every 5th year this drops to $15/cultivated acre (calculated from Appendix Table VII-3). For livestock producers, periodic droughts also dictate hauling supplementary feed into the Meridian area and this is yet another cost which could be circumvented with irrigation. This risk has been incorporated into the economic analysis in two ways: i) inclusion of 40% summerfallow in the cropping pattern; and ii) inclusion of Crop Insurance premiums in crop costs-of-production (see Appendix Table VII-3).

c) Enhanced Stockwater Availability

The Meridian Dam would also provide a more secure source of water for domestic and stockwatering purposes for landholders along the various irrigation system conveyance routes, as well as to areas near the respective irrigation blocks and the reservoir itself.

In the Meridian area there are presently about 700,000 acres (283,000 ha.) of pasture land (Table 6.3-5) and perhaps 1,000 dugouts.[15] With inadequate water supplies, these dugouts very often

[14] Farm Business Management Branch/Crop Insurance Review, as reported in **SAWSP Project Rationale,** Edmonton, December 1992, p. 19.

[15] Based on prior research in the Special Areas. Approximately one dugout per section.

require seasonal re-filling at an estimated cost of $750 per dugout.[16] Thus, the Meridian proposal could generate an additional annual cost-saving for livestock producers of, say $375,000/year (i.e., ½ Re-fills X 1000 X $750). This would begin in Year 5.

d) Additional Livestock Value-Added

The benefits of irrigation to agriculture are underestimated if only the incremental value of the additional crop production is considered. Feed grain, barley silage, and alfalfa/hay production is often fed to complimentary on-farm livestock operations. This allows farmers to generate additional on-farm income (value-added) from their primary crop production.

This approximate incremental benefit is given in Table 8.3-3 (see calculations in Appendix Tables VII-2 and VII-3). It is expected that this additional benefit would parallel the irrigation benefit projections.

Table 8.3-3 Additional Livesotck Value-Added Benefits[1]

Farm Type	Margin/Irrigated Acre	Margin/Dryland Acre	Difference
With Livestock	$106.48	$7.50	$98.98
W/o Livestock	$ 97.67	$6.12	$91.55
Margin Change			$7.43/acre ($18.35/ha.)

[1] 20% of gross margin for forage and feed grains.

e) Improved Domestic and Municipal Water Supplies

Drinking water is at a premium in the Meridian area. However, nearby communities generally seem to have ample, reliable municipal water systems. No acute problems have been reported and it is generally considered that most potable water shortages are now restricted to outlying farms and ranches. The Meridian Dam would probably facilitate some additional improvements but the overall monetary value of this additional benefit would be relatively small.

[16] Detailed calculations provided in: MAA, **Socio-Economic Impacts of the Proposed Special Areas Water Supply Project,** Special Areas Board, Hanna, August 2000, p. 25.

f) Regional Growth Stimulus

For most human activity, water is a prerequisite. Thus, the Meridian Dam would undoubtedly provide the impetus for some entirely new economic activities in the region. An underlying assumption of the economic analysis, however, is that this activity would not represent a net GDP increase to the province(s). It would simply represent a re-location of this activity. Regional impacts (as opposed to provincial benefits) are briefly addressed in Section 6.

8.4 Economic Assessment

A discounted cash flow analysis was conducted for each of the three potential development scenarios. The methodology for this analysis is detailed in Section 8.1, and estimated costs and projected benefits are quantified in Sections 8.2 and 8.3, respectively.

The basic economic assessment for the potential Meridian development is provided in the following section. Sensitivity tests to bracket these results are reported in Section 8.4.2, followed by a brief analysis of two related issues: the Alberta - Saskatchewan breakdown of benefits and costs (Section 8.4.3), and a hydropower only scenario (Section 8.4.4).

8.4.1 Base Case Scenarios

The economic analysis from Year 1 through Year 44 is shown in Table 8.4-1. A summary of the estimated benefit-cost ratios and their corresponding net present values (both calculated by employing a 5% discount rate) is provided in Table 8.4-2.

To be economically feasible, the B/C ratio would need to be at least 1.0 and the NPV would have to be positive. Neither criteria is met. Given the annually projected benefit and cost streams for each of the three potential development scenarios, from a provincial perspective and over a 44 year period, real costs would be about three times as large as projected real economic benefits. The cost and benefit streams for Scenario 3 are shown in Figure 8.4-1, and the relative importance of the various benefit and cost components is illustrated in Figures 8.4-2 and 8.4-3.

The internal rate-of-return cannot be calculated because there are no positive numbers in the annual incremental net B/C stream. Similarly, no re-payment period can be calculated. This implies that it is unlikely any of these development options would be economical.

Table 8.4-1 Economic Analysis for Years 1 through 44 – Scenarios 1, 2, and 3

YEAR	SCENARIO 1 (1M ac.ft.)			SCENARIO 2 (2M ac.ft.)			SCENARIO 3 (3M ac.ft.)		
	Benefits	Costs	Difference	Benefits	Costs	Difference	Benefits	Costs	Difference
Column No.	3	4	5	7	8	9	10	11	12
1	0	337775	-337775	0	376350	-376350	0	442150	-442150
2	0	320680	-320680	0	351555	-351555	0	411255	-411255
3	0	317435	-317435	0	348310	-348310	0	408010	-408010
4	0	378968	-378968	0	413440	-413440	0	475066	-475066
5	26892	118355	-91463	30812	132663	-101850	39422	145157	-105735
6	31254	121980	-90727	35152	136209	-101057	43625	148697	-105073
7	35615	125606	-89991	39491	139755	-100264	47827	152238	-104411
8	39976	129232	-89256	43831	143302	-99471	52029	155779	-103750
9	44337	132858	-88521	48170	146849	-98679	56231	159320	-103089
10	48698	133084	-84387	52510	146997	-94487	60433	159461	-99028
11	53059	136711	-83653	56849	150545	-93695	64636	163003	-98368
12	57420	140339	-82919	61189	154093	-92904	68838	166545	-97708
13	61781	143966	-82186	65528	157642	-92114	73040	170088	-97048
14	66142	147594	-81453	69868	161191	-91323	77242	173631	-96389
15	70303	151223	-80920	74007	164741	-90733	81244	177174	-95930
16	74464	154852	-80388	78147	168291	-90144	85246	180718	-95472
17	78625	158481	-79857	82286	171841	-89555	89249	184263	-95014
18	82786	162111	-79326	86426	175392	-88966	93251	187808	-94557
19	86947	165742	-78795	90565	178944	-88379	97253	191353	-94101
20	91108	169373	-78265	94705	182496	-87791	101255	194900	-93644
21	95269	155305	-60036	98844	157749	-58905	105257	159946	-54689
22	99430	158937	-59507	102984	161302	-58318	109259	163494	-54234
23	103591	162570	-58980	107123	164856	-57733	113262	167042	-53780
24	107752	166204	-58452	111263	168411	-57148	117264	170590	-53327
25	111913	169839	-57926	115402	171967	-56564	121266	174140	-52874
26	116074	173474	-57400	119542	175523	-55981	125268	177690	-52422
27	120235	177110	-56875	123681	179080	-55399	129270	181241	-51971
28	124396	180747	-56351	127821	182638	-54817	133272	184793	-51520
29	128557	184385	-55828	131960	186197	-54237	137275	188345	-51071
30	132718	167514	-34796	136100	189756	-53657	141277	191899	-50622
31	135464	124527	10937	140239	193317	-53078	145279	195454	-50175
32	135464	115746	19718	144378	196879	-52500	149281	199009	-49728
33	135464	115768	19696	148518	200442	-51924	153283	202566	-49283
34	135464	115792	19672	152657	204006	-51348	157286	206124	-48839
35	135464	115817	19647	156797	207571	-50774	161288	209683	-48396
36	135464	115843	19621	160936	211137	-50201	165290	213244	-47954
37	135464	115871	19593	165076	165929	-853	169292	216805	-47513
38	135464	115900	19564	166141	140608	25533	173294	220368	-47074
39	135464	115930	19534	166141	137324	28817	177296	223933	-46636
40	135464	115962	19502	166141	137356	28785	181299	227499	-46200
41	135464	115996	19468	166141	137389	28752	185301	231066	-45766
42	135464	116031	19433	166141	137425	28717	189303	234636	-45333
43	135464	116068	19396	166141	137462	28680	193305	238207	-44902
44	135464	116107	19357	166141	137500	28641	197307	174730	22578
ACTUAL $	3985834	6973812	-2987978	4415847	8082428	-3666581	4761594	9199121	-4437526
Discounted@5%	1126929	3202878	-2075949	1221914	3584672	-2362757	$1,331,504	4012118	-2680614
BENEFIT-COST RATIO			0.35			0.34			0.33
NET PRESENT VALUE ($'000)			-$ 2,075,949			-$ 2,362,757			-$ 2,680,614
INTERNAL RATE OF RETURN			-10%			-13%			#DIV/0!
PAY-BACK PERIOD			N/A			N/A			N/A

Table 8.4-2 Summary of Base Case B/C Ratios and Net Present Values

Scenario	Benefit-Cost Ratio	Net Present Value
1	.35	-$2.1 billion
2	.34	-$2.4 billion
3	.33	-$2.7 billion

The gross benefits of irrigation make up about 70% of all projected benefits; however, with the net of on-farm irrigation capital and operating costs, this shrinks to a value which is actually less than the projected net hydropower benefits. At the same time, there are some very major development costs involved. Scenario 3 costs total almost 5 billion in current dollars (irrigation delivery system at $3 billion, infrastructure costs at $1 billion, and the dam itself at $900 million). In real terms (i.e. discounting for when the costs are actually incurred), these costs represent over two thirds of total projected costs. In relative terms, the irrigation delivery system is particularly expensive.

These findings are consistent with previous analyses which have examined similar proposals. For example, in 1980 it was estimated[17] that the SSRIP-West Side irrigation development would probably result in a direct benefit-cost ratio of about 0.146. Other Saskatchewan-based studies have been equally pessimistic.[18] A cursory Alberta-based overview of the Meridian proposal in 1998 also gave the Meridian a "poor" rating, largely because of its anticipated high capital cost per irrigated acre.[19]

Detailed economic simulations can be found in Appendix Tables VIII-1 through VIII-6.

[17] Johnson, T. G., **The Feasibility of Phased Irrigation Development in the SSRIP-West Side,** Dept. of Agricultural Economics/U of S, Saskatoon, June 1980.
[18] Van Fliet, H. G. Haase, and R. A. Stutt, **An Economic Appraisal of the Irrigation Phase of the Proposed South Saskatchewan River Development,** October 1951.
[19] AAFRD/Alberta Environment, **Priorization of Irrigation/Water Management Projects,** Lethbridge, October 1998.

Figure 8.4-1 Discounted Cost and Benefit Streams - Scenario 3

Figure 8.4-2 Relative Importance of Various Projected Benefits – Scenario 3

Figure 8.4-3 Relative Importance of Various Projected Costs – Scenario 3

8.4.2 Sensitivity Tests

a) Discount Rates

The choice of an appropriate real discount rate affects socio-economic feasibility. A project generally looks less attractive when a higher real discount rate is used, and more attractive when a lower real discount is used. However, the long-term real opportunity cost of capital and the (after-tax) consumption rate of interest in Alberta and/or Saskatchewan are not known with certainty The conceptual framework is complex[20] and there is no widely-held concensus.[21] Thus, acknowledging this uncertainty, real discount rates of 3% and 7% were also utilized to assess economic feasibility of the proposed Meridian development[22].

Table 8.4-3 - Sensitivity to Social Discount Rate

Criteria	Social Discount Rate		
	3%	Base Case 5%	7%
Benefit-Cost Ratio	.40	.33	.27
Net Present Value	$ -3.2 B	$ -2.7 B	$ - 2.3 B

As shown in Table 8.4-3, the choice of an appropriate social discount rate has a fairly large impact on the economic results of this project.

b) Maximum Range

A sensitivity analysis typically addresses risk and uncertainty by changing the value of only one variable at a time, usually by plus or minus 20 percent. In this way, while holding all other variables constant, the impact of changing a single variable on various economic feasibility criteria is ascertained. This approach can grossly underestimate the possible range of values.

A more adequate sensitivity analysis is simply to develop a “worst case” and “best case” scenario. Based on extensive national and international experience[23], the appropriate range of values has been determined to be approximately as follows:

[20] See, especially: Belli, P., et. al., **Economic Analysis of Investment Operations: Analytical Tools and Practical Applications,** World Bank Institute Development Studies, Washington, D. C., 2001, pp. 222-244.
[21] An earlier literature review can be found in: Marv Anderson & Assoc., **Socio-Economic Analysis of Water Supply Alternatives, Milk River Basin Studies, Part II,** Alberta Environment, Edmonton, 1981, Annex D (5 pages).
[22] Estimates generated using the same 44 year time frame for each discount rate.
[23] UNIDO, **Guide to Practical Project Appraisal: Social Benefit-Cost Analysis in Developing Countries,** New York, 1978.

Best Case: Costs = -20% and Benefits = +20%

Worst Case: Costs = +20% and Benefits = -20%

The ± 20% sensitivities represent uncertainties associated with various aspects of the project components. These include:

- Hydropower benefits and pumping costs: fluctuations in future energy prices;
- Cost of main delivery pipeline system: extrapolation of costs from existing projects of a significantly smaller scale;
- Cost associated with impacts on the oil and gas industry: number of wells and facilities, and fluctuating value of resources;
- Potential flood impacts in low-lying areas north of the potential reservoir; etc.

Sensitivity simulations for Scenario 3, with a base case social discount rate of 5%, suggest a range of values for the B/C ratio and NPV as shown in Table 8.4-4.

Table 8.4-4 Possible Range of Values for the B/C Ratio and NPV

Criteria	Base Case	Confidence Band	
		Worst	Best
Benefit-Cost Ratio	.33	.22	.50
Net Present Value	-$2.7 billion	-$3.7 billion	-$1.6 billion

Given the present proposal and the existing cost and price structure, the "real" B/C ratio and the "real" NPV would likely lie within this range. The range of values expected for Scenarios 1 and 2 would be similar. This analysis, therefore, suggests that under a worst-case scenario, real (provincial) costs could exceed real (provincial) benefits by a factor of five. Even under the best-case scenario, real (provincial) costs would probably exceed real (provincial) benefits by a factor of two.

8.4.3 Relative Alberta-Saskatchewan Benefits & Costs

A related issue to the above economic analysis is how the relative costs would be shared between Alberta and Saskatchewan, and how benefits would impact the respective provinces. For example, if all the costs were shared equally (including the irrigation development costs) and Saskatchewan-Alberta irrigation development was also split 50-50, Saskatchewan might still benefit less than Alberta because of negative downstream impacts, particularly with respect to Saskatchewan's hydro-generating capacity, both now and in the future.

It is likely that more irrigation development would occur in Alberta (see Section 8.3.1) than in Saskatchewan. This would have a different implication in terms of benefits and costs. For the purposes of this preliminary analysis, it is assumed that 60% of all projected irrigation development and associated costs would be undertaken by Alberta and 40% by Saskatchewan. Dam costs would be shared equally and all other costs and benefits are assumed to impact geographically. This simulation suggests the following feasibility for Scenario 3 (see Table 8.4-5).

Table 8.4-5 Comparative Feasibility in Alberta and Saskatchewan

Criteria	Combined Alta.-Sask.	Alberta	Saskatchewan
Benefit-Cost Ratio	.33	.30	.36
Net Present Value	-$2.7 billion	-$1.7 billion	-$1.0 billion

A somewhat counter-intuitive result arises with a lower benefit-cost ratio for Alberta and a higher one for Saskatchewan compared to the combined benefit-cost ratio. This is due in large part to the proposed irrigation which is not expected to pay for itself. Thus, as more irrigation is developed, the proposed development becomes increasingly less economical. At the same time, this does not consider the potential loss of additional future hydro development in Saskatchewan.

8.4.4 Private versus Public Benefits and Costs

A social benefit-cost analysis compares the magnitude of all projected costs to all projected benefits, regardless of their incidence. Nevertheless, exactly who would pay and who would benefit is often a very real concern.

If historical precedents were maintained, this would suggest the following items would likely be public costs: the dam and spillway; all major irrigation system delivery (including operation and maintenance); 75% of the secondary irrigation system delivery (capital only); local roads; recreational losses; all environmental costs; all infrastructure costs (including compensation to the oil and gas sector); and all downstream hydro impacts. This amounts to more than $6 B (in nominal terms) over 44 years. All other costs would probably be paid for by the private sector - hydro installation and operation, 25% of secondary irrigation development (capital), all secondary irrigation system O&M, all on-farm irrigation development (incl. electricity installation), and all on-farm irrigation production costs.

At the same time, the projected benefits would largely accrue to the private sector, principally through irrigated crop production (including related benefits) and hydro-electric revenues. This would suggest the following comparative B/C analysis:

Table 8.4-6 Comparative Public and Private Sector Benefits and Costs

Criteria	Total (Base Case)	Private Sector
Benefit-Cost Ratio	.33	1.25
Net Present Value	-$ 2.7 B	+$0.2 B

From a private perspective, if farmers and hydro-electricity producers paid only about 24% of real direct costs but captured about 89% of the real direct benefits, a B/C ratio of greater than one (and a positive NPV) is suggested. To the private sector, therefore, the potential Meridian development would likely be considered financially feasible. From the public perspective, the opposite would be true.

8.4.5 Exclusive Hydropower Development

It is useful to assess the economic feasibility of an exclusive hydropower option. Without irrigation, it would be possible to produce increased hydropower on a sustainable basis at approximately 575 GWh/year for a reservoir the size of that considered in Scenario 3 (see Section 3.4 and Appendix V). By eliminating all irrigation-related costs and benefits, the probable economic feasibility of a hydro-only option can be determined as shown in Table 8.4-7.

Table 8.4-7 B/C Ratios and NPV's for the Exclusive Hydro Option

Scenario	Benefit-Cost Ratio	Net Present Value
3	.29	-$1.4 billion

Note: exclusive hydro options were note evaluated for Scenarios 1 and 2.

This analysis was conducted assuming the real value of electricity throughout the year is $.05/KW-h, and an environmental benefit for "green" energy would be worth $.02/KW-h. The hydro-only option appears to be less economically feasible than the basic scenario including irrigation development. This is due to the costs associated with dam and reservoir construction. Previous industry studies (completed at a cursory level) also suggested that a hydro development at this location would only be feasible (at current costs and prices) if it could be piggybacked on a multiple-use water development.

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APPENDIX I-1

ISSUES IDENTIFICATION MEETINGS: MEDICINE HAT, LETHBRIDGE, CALGARY

APPENDIX I-2

ISSUES IDENTIFICATION MEETINGS:
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