CANADA-SASKATCHEWAN
SOUTH SASKATCHEWAN RIVER BASIN STUDY

TECHNICAL APPENDIX III

THE FRAMEWORK PLAN

PREPARED BY:

CANADA-SASKATCHEWAN
SOUTH SASKATCHEWAN
RIVER BASIN STUDY OFFICE

AUGUST, 1991

ACKNOWLEDGEMENTS

This technical appendix was assembled by the staff of the South Saskatchewan River Basin Study Office. It is based on information from the references cited in the document, the technical reports listed in Appendix A, and extensive consultation with private and government interest groups. The efforts of R.S. Pentland, Water Resource Consultants Ltd., in the preparation of this document are appreciated.

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1.0 INTRODUCTION

1.1 THE SOUTH SASKATCHEWAN RIVER BASIN STUDY

The results of the Canada-Saskatchewan South Saskatchewan River Basin Study (SSRBS) are documented in a series of reports. The final report provides a summary of the findings in a form suitable for use by the general public. The final report is supported by seven technical appendices: Issues Documentation, Water Quantity, Water Quality, Water Use, Environment, Water Management and The Framework Plan. The technical appendices provide sufficient detail for use by water management professionals. The technical appendices are based on detailed studies reported in more than 60 technical reports prepared for the basin study and various reports on the study area prepared for other purposes. A complete list of the technical reports is included in Appendix A of this report.

This technical appendix, "THE FRAMEWORK PLAN", describes the development of a plan for the management of the water resources of the Saskatchewan portion of the South Saskatchewan River Basin. In order to provide some context for this report, sections have been included on the background to the study and on the water resources of the study area.

1.2 STUDY BACKGROUND

The South Saskatchewan River is the most reliable supply of good quality water in the southern half of Saskatchewan. It contributes significantly to the social and economic well-being of the people of the region. During the early 1980s, several events led to increasing concern about the ability of the river to meet future needs.

The water resources of the South Saskatchewan River are intensively used by Alberta. Alberta irrigates more than a half million hectares of land in its portion of the basin. During the mid-1980s, Alberta completed a planning study which identified a range of future development options. Several of the options provided for significant expansion of irrigation which would further reduce the amount of water passed to Saskatchewan.

Since its joint development by the federal and provincial governments more than 20 years ago, Lake Diefenbaker has become a focus for development in the Saskatchewan portion of the basin. This multi-purpose reservoir supports irrigation, hydro-electric energy generation, recreation, industrial and municipal water supply. In Saskatchewan, plans were also laid during the 1980s for further development based on the water resources of the South Saskatchewan River, particularly Lake Diefenbaker.

These plans included significant irrigation development. At the same time, proposals were made to further develop the recreation potential of the reservoir. Such developments would place additional demands on the water resources of the South Saskatchewan River.

While further development was being considered for the South Saskatchewan River Basin in both Alberta and Saskatchewan, there were several drought years in the 1980s. The droughts led to increased demand for water while the supply was reduced. In Saskatchewan, this caused problems for most water uses. There was concern regarding the ability of Lake Diefenbaker to support continued development. Weed growth at the upstream end of Lake Diefenbaker also led to concerns that the high quality water in Lake Diefenbaker was at risk.

The possibility of increased development, coupled with a reduced supply, led to greater concern about diverting water from the basin. Prior to the study, there had been a number of options identified for increased diversion of water from the South Saskatchewan River. However, when such diversions were identified, existing users expressed concern about the possible impacts. There was a clear need to determine the importance of the water in the basin to existing and future users.

The Canada-Saskatchewan South Saskatchewan River Basin Study was undertaken to provide information to guide water management. It will help ensure that the water resources of the basin can meet the needs of existing and future users.

1.2.1 The Study Agreement

On May 16, 1986, Federal Environment Minister Tom McMillan and Minister Responsible for SaskWater, Eric Berntson, signed the Canada-Saskatchewan South Saskatchewan River Basin Study Agreement. The agreement set aside 1.6 million dollars for the study with expenses shared equally by SaskWater and Environment Canada. The agreement established policies and procedures for a study of the Saskatchewan portion of the South Saskatchewan River Basin.

The Agreement identified three objectives for the study:

(a) "document the current and emerging water and related issues in the South Saskatchewan River Basin in Saskatchewan;

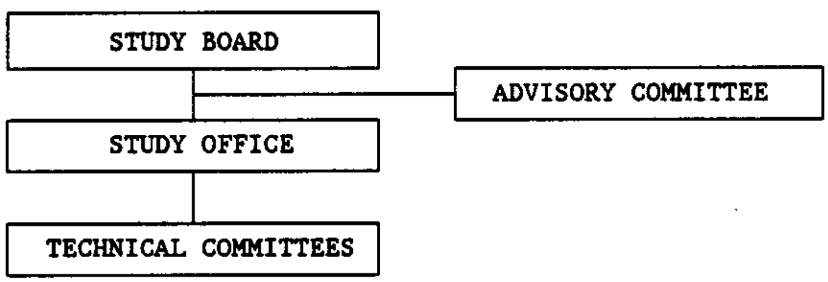
(b) "carry out an assessment of the water and related resources of the South Saskatchewan River Basin, and their current and future use;

(c) "develop a framework plan for the conservation and management of the water in the South Saskatchewan River Basin in Saskatchewan which allows for the evaluation of water resource projects."

1.2.2 Study Organization

The South Saskatchewan River Basin Study Board was responsible for the completion of the study. The board had one representative from each of the two sponsoring agencies: Environment Canada and SaskWater.

STUDY ORGANIZATION



An advisory committee provided policy information to the study board. Senior officials, representing agencies with water management responsibilities or interests in the basin, made up the advisory committee.

The study board set up the South Saskatchewan River Basin Study Office and staffed it with a director, assistant director and secretary. The director was responsible to the study board for the day-to-day administration of the study.

Technical committees assisted the study office. Representatives for the committees were drawn from agencies with responsibilities for water management. The agencies included federal and provincial departments, crown corporations and municipalities. The technical committees provided the study office with expert advice on water quantity, water quality, water use and public involvement. A management strategies technical committee was responsible for drawing together the information produced by the other technical committees and identifying management options.

The technical committees also helped develop terms of reference for work carried out by consultants. More than 20 different consultants participated in the study. The consultants played a role in compiling the basic information needed to carry out the study.

PARTICIPATING AGENCIES

Environment Canada
SaskWater

Agriculture Canada
- Agri-Food Development Branch
- Prairie Farm Rehabilitation Administration

Western Economic Diversification

Saskatchewan Environment and Public Safety
Saskatchewan Parks and Renewable Resources
Saskatchewan Culture, Multiculturalism and Recreation
Saskatchewan Rural Development
Saskatchewan Agriculture and Food

SaskPower
City of Saskatoon
Meewasin Valley Authority

1.2.3 Planning Process

Early in the study, the study board defined the planning process and eight planning principles. These principles guided the study.

THE PLANNING PROCESS

establish goals and objectives

↓

identify issues

↓

assess the resource

↓

identify management strategies

↓

evaluate management strategies

↓

develop recommendations and prepare the framework plan

PLANNING PRINCIPLES

THE WISE AND EFFICIENT MANAGEMENT AND USE OF WATER SHOULD BE PROMOTED THROUGH ALL POSSIBLE MEANS.

THE ECOLOGICAL INTEGRITY OF WATER RESOURCE SYSTEMS SHOULD BE MAINTAINED.

PUBLIC INVOLVEMENT IS ESSENTIAL FOR THE STUDY TO ACHIEVE ITS OBJECTIVES.

ALL WATER USES THAT HAVE SOCIAL, ECONOMIC OR ENVIRONMENTAL VALUE SHOULD BE CONSIDERED.

DOMESTIC WATER USE SHOULD BE THE HIGHEST PRIORITY AMONG ALL USES.

THE WATER RESOURCES OF THE BASIN SHOULD BE MANAGED FOR THE BENEFIT OF ALL PEOPLE IN THE PROVINCE.

WATER RESOURCES SHOULD BE DEVELOPED AND MANAGED CONSISTENT WITH THE CONCEPT OF SUSTAINABLE DEVELOPMENT.

INTERPROVINCIAL SHARING OF WATER IS BASED ON THE MASTER AGREEMENT ON APPORTIONMENT.

The planning process included the use of a base year as the reference point for the analysis of future conditions. The base year for the South Saskatchewan River Basin Study was 1986 -- the year the study began.

There were three separate planning exercises undertaken. They related to three different time horizons. The short-term planning exercise focused on the year 2000 and dealt with water management issues in the basin. The long-term planning exercise looked at the year 2020 and established a range of development options. The third and final planning exercise was the system-limit. It helped put the long-term planning exercise in perspective by identifying the development limits of the basin.

There are three main components to the study area: Mainstem South Saskatchewan River, Saskatoon Southeast Water Supply (SSEWS) system and Swift Current Creek. Although water management in these components is interrelated, the interrelationships are minor. Therefore most aspects or the study considered each component separately. The Mainstem includes the South Saskatchewan River from the Alberta border to the confluence with the North Saskatchewan at the downstream end of the study area. Lake Diefenbaker is included in the Mainstem component. The effects of actions on this mainstem area on the Saskatchewan River downstream of the study are were also considered in the mainstem section of the report. For this study, the SSEWS system was considered to include all of the works downstream of the East Side Pump Station near Gardiner Dam on Lake Diefenbaker. The Swift Current Creek Basin includes the Rushlake Creek basin.

1.3 SYSTEM DESCRIPTION

The following is a brief introduction to the water resources of the study area. More details are provided in the body of this report and in the other reports of this series.

1.3.1 Mainstem

The South Saskatchewan River rises in southern Alberta where it receives runoff from about 120 000 km^2 of drainage area. A portion of this drainage basin is located on the eastern slopes of the Rocky Mountains and foothills. This portion is a highly productive runoff area, producing virtually all of the flow received at the Alberta - Saskatchewan border where the average annual natural flow is 9 200 000 dam^3. This natural flow has ranged from lows of about 4 800 000 dam^3 in dry years to 16 000 000 dam^3 in wet years. On average, about two-thirds of the runoff occurs in the May to August period and less than ten percent occurs in the December to March period.

In Alberta the water is used for irrigation, municipal, industrial, hydro-electric, fish, wildlife and recreation uses. On average, the flow is reduced by about 1 900 000 dam³ per year, with irrigation taking about 95 percent of the water.

In Saskatchewan the river flows through a region of very low runoff. On average, the local runoff augments the natural flow by about two percent with half of this local flow originating In Swift Current Creek. Figure 1 shows the drainage area in Saskatchewan.

The largest water uses in Saskatchewan are centred around Lake Diefenbaker and the city of Saskatoon. Total water consumption averages about 500 000 dam³ per year. Evaporation from Lake Diefenbaker accounts for about half of this total, irrigation is the second largest user. Municipal and industrial users take a relatively small portion of the flow. Although less than ten percent of the water is consumed, the remaining water is used for important instream purposes, including hydro-electric generation, recreation and fish and wildlife.

Downstream of the study area the South Saskatchewan River joins the North Saskatchewan River and their combined flow continues east in the Saskatchewan River. Within Saskatchewan the flow is used to generate electric energy at the Nipawin and E. B. Campbell Power Station.

Downstream of the Saskatchewan - Manitoba border, the Grand Rapids Power Station uses the river before the water discharges to Lake Winnipeg. At Lake Winnipeg the water joins other flows from the south and east as it flows down the Nelson River to Hudson Bay. Along the Nelson River, there are additional power stations. In addition to the power stations the rivers downstream of the study area serve as local transportation routes, provide habitat for fish and wildlife and serve the water supply needs of several communities.

The quality of the water in the mainstem is very good, meeting the requirements of all of the existing and projected users. Upstream of Lake Diefenbaker the quality varies from season to season with the rate of flow but in the lake the seasonal variations are mixed, producing a very uniform quality downstream. Within the study area the greatest pollution threat arises from municipal and industrial effluents in the Saskatoon area where effluent treatment requirements are regularly under review.

1.3.2 SSEWS System

The SSEWS is a manmade water delivery system which draws water from Lake Diefenbaker and delivers it to an area northeast of the lake as far as Lanigan as shown on Figure 2. The major uses of the water are irrigation, industries, municipalities, recreation and wildlife. The largest irrigation project is the South Saskatchewan River Irrigation District which serves over 16 000 ha. Potash mines are the main industrial users.

The quality of the water at the upstream end of this system is equal to the mainstem, since it is drawn from Lake Diefenbaker. As the water moves downstream in the system, local surface and ground water inflows of less desirable quality are added and evaporation concentrates impurities resulting in a lower quality of water. The quality is satisfactory for the uses made of it, but is less than ideal.

1.3.3 Swift Current Creek

Swift Current Creek is the largest tributary to the mainstem in Saskatchewan. This creek drains a portion of the Cypress Hills as shown on Figure 3. The average natural flow is about 80 000 dam³ and the annual flow ranges from about 20 000 dam³ to 265 000 dam³.

Swift Current Creek water is used for irrigation and as a source of supply for municipal water at the city of Swift Current and the Village of Herbert. The irrigation and municipal systems rely on Duncairn Reservoir for flow regulation to overcome natural periods of low flow. The water supply system from Swift Current Creek extends to areas of the neighbouring Rushlake Creek Basin. In addition to the consumptive water uses, the water of this creek is used for recreation, fish and wildlife. Although the quality of the water in this area is not as good as that in the mainstem, it has been satisfactory for the current uses.

FIGURE 1 THE STUDY AREA

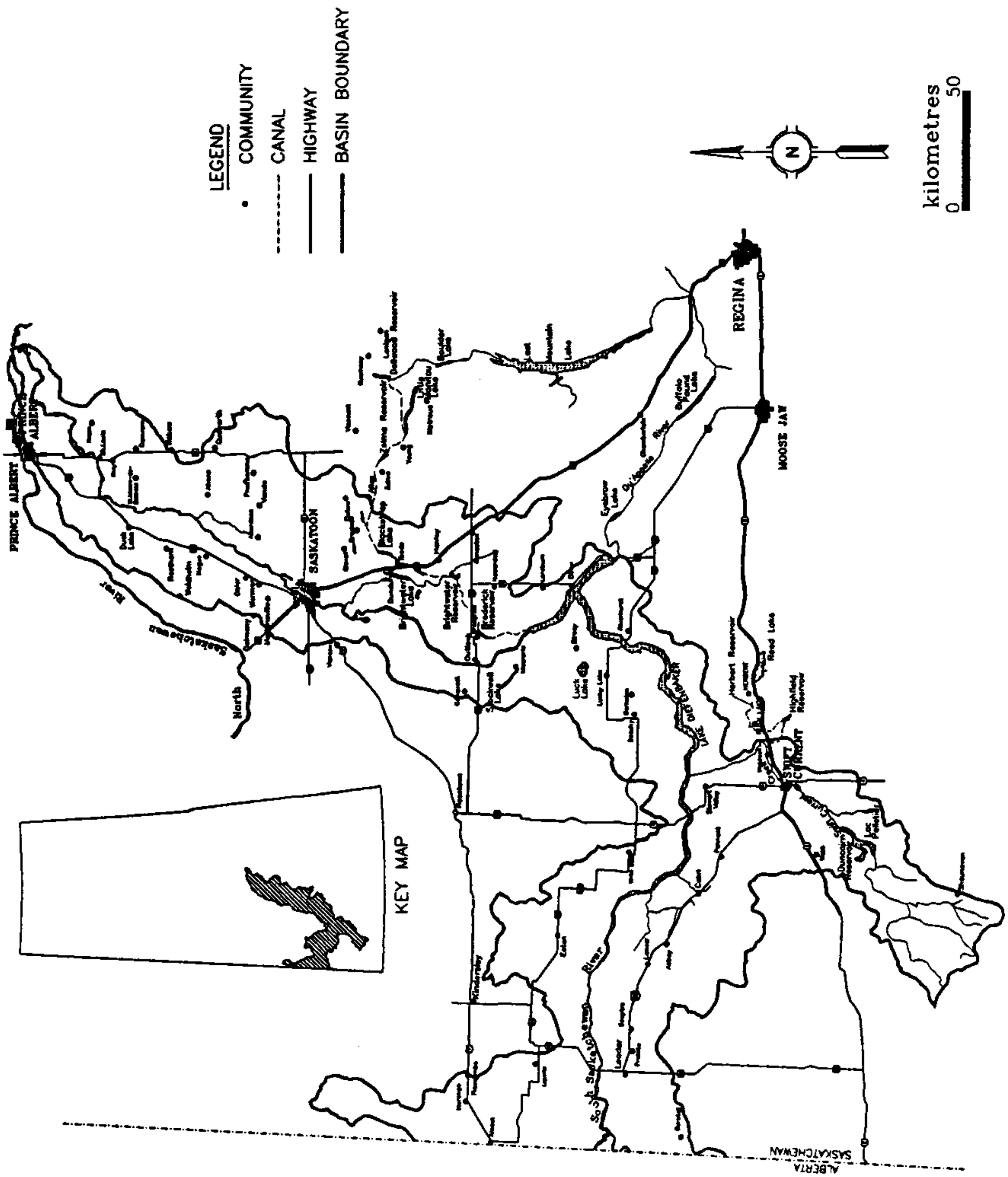


FIGURE 2 SASKATOON SOUTHEAST WATER SUPPLY (SSEWS) SYSTEM

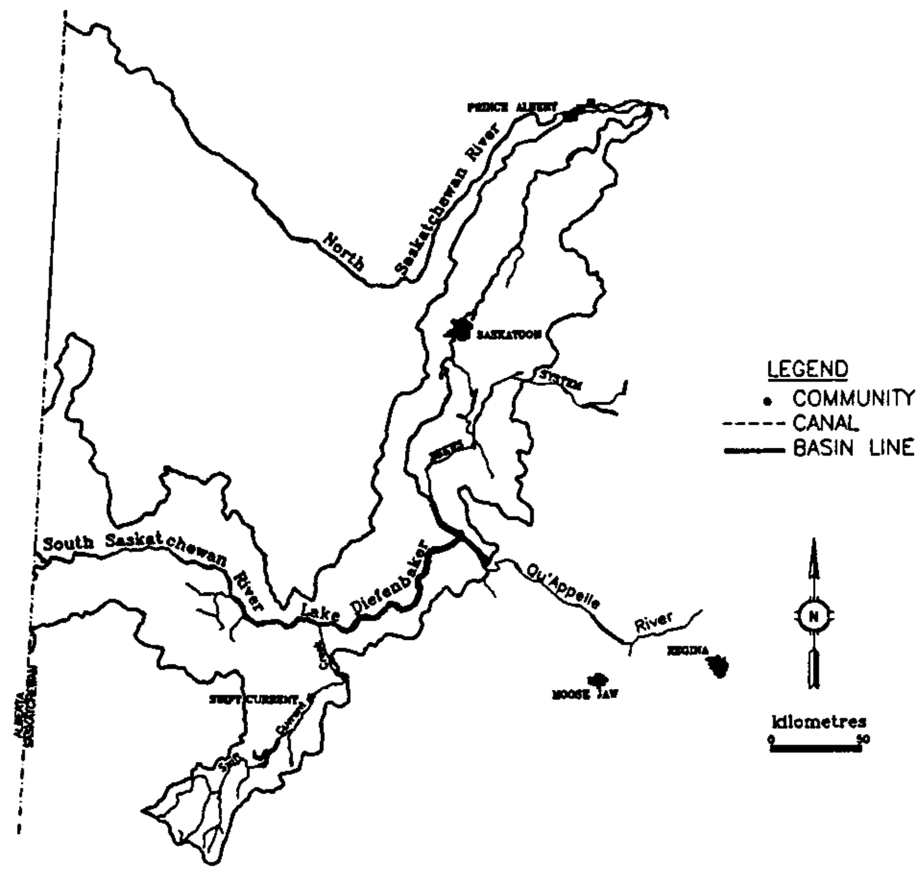
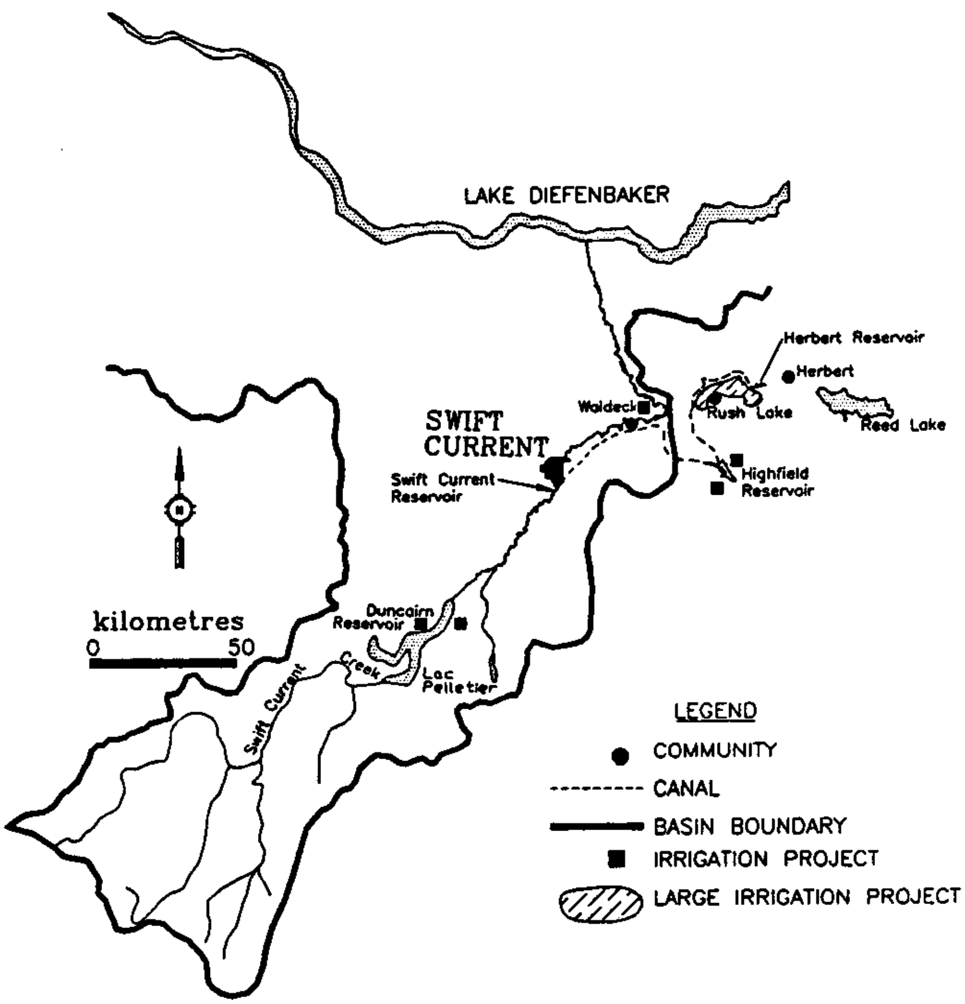


FIGURE 3 SWIFT CURRENT CREEK



2.0 DEFINITION OF THE FRAMEWORK PLAN

Even though this study utilized a broad cross-section of expertise and included extensive input from the public and water users, it would be presumptuous to assume that all future options, potentials and preferences for water management can be predicted. The constantly changing technological, economic and social structures prevent any management plan from being a rigid blueprint for the future. The plan must consider future uncertainty by building in mechanisms to cope with and respond to, changing conditions.

The economy of southern Saskatchewan is based on agriculture; mineral extraction including potash, oil and coal; and service industries. Export markets, beyond the influence of local conditions, are critical to this economy. As this socio-economic structure matures, its dependence on external forces may change. The key to sustained improvement in economic performance will be the ability to adjust to changing circumstances. Therefore, it was necessary to develop and evaluate a wide range of future economic scenarios and their implications for water management.

In order to provide useful results, the Framework Plan must consider strategies to resolve the issues and problems that are known to presently exist. In addition to resolving the current issues, it must ensure that solutions will be sustainable in the future.

Although issues or problems tend to be unique to specific uses of the water, the resolution of one problem cannot be successfully implemented with unacceptable damage to other users. Therefore the interrelationships among users must be considered.

The area under consideration in this study, the South Saskatchewan River Basin in Saskatchewan, is a small part of a much larger river system. Over 95 percent of the water available arises upstream of the study area in Alberta where it supports extensive economic activity. Downstream of the study area, along the Saskatchewan and Nelson Rivers, the water is used for hydro-electric generation and transportation which can be affected by activities in the study area.

The Framework Plan is not a specific set of development proposals. It includes proposals to deal with the current issues in the study area. It demonstrates the potential for current uses and for current development trends to be sustained in the future. It describes how various alternatives for future development would affect the resource and existing use trends. Specific long-term development proposals are not recommended, instead, the tools that will assist decision-makers to evaluate alternatives are provided.

The Framework Plan addresses the current issues; evaluates current uses and current use trends to determine if they are sustainable in the long term; and provides the tools and information to evaluate future development proposals.

The Framework Plan has three main components:

1. BASIN MANAGEMENT STRATEGIES

   The Basin Management Strategies chapter describes the planning process, public involvement, the evaluation criteria and the results of the short-term, long-term and system-limit studies.

2. PROJECT EVALUATION PROCEDURES

   The Project Evaluation Procedures chapter provides a description of procedures developed by this study of evaluating future proposals which might impact on the water resources of the study area.

3. INTER-AGENCY IMPLEMENTATION PLAN

   The Inter-agency Implementation Plan chapter discusses the role and responsibilities of agencies in the management of the water resources of the study area.

3.0 BASIN MANAGEMENT STRATEGIES - METHODOLOGY

In chapter one, the steps of the planning process were listed on page 3. In this section, a more detailed discussion of this process is provided.

3.1 GOALS, OBJECTIVES AND ISSUES

The basin goals and objectives of the study were defined in the study terms of reference and are listed on page 2 of this report. An early priority of the study was to expand upon these basic goals and objectives. In order to accomplish this, it was necessary to carry out extensive contacts with government agencies and the public. At the same time, these agencies and members of the public were requested to assist in the identification of the water management issues in the basin. Since establishing goals and objectives and identifying issues were completed in tandem, these two steps in the planning process are discussed together in this section.

In order to get the broadest possible range of input, all of the government agencies with interests in the water resource, representatives of the main water user groups, and the general public, were invited to participate.

As a first step in this process, representatives of the agencies and public user groups who expressed an interest in the problem solving process were invited to participate in an iterative process to assist in setting objectives for water management in the basin. Initially, 89 participants were involved. Of these, 77 participated in the full process. Roughly half were from non-government organizations:

irrigation groups
Indian Bands
wildlife groups
conservation and development area authorities
boating groups
boards of trade
municipal councils
politicians

The other half were staff of federal, provincial, municipal and other government agencies.

The survey was undertaken in five rounds. In the first round a discussion paper on the issues was presented and participants were invited to suggest changes and additions and to indicate the relative importance of the issues. This step helped to add to the list of issues and ensure that there was common understanding of the issues.

In the second to fifth rounds an iterative process of suggesting and ranking solutions to the issues was undertaken.

Because of time constraints, this process was undertaken at the same time as the detailed component studies were under way so participants did not have access to the detailed understanding of the basin resources presented in this final series of reports.

Based on the study terms of reference; input from the public and government agency surveys; and preliminary technical study results, the Study Board adopted the set of planning principles listed on page 4 of this report.

The final identification of water management issues is detailed in the South Saskatchewan River Basin Study Issues Documentation Technical Appendix. Section 3.2 of this report reviews the issues and presents management strategies to deal with these issues in the short-term.

3.2 RESOURCE ASSESSMENT

In order to assess the water and related resources of the study area a total of over 60 working reports were prepared. Each of these reports detailed one aspect of the resource or uses of the resource. In order to summarize the findings of these studies and other references which were available from other sources, detailed reports on all aspects of the resource were prepared and are available in the South Saskatchewan River Basin Study Technical Appendices: Water Quantity, Water Quality, Water Use, Environment and Water Management.

3.3 MANAGEMENT STRATEGIES IDENTIFICATION

The reports on issues and the resource include details on the problems and the basic resource but they do not provide an overall synthesis of this technical information into management strategies for the Framework Plan. This synthesis required a separate effort after most of the detailed studies were complete.

For this purpose, the Study Board appointed a Management Strategies Technical Committee. This committee was made up of senior water managers of the federal and provincial governments. The committee members were each specialists in various aspects of the problems facing water resource management and their experience overlapped all aspects of water management in the basin. The committee members were also involved in technical studies undertaken for the basin study and had ongoing management responsibilities relevant to the study area.

This committee utilized the results of the study, including the goals, objectives, issues and resource data, along with their own experience, to develop the management strategies discussed in this report.

3.4 EVALUATION

In evaluating strategies, a range of data and models were utilized. A few of the key components are discussed in this section.

3.4.1 Water Uses

The underlying concern in all of the water management issues relates to the use of the water. It is important to note that the term "use" includes uses like municipal, industrial and irrigation that remove water from the stream and in-stream uses like recreation, fish, wildlife and hydro-electric generation which use the water without withdrawing it from the stream. Both the quantity and quality of water affects its use.

The South Saskatchewan River Basin Study Water Use Technical Appendix provides detailed information on water use. A brief summary is provided here.

The largest consumptive water uses from the South Saskatchewan River occur upstream of the study area in Alberta. The average annual natural flow at the Alberta/Saskatchewan border for the 75 year study period was estimated to be 9 200 000 dam^3. Modelling studies indicate that if the uses which existed in 1986 had been in place throughout the study period, the average flow would have been 7 200 000 dam^3 or 78 percent of the natural. By about the year 2000, it is anticipated that the average flow will be about 6 700 000 dam^3 or about 72 percent of the natural. By about the year 2020, the average flow is expected to be 6 100 000 dam^3 or about 67 percent of the natural. Ultimately Alberta uses could reduce the average flow to 50 to 60 percent of natural. Simulation models of the Alberta portion of the basin were used to estimate how these flows might vary from year to year and month to month.

In the Saskatchewan portion of the basin, the largest water use commitment is the provision of a base flow of 42.5 m^3/s in the river downstream of Gardiner Dam. This requires about 1 300 000 dam^3 of water per year.

The largest consumptive use of water in the past was evaporation from Lake Diefenbaker and other reservoirs which removes an average of 265 000 dam^3 of water per year from the river system.

Irrigation is the largest use with the largest potential for growth. In 1986, the average use was about 170 000 dam^3 per year. By the year 2000, it is expected that irrigation will be using about 248 000 dam^3 per year and by the year 2020 this use is expected to average about 425 000 dam^3 per year if past trends continue.

Water releases to the Qu'Appelle River which serve a combination of irrigation, municipal, industrial and recreation uses have averaged about 88 000 dam^3 per year in the recent past and are expected to rise to about 110 000 dam^3 per year by the year 2000 and 142 000 dam^3 per year by the year 2020.

Municipal and industrial water uses are expected to rise from about 52 000 dam^3 to 68 000 dam^3 and 84 000 dam^3 by the year 2000 and 2020 respectively.

3.4.2 Analysis Models

In order to analyze a complex river system with multiple users, it is necessary to utilize models to simplify and summarize answers for comparison among alternatives. As described in the chapter on Project Evaluation Procedures, a number of models were developed which simulate various physical, economic and environment aspects of the water resource. These models were used in the analysis of basin management strategies.

3.4.2.1 Water Quality Models. Described in detail in the South Saskatchewan River Basin Study Water Quality Technical Appendix, the technical studies of water quality determined that in general water quality is not a limitation on any present or anticipated uses of the water in the study area. Management strategies must therefore concentrate on ensuring that this quality is protected and where possible enhanced. There are several critical areas for water quality.

Lake Diefenbaker is the source of supply for the three largest urban municipalities in the province and many smaller urban users; most of the industrial water in southern Saskatchewan, and the largest existing and potential irrigation projects in the province. In addition, the lake is becoming a major recreation area and has additional recreation potential. In its brief two decades of existence, it has provided suitable water of ideal quality for all these uses. Studies indicate that eutrophication is the greatest threat to the usefulness of this lake. Modest eutrophic conditions, resulting from nutrients contained in the inflow, occur regularly at the west end of the lake. Phosphorous compounds were found to be the controlling influence on the trophic state of Lake Diefenbaker. As a result of these findings, a computer model of the trophic state of Lake Diefenbaker was developed.

The model and past measurements show that the inflowing phosphorous is mostly contained in suspended sediments which rapidly settle to the bottom of the west end of the lake. The soluble phosphorous is consumed by the heavy plant growth in the eutrophic west end of the lake. The main body of the lake is relatively low in phosphorus and associated plant growth so its trophic state is good. The greatest hazard to the trophic state identified is the phosphorous that is presently bound to the sediments and natural soils of the lake bottom, which could become soluble if the dissolved oxygen level in the lake were depleted.

The trophic state model for Lake Diefenbaker clearly demonstrated that management strategies must avoid depleting the oxygen content of the lake water.

Water quality modelling was also developed for the South Saskatchewan River upstream and downstream of Lake Diefenbaker. The quality parameters that are most critical were modelled. This model was found to be most useful in evaluating the impacts of the large concentration of urban effluent at Saskatoon and potential impacts of changes in that effluent.

In the past, salinity, or the total concentration of dissolved solids in the water of the downstream end of the SSEWS system, has approached acceptable limits. Measurements indicated that this problem was worst in the early years of operation and has diminished slowly with time. A computer model of this phenomena was developed and used to evaluate the likely trends of salinity which changes in management might cause.

3.4.2.2 Economic Models. Models that integrate economic inputs, outputs and water use were developed. It was found that because Saskatchewan's economy is dominated by exports and imports, water use and water management are relatively insensitive to the local economy. In order to model the water use for the major industrial user, potash mining, a model would have to include the major export destinations. Similarly, irrigation, the major water user, depends on world prices for commodities and senior government initiatives which are not significantly tied to local economic conditions.

3.4.2.3 Environmental Models. The South Saskatchewan River Basin Study Environment Technical Appendix describes the environmental conditions as they relate to water resource management. The primary use of this type of information would relate to evaluation of specific structural changes such as construction of a dam to create a lake or similar projects. Since the Framework Plan does not include specific development proposals, detailed environmental evaluation of physical works was not required. Rather, the environmental data was useful background information for the more general strategies being evaluated.

3.4.2.4 Flood Models. Three key flooding problems were noted in the study area: urban flooding at Swift Current and Saskatoon, and agricultural flooding along the South Saskatchewan River. Detailed studies of the urban flooding were available from past work of the Canada/Saskatchewan Flood Damage Reduction Program. Based on this data, and hydrologic analysis of impacts of changes in reservoir operation, models of the relative flood hazard for various operating strategies were developed as described in the South Saskatchewan River Basin Study Water Quantity Technical Appendix. A model of agricultural flood damages was also developed.

3.4.2.5 Water Quantity Models. Since virtually all of the water of the study area is used in some way, the dominant issues and opportunities for new strategies relate to optimizing the supply among the uses. Therefore water quantity modelling was a key analysis tool. Two main water quantity models were developed for the study.

The Hydro System Simulation Model (HYDSIM) is a river simulation model that is designed to accurately trace the performance of the hydro-electric generation of the Coteau Creek Generating Station on the South Saskatchewan River and the Nipawin and E. B. Campbell stations on the Saskatchewan River. This model was developed by SaskPower to study the integrated operation of their thermal and hydro generation system.

The Water Resource Management Model (WRMM) is a more general water resource model that has been developed to simulate any multi-user river system. The particular version of this model used for this study was developed by Alberta Environment for analysis of their portion of the South Saskatchewan River Basin.

The Water Resource Management Model analyses a sequence of inflows, water uses and preferred water levels and flows, as defined by penalty points. Through an iterative solution, it defines the conditions for each time period that best meet the objectives. That is, the overall penalty for each time period is minimized.

For this study, separate Water Resource Management Model analyses were completed for the mainstem of the South Saskatchewan River, SSEWS system and Swift Current Creek.

Figures 4, 5 and 6 show schematic diagrams of the configuration of the Water Resource Management Model for each segment of the study area.

The analysis was completed for monthly flows for the 75 year period from 1912 to 1986, a total of 900 time periods. The model output included monthly flows at each node, monthly water use for each withdrawal point, monthly power production, month end water elevations and details of penalty points for each month. If printed to paper output, the output from a single run of this model would produce a major volume which no individual could effectively evaluate, let alone compare to results of a second run of the model with different operating strategies. Therefore, the model results were stored on electronic media and only summary results from selected parameters were selected for printed output.

The evaluation parameters are discussed in detail in the next section of this report and the summarized WRMM output are listed in Appendix C.

3.4.3 Evaluation Criteria

The many users of the water resources of the study area have diverse needs. Each user has specific preferences for water levels, rates of flow and flow velocities. In order to evaluate how well or how poorly the system is meeting the needs and desires of its many users, a system of evaluation criteria was developed. As alternative operating or development scenarios were proposed, their success or failures were evaluated against these criteria.

The study was intended to provide a broad Framework Plan for the study area. It was not intended to design or recommend specific structural developments. Therefore, economic criteria such as cost versus economic benefit have little relevance. Cost-benefit analysis will be required when specific projects are proposed in the future but, for this study, the emphasis is on the underlying factors that generate economic costs or benefits.

3.4.3.1 General.

DOMESTIC WATER USE

Certain water uses have been assured of a reliable water supply through both law and traditional water management practice. Water use for household purposes such as drinking, cooking, cleaning, stockwatering and irrigating gardens has always been given the highest priority among water uses. Access to water for these basic needs has traditionally been protected by water management laws, including the current Saskatchewan Water Corporation Act.

FIGURE 4 **WATER RESOURCE MANAGEMENT MODEL MAINSTEM CONFIGURATION**

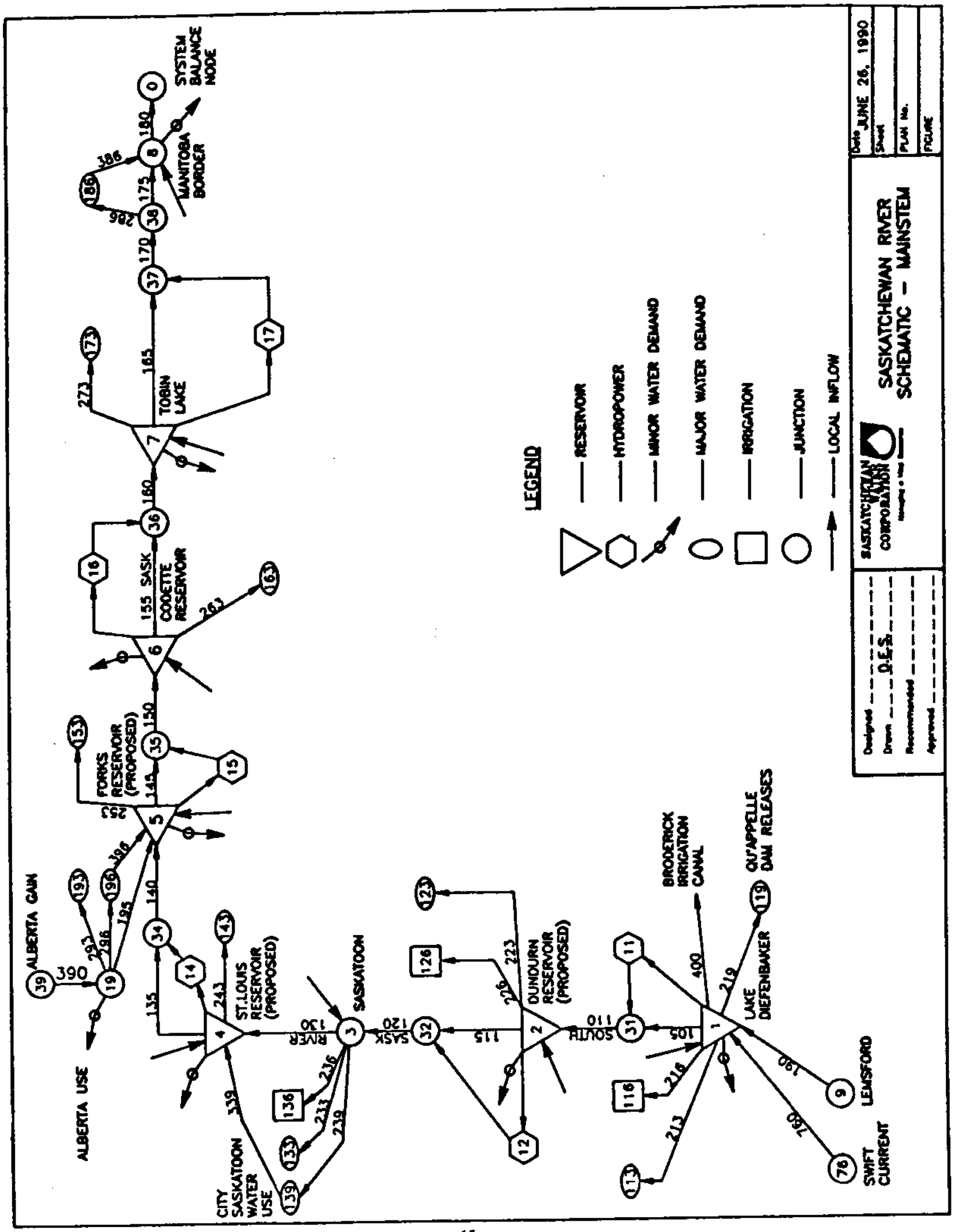


FIGURE 5 WATER RESOURCE MANAGEMENT MODEL SSEWS CONFIGURATION

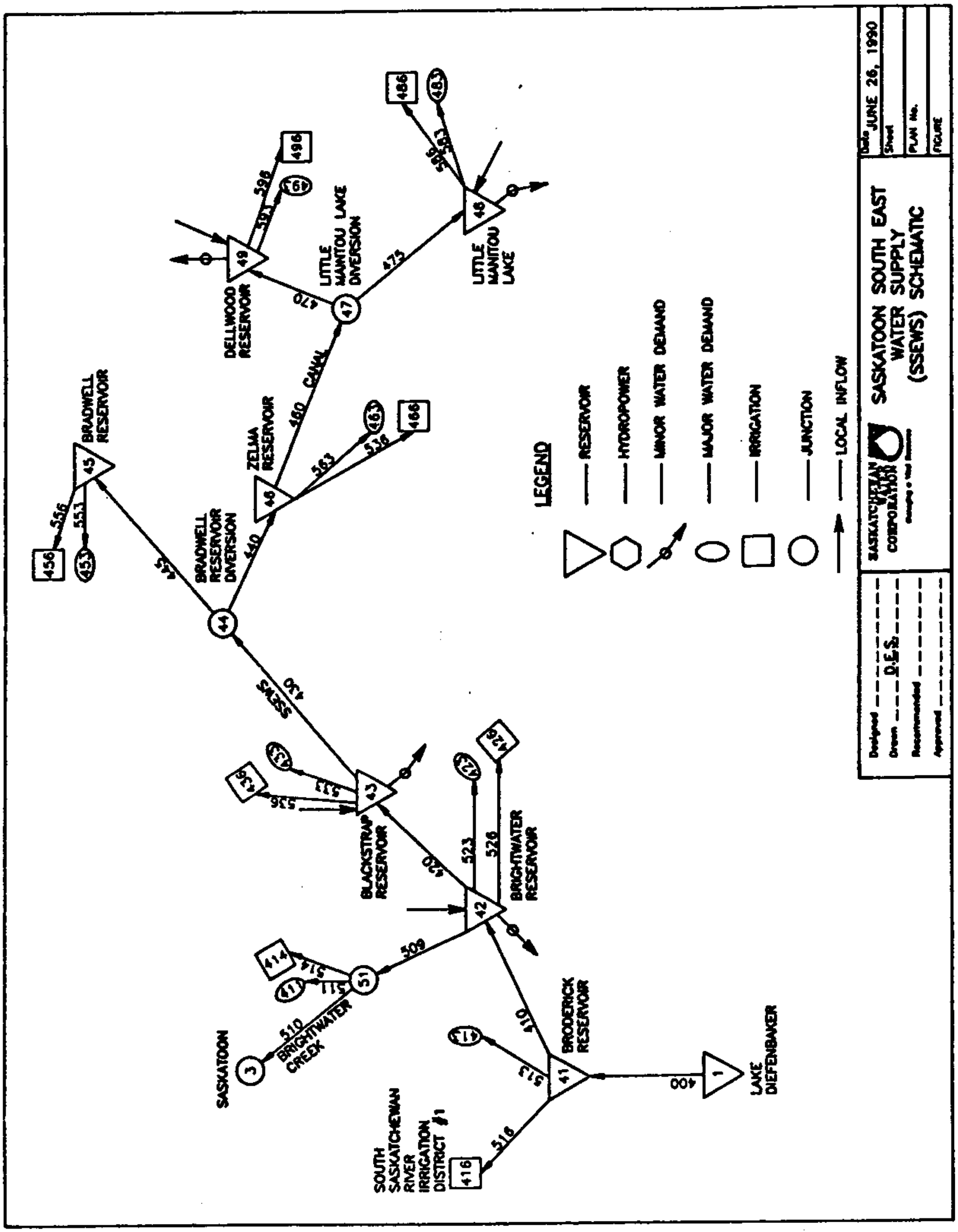
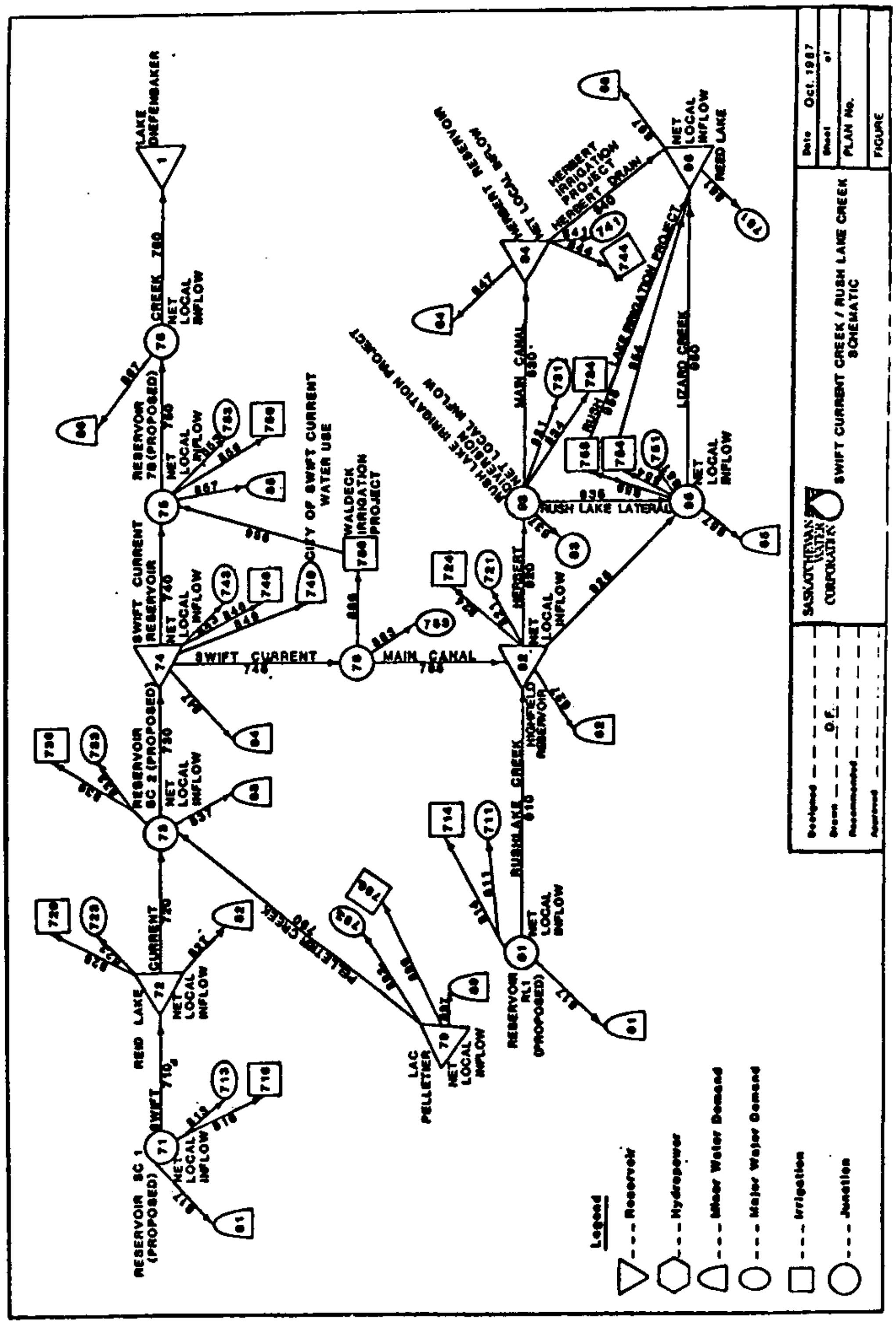


FIGURE 6 **WATER RESOURCE MANAGEMENT MODEL**
SWIFT CURRENT CREEK CONFIGURATION



At present, all water control works are operated to ensure that these basic water needs are met and for this study, all operating or development scenarios also assured that these domestic needs would always be met. Specific evaluation criteria for domestic supplies were therefore the same for all alternatives and are not reiterated in each evaluation.

MUNICIPAL WATER USE

Municipal water systems serve similar uses to the domestic uses above through an integrated network in urban centres. In addition to domestic needs, commercial, industrial, institutional, fire fighting and other uses are served. Since a municipal water system combines the resources of many users, it has some advantage over an individual domestic user. Therefore, the individual domestic user is given the protection of the highest priority while municipal uses, which are very similar, are provided the next highest priority.

In the study of alternative scenarios, municipal water uses were assumed to always receive an adequate water allocation. Since their needs were always met and since there are more than adequate water supplies for all existing and expected municipal water uses, separate evaluation criteria for municipal supplies in each alternative scenario were not required.

It should be noted that some municipalities in the study area do have inadequate quantity and quality of water available. However, these problems relate to the localized infrastructure inadequacies. The overall basin water supply is more than adequate.

INDUSTRIAL WATER USE

Industrial water use is important in economic terms. Obviously human domestic and municipal needs take priority over industries because people must survive before they can undertake economic activities. However, after survival, economic activity to generate jobs and wealth is a high priority. In general, industrial water users start with very high capital investments which can only be undertaken if the resulting enterprise is assured that it can have secure supplies of all inputs, including water. Therefore, industrial water uses only establish at locations of adequate water supply.

For this study, it was assumed that all industrial water use will be met. This made separate evaluation criteria for industrial water use for each scenario unnecessary.

3.4.3.2 Mainstem.

IRRIGATION

Irrigation is the largest consumptive user of water from the mainstem, using about 5 percent of the average annual flow. This proportion rises to 10 percent in drought years.

Since irrigation water use has been a small part of the total flow, it has not historically suffered shortages or rationing due to lack of supply. Assuming that development does not exceed the capacity of the supply, shortages will not occur in the future.

Therefore, the evaluation criteria for irrigation can be expressed as area in hectares receiving a full irrigation of 450 mm of water.

HYDRO-ELECTRIC GENERATION

Electricity is a valuable, refined form of energy. Hydro-electric generation operating costs are very low. Its economic value as an input to industry or household use is demonstrated by the price that consumers pay. However, the price paid by the consumers is an average of all the costs of generating, transmitting and delivering the energy. The costs of transmitting and delivering the energy are common to all sources of electric generation. The value of hydro-electric energy can be evaluated by comparison to the cost of generating or buying energy from other sources. In economic terms this is difficult to define because alternatives can vary in price by a factor of three from hour to hour during the day. Prices of fuels vary with time as competing uses and vagaries of supply (overseas wars, price cartels, etc.) change. At some times alternative energy may not be available at any price.

Since prices can be unstable and may not define the value in cases where no alternative supply is available, it was decided to evaluate hydro-electric energy production in the basic units of energy produced, megawatt-hours.

The cold winter of Saskatchewan increases the demand for electric energy seasonally. Peak power demands and the highest sustained power demands make winter the critical period. Therefore, in addition to the total energy output, the proportion of the output available in winter was used to evaluate hydro-electric generation.

A third critical factor is the output that can be relied upon in dry years, or the firm power supply. This determines the investment that must be made in alternative capacity.

Hydro-electric generation occurs at one location, Coteau Creek Generating Station at Gardiner Dam, within the study area. Additional stations, Nipawin and E. B. Campbell, on the Saskatchewan River are affected by changes in seasonal flow patterns caused at Gardiner Dam. Generation at these stations was, therefore, also evaluated.

There are additional power stations on the Saskatchewan River and Nelson River in Manitoba that are also affected by operation of Gardiner Dam. However, these stations include very large storage reservoirs which can re-regulate flows to suit their own needs. Therefore the changes in Saskatchewan are insignificant and were not evaluated.

In the future, additional hydro stations could be developed in Saskatchewan downstream of Gardiner Dam. These potential projects were also evaluated in terms of total, seasonal and drought year energy production for some scenarios.

In Saskatchewan, the major electrical energy source is from coal-fired plants which contribute to carbon dioxide in the atmosphere at a rate of about one kilogram per kilowatt hour. This is an environmental concern as it contributes to the greenhouse effect. Hydro, by contrast emits no atmospheric pollution. Thus, in addition to economic value, hydro generation has environmental value.

3.4.3.3 Upstream of Lake Diefenbaker. The rate of flow determines the level and velocity of the water which affects users along this reach.

This section of the river is not heavily used. There are modest domestic, municipal and irrigation withdrawals. These consumptive users are assured of an adequate supply because even the lowest flows greatly exceed their uses but they do experience difficulty obtaining their water supplies if water levels drop below intakes. Most of the intakes perform adequately as long as the flows exceed 42.5 m^3/s.

Recreation use of this reach of the river is concentrated at Eston Riverside Regional Park and Lemsford Ferry Regional Park. The main use of the river is for boating, fishing and as an aesthetic focus for the parks. In addition to the parks, the river is used for occasional canoeing. At Eston Riverside Regional Park flows below 68 m^3/s are undesirable because of the shallow water depth; flows of about 150 m^3/s are best because the depth is adequate. As flows go higher, conditions are less desirable because velocities become too strong at about 400 m^3/s; and, at flows greater than 1 000 m^3/s, flooding of low segments of the park begins. Lemsford Ferry Regional Park does not include significant river activities. The few groups that canoe this reach would likely find the flows identified for Eston Riverside Regional Park satisfactory.

River flows affect the operation of three ferries: Lancer, Lemsford and Estuary. At Lancer Ferry, the required flow conditions change as sandbars shift. In 1987 flows as low as 50 m^3/s permitted operation but in some periods flows as high as 150 to 200 m^3/s were inadequate. By adjusting the crossing arrangement and restricting loads, low flows can be managed. Optimum flows are about 250 to 300 m^3/s. Flows of 1 100 m^3/s are the maximum for ferry operation.

At Lemsford Ferry low flows are not a problem because low level approaches accommodate operation. Flows of 175 m^3/s are preferred. Flows over 1 200 m^3/s result in excess current and flooding of approach ramps.

Estuary Ferry is located just downstream of the confluence of the Red Deer and South Saskatchewan rivers. Because of shifting sandbars, the low flow operations vary from 55 to 75 m^3/s. Optimum conditions are 75 to 340 m^3/s. This ferry can operate at flows up to 2 700 m^3/s.

Fishing is a popular use of this reach of river. Walleye, sauger, goldeye, pike and burbot are fished. Little is known about the effect of flow on fish in this reach. A generalized fish habitat evaluation tool, the "Montana Method" was applied. Flows of 84 to 210 m^3/s provided good to optimum summer fish habitat. Flows above 63 m^3/s are fair and lower flows are poor. Maximum flows of 420 m^3/s provide flushing.

Waterfowl staging in the fall is the only wildlife use that is affected by flows. Flows low enough to expose islands are desirable during the fall migration.

Optimum flows for all uses do not coincide but there is considerable overlap. Because the river has been regulated by Alberta with a minimum of 42.5 m^3/s in recent years, most of the users have come to expect this base and would be greatly inconvenienced if the flow dropped below this rate any time of the year. Recreation and ferries are open water season uses. Most of the optimum ranges overlap in the 60 to 150 m^3/s range and all uses can function in this range, therefore, this was identified as the preferred range. Flow from 42.5 to 500 m^3/s include the optimum ranges of all users and permit almost all users to function, although with limitations. Flows from 500 to 1 000 m^3/s generate increasing problems with the strong current and above 1 000 m^3/s flooding of farm land, ferry approaches and park areas is a problem.

Flow conditions in this reach were evaluated on the following basis:

1 000 m^3/s and over	Flood risk
400 to 1 000 m^3/s	Unacceptable due to hazard to ferries, recreation and erosion
150 to 400 m^3/s	Useable with limitations due to strong currents
60 to 150 m^3/s	Preferred
42.5 to 60 m^3/s	Useable with limitations on ferries
42.5 m^3/s and less	Unacceptable to most users

3.4.3.4 Lake Diefenbaker. The water level of Lake Diefenbaker affects all users of the lake and downstream river either directly or indirectly. For this section of the report, only the lake users are considered. The downstream river is discussed in a later section.

RECREATION

Recreation is a major use of the lake. There are three provincial parks, four regional parks, four institutional camps, one recreation site, four cottage subdivisions and two picnic grounds adjacent to the reservoir. Most of these facilities were constructed in the late 1960s and early 1970s and have been expanded since. The lake is an important part of these developments as it is used for swimming, fishing, boating and as an aesthetic focal point. The facilities affected by lake levels are discussed individually below.

Elbow Harbour Recreation Site

The Elbow Harbour is located in a natural bay on Lake Diefenbaker. A marina with 125 piers and sufficient depth of water for sail boats with keels has been developed along with associated shore activities such as camping, picnic sites and a golf course.

- The minimum lake level for the marina boat launch is 550.25 m.
- The marina can operate at a minimum level of 552 m but capacity is reduced when water levels drop below 552.7 m. Other sheltered bays used by boats from Elbow also become inaccessible at similar low levels.
- The preferred level for sailing is about 555 m.
- High levels, up to 556.87 m (FSL) do not affect boating but above 556.6 m beaches disappear, reducing aesthetic appeal.
- The Tufts Bay boat launch near Elbow is designed to operate at all levels from 552 to 556.87 m.

Danielson Provincial Park

This park includes a beach, boat launch, camping and picnicking facilities on the west end of Gardiner Dam.

- At lake levels below 553.8 m littoral drift of beach material blocks the boat launch area.
- Preferred levels are about 554 to 554.5 m.
- Levels above 556.6 m flood beaches and erode shoreline facilities.

Douglas Provincial Park

This park provides similar facilities to Danielson Park on the northeast side of the Qu'Appelle Arm of the lake.

- Water level requirements are similar to Danielson Park with the preferred levels slightly higher at about 555.2 m.

Palliser Regional Park

This park, located near Riverhurst includes a beach, pool, boat launch and marina with 150 berths.

- Launching boats is difficult with lake levels below 552.9 m.
- Preferred levels are 554.4 to 555.4 m.
- Levels above 556.6 m cause erosion to steep banks.

Prairie Lake Regional Park

This small park located near Beechy offers a beach, boat launch, boating, fishing and trailer sites.

- Levels below 553.2 m cause problems to boating and swimming facilities.
- The preferred level is about 554.2 m.
- Maximum levels near FSL wash out banks and reduce beach area.

Herbert Ferry Regional Park

This park on the south shore across from Prairie Lake Regional Park offers similar facilities.

- Minimum operating levels are about 554.0 m.
- Preferred levels are about 556.6 m.
- No maximum levels were identified.

This park was developed during a period of high lake levels and therefore low levels cause extra problems.

Saskatchewan Landing Provincial Park

This park has two beaches, a boat launch, houseboat, canoe and other boat rentals and picnicking and camping.

- Minimum design levels for facilities are about 550 m.
- Preferred levels are about 554.5 m.
- Levels above 556.3 m erode shorelines and flood beaches.

Cabri Regional Park

This park is located 30 km west of Saskatchewan Landing. The park has boat launching, overnight docking and swimming facilities.

- Water levels below 553.8 m are too low.
- Preferred levels are about 555.2 m.
- Maximum levels to 556.8 m cause minor problems.

Camp Raynor

This camp provides canoeing and swimming on the lake. Variable water levels have not been a serious problem.

- Minimum levels as low as 551.5 m are not a serious problem.
- Preferred levels are 553.1 to 554.9 m.
- Water levels above 555.6 m cause erosion and limit beach area.

Provincial Girl Guide Camp

This camp uses the lake for swimming and canoeing.

- Water levels below 553.9 m cause muddy beach conditions.
- Water level variations above this level do not cause problems.

Central Butte Lions Club

This campsite receives limited local use for swimming, fishing and canoeing.

- Water levels from 553.2 to 556.6 m are acceptable.

Cottage Subdivisions

Cottage lots have been established at Mistusinne, Hitchock Bay, Coteau Beach and Beaver Flats. These subdivisions were designed to accommodate the wide range of fluctuations and have few problems with lake levels.

- Boat launches only function above 553 m.

Boat Launches

Boat launches around the lake developed by the provincial government are generally designed to function for the full operating range of the lake.

- Minimum operating levels range from 549 to 549 to 552 m.
- All boat launches were designed to function up to FSL.

FISH AND WILDLIFE

The creation of Lake Diefenbaker has converted about 220 km of river valley into a lake with an area of 40 000 ha and a volume of 9 400 000 dam^3. Through stocking and reproduction of the native river species, a thriving fish population has become established.

Waterfowl have taken advantage of this water body as a staging site during migration. The waterfowl use of the lake is not particularly affected by its levels.

Although many species of fish thrive in the lake with its present widely varying levels, more stable levels would further enhance the fishery. The maximum volume of fish habitat exists when the lake is at FSL. Therefore this is the preferred fishery level. If water levels were kept above 552 m, effects on fish would be minimized.

FERRY TRANSPORTATION

The Riverhurst Ferry crosses Lake Diefenbaker.

- At lake levels less than 551.4 m ferry operation is limited due to sandbars.
- The ferry operates up to FSL.

HYDRO-ELECTRIC GENERATION

Ideally SaskPower would like to have Lake Diefenbaker as high as is practical to maximize the head available for power generation and would like to run the Coteau Creek Generating Station as near to capacity as possible. However, there is not a uniform inflow available, making these two objectives impossible to attain. The storage capacity of the lake must be used to regulate the flow for power generation at Coteau Creek and downstream at Nipawin and E. B. Campbell.

Since power demands are highest in winter, having the lake full for power generation is most critical in fall in order that the maximum head and withdrawal from storage can coincide with the demand for energy.

IRRIGATION

At present and the foreseeable future there is an adequate water supply for irrigation. The main concern of irrigation operators is the cost of pumping water from the lake to upland areas. The cost is proportional to the vertical lift. Therefore high lake levels during the irrigation season are desirable.

Some irrigators have experienced problems with low water preventing the functioning of intake structures. Programs to rebuild intakes with sufficient depth have largely overcome these problems in recent years.

SUMMARY

Lake Diefenbaker is a flow regulation reservoir which is intended to vary widely in level. In general shoreline developments on the lake have been controlled and designed to accommodate a wide range of operation.

The levels identified as undesirable are usually only modestly inconvenient for users and if the level was consistently outside their preferred ranges, users would adjust facilities and activities to fit. Although preferred ranges are identified, it should be recognized that recreation interests are more concerned with "consistent" levels than with "specific" levels. The following levels were identified:

556.87 m and over	Flood damages
556 to 556.78 m	Usable with some limitations
554 to 556 m	Preferred
551 to 554 m	Usable with some limitations
545.6 to 551 m	Usable with significant limitations
545.6 m or lower	Unacceptable

3.4.3.5 Downstream of Lake Diefenbaker. Prior to construction of Lake Diefenbaker the South Saskatchewan River carried widely varying flows, and a heavy sediment load. Use of the river for recreation was light, as it still is above Lake Diefenbaker. Since construction of Lake Diefenbaker, the more stable flows and clear water have made the river more attractive for many activities. Although the river is an improved recreation opportunity, it could be more desirable.

RECREATION

Outlook Area

In the river reach close to Lake Diefenbaker near Outlook, the river is not directly used for recreation because of very wide fluctuations in level due to variations in releases from the lake during each day. These fluctuations make the river unusable at flows below 100 m^3/s.

- Optimum conditions occur around 190 m^3/s.
- Flows above 400 m^3/s threaten the regional park and golf course.

Saskatoon Area

Around Saskatoon the river is used for a wide range of activities.

Water skiing and motor boating occurs upstream of the Saskatoon weir.

- Can operate at flows down to 42.5 m^3/s but safe area is limited.
- Flows of 55 to 110 m^3/s are optimal.
- Flows of over 550 m^3/s produce hazardous velocities.

Board sailing is best at flows around 190 m^3/s.

- flows below 55 m^3/s are too low.
- high flows are not a problem.

Recreational canoeing and kayaking can be practised at almost any flow.

- Flows over 55 m^3/s improve opportunities.
- Velocities become dangerous above 450 m^3/s.

Competitive canoeing and rowing requires very low velocities.

- Minimum flows of 42.5 m^3/s are sufficient.
- Optimum flows are about 55 m^3/s.
- A flow of 75 m^3/s produces velocities above accepted standards for competition.

Tour boats operate on the river in Saskatoon.

- Can function at minimum flows of 42.5 m^3/s but area of operation is limited.
- Good operating area at about 75 m^3/s or more.
- Area of operation expands up to about 450 m^3/s.
- Safety becomes a problem at about 650 m^3/s.

Swimming, wading and sunbathing occur in some areas although these activities are not recommended due to the current.

- Flows in the 80 to 220 m^3/s range are best.
- Flows of 450 m^3/s flood all the river bed sand so no beaches are available.

Riverside parks rely on the river for aesthetic appeal.

- Flows of 80 to 220 m^3/s provide the most appealing river.

Downstream of Saskatoon

Downstream of Saskatoon the river bed changes from sand to cobbles and rocks. Recreation use is less intense. The river is a designated canoe route and some fishing occurs. Flows similar to those in Saskatoon would be desirable.

FISH AND WILDLIFE

Desirable flows for fish would be similar to those upstream of the lake.

- Flows of 84 to 210 m^3/s provide good to optimum habitat.
- Flows above 63 m^3/s are fair.
- Maximum flows of 420 m^3/s provide flushing.

IRRIGATION

Irrigators along the South Saskatchewan River experience difficulties with intakes. The greatest difficulty results from the fluctuating flow which requires frequent moving of portable intakes. In general irrigators have developed intake facilities that can accommodate the common range of flows from 42.5 to 400 m^3/s.

FERRY TRANSPORTATION

There are five ferries in this reach: Weldon, Fenton, St. Laurent, Hague and Clarkboro.

At Weldon Ferry the minimum operating flow is 53 m^3/s. Preferred flows are about 210 m^3/s. At flows greater than 300 m^3/s the current causes problems and above approximately 1 500 m^3/s the ferry is shut down.

At Fenton Ferry the minimum operating flow is about 50 m^3/s. Preferred flows are about 310 m^3/s. No maximum flow was identified.

At St. Laurent Ferry the minimum, preferred and undesirable high flows are 50, 210 and 1 150 m^3/s.

At Haque Ferry the minimum, preferred and high flows are 52, 190 and 1 900 m^3/s.

At Clarkboro Ferry these flows are 50, 150 and 300 m^3/s.

SUMMARY

Although optimum flows for all users do not coincide, it was possible to identify flow ranges that generally overlap most of the user preferences:

1 000 m^3/s and over	Flood risk
400 to 1 000 m^3/s	Unacceptable due to hazard to ferries, recreation and erosion
150 to 400 $^3/s$	Useable with limitations due to strong currents
60 to 150 m^3/s	Preferred
42.5 to 60 m^3/s	Useable with limitations on ferries
42.5 m^3/s and less	Unacceptable to most users

3.4.3.6 SSEWS System. The SSEWS system provides water for irrigation, industrial, municipal, recreation and wildlife uses. This system was designed and built with these uses planned so it generally meets all these requirements at present. The industrial and municipal demands are given high priority and are a small proportion of the total demand so they are consistently met in all alternative scenarios.

IRRIGATION

The SSEWS system has a reliable source of water at Lake Diefenbaker and irrigation development has been intense with high capital costs on the assumption that no shortages will occur. For evaluation purposes this firm water supply with no shortages has been assumed to continue and the evaluation criteria was based on the area that can be irrigated.

RECREATION

Although recreation developments at Blackstrap and Little Manitou lakes are assured of a water supply from the SSEWS system, recreation is the lowest priority and the lake levels are allowed to fluctuate to store water for other users. The stability of these lakes for recreation use changes if other users of the system change.

BLACKSTRAP LAKE

The following summarizes Blackstrap Lake ranges:

534.47 m (FSL) or higher	Flood damages
534.2 to 534.47 m	Preferred
533.4 to 534.2 m	Usable with some limitations
525.8 to 533.4 m	Severe negative impacts
525.8 m or less	Below outlet

LITTLE MANITOU LAKE

The following summarizes Little Manitou Lake ranges:

497.2 m or higher	Flood damages
493.47 to 497.2 m	Undesirable high
492.56 to 497.2 m	Preferred
492.56 m or less	Unacceptable

TOTAL DIVERSION

Since the water diverted to SSEWS system is lost to the main river, the average annual total diversion is an important consideration.

3.4.3.7 Swift Current Creek.

DUNCAIRN RESERVOIR

In addition to functioning as a water supply reservoir for irrigation, Duncairn Reservoir supports municipal water supplies, recreation, fish and waterfowl.

Recreation users prefer levels near full but have adapted facilities to a fairly wide range of levels. The preferred range is from 803.72 m to FSL (807.72 m).

Sport fish including walleye, perch and pike thrive in Duncairn Reservoir. At high water levels, (approaching FSL) the reservoir has more fish habitat. Fisheries managers prefer minimum depths of about 10 m (801 m) in winter to ensure winter survival of a breeding population to replenish stocks when water levels rise later. Therefore, the fishery criteria suggests desirable levels are as near to FSL as possible with absolute minimum levels of about 801 m.

Waterfowl use of Duncairn Reservoir is mainly for fall staging. Although higher levels provide modest increases in water area, the main value of the reservoir is its existence as a reliable, permanent water body for night roosting. Water levels are not critical.

Municipal water supplies have traditionally been assured by reserving a sufficient volume of storage exclusively for this use. Water supply studies indicate that irrigation water use could draw the reservoir down to 799.25 m without endangering the municipal water supplies in the historic droughts.

The main water user, irrigation, would prefer that Duncairn Reservoir be kept as full as runoff conditions permit but in order to utilize the water, the lake must be drawn down. Therefore, for irrigation high levels are desirable but a wide operating range to maximize usable storage is also important.

The following summarizes the Duncairn Reservoir ranges:

807.72 m (FSL) and over	Flood damages
803.72 to 807.72 m	Preferred
801 to 803.72 m	Usable with some limitations
790.8 to 801 m	Usable with significant limitations
790.8 m or lower	Unacceptable

IRRIGATION

The reliable base flow of Swift Current Creek is inadequate to sustain significant irrigation development in drought periods. Therefore, to take advantage of the variable water supply, irrigation has been developed beyond the assured water supply and when necessary shortages in the supply are managed by rationing. The frequency of shortages is critical to the success of irrigation developments. The second basic measure of irrigation success is the area under irrigation.

4.0 MANAGEMENT STRATEGIES: SHORT-TERM PLANNING

The short-term planning was intended to develop recommendations to deal with the immediate issues in the study area as defined in the South Saskatchewan River Basin Study Issues Documentation Technical Appendix. In the short-term, it was assumed that infrastructures and regulations that are currently in place, and projects that have been initiated or committed will continue, but no allowance for major changes in the infrastructure or regulatory structure was anticipated.

The year 2000, ten years after the completion of the study, is the time horizon used for the short-term. The anticipated Alberta water supply and projected water uses for the year 2000 were used.

Although the discussion in this section concentrates on the short-term conditions, it should be noted that, in developing conclusions and recommendations, the results of the long-term and system limit studies were also taken into account.

4.1 BASIN-WIDE ISSUES ASSOCIATED WITH THE RIVER

This section deals with those issues which are common to most of the basin but are not related to water quality. In general, the issues in this group could have widespread implications for water management in the study area. The issues are as follows:

Quantity of Water Coming from Alberta
Indian Land Claims

Each of the above issues is discussed in some length in the following pages. Background information, analysis, conclusions and recommendations are provided for each issue.

4.1.1 Issue: Quantity of Water From Alberta

This section deals with water quantity issues that are relevant to more than one component of the basin.

4.1.1.1 Background. Approximately 98 percent of the water available for management in the South Saskatchewan River Basin in Saskatchewan originates in the headwaters upstream in Alberta. Alberta has water use projects in place that substantially alter the quantity of water reaching Saskatchewan. Additional opportunities exist in Alberta for water development which could further reduce the flow. Planning in Saskatchewan must allow for the developments in Alberta.

4.1.1.2 Analysis. The South Saskatchewan River has been recognized by Alberta, Saskatchewan and Canada as the only major source of reliable water supply for southern Alberta and southern Saskatchewan. Ever since major irrigation developments began in Alberta early in this century, the impacts on the flow of the river have been monitored closely. The following summarizes the development of irrigation in Alberta:

The quantity of water used each year varies with the weather conditions. In recent years irrigation water use has averaged about 1 800 000 dam^3. This included losses and water applied to the fields.

Other uses have little impact on the flow reaching Saskatchewan. The human population of over 1 000 000 in the Alberta portion of the basin uses significant quantities of water but after the return of treated effluent to the river, the net depletion is only about 60 000 dam^3. Hydro-electric generation projects store summer flows to augment winter generation. Over the annual cycle, the hydro projects do not use any water and they augment the winter flows which enhances the river for Saskatchewan uses such as fisheries and hydro. Low flow augmentation also improves water quality.

By the 1960s the three Prairie Provinces and Canada decided that, although water uses were not greatly changing the natural flows at that time, all planning major projects that could be impacted by changing flow patterns. Alberta was planning large irrigation developments. Saskatchewan had completed the E. B. Campbell hydro station on the Saskatchewan River and was building the Lake Diefenbaker project with PFRA. Manitoba had completed the Grand Rapids hydro project on the Saskatchewan River and Kelsey hydro project on the Nelson River and was planning several more Nelson River hydro projects.

TABLE 1	HISTORICAL IRRIGATION DEVELOPMENT IN ALBERTA
YEAR	HECTARES
1920	73 000
1930	138 000
1940	166 000
1950	182 000
1960	143 000
1970	259 000
1980	356 000
Present (1987)	544 000

The three Prairie Provinces and Canada agreed that some equitable sharing of the flow of interprovincial rivers was necessary. Agreement was equally important to all three provinces. The upstream provinces needed to know how much water was available for their developments and how much must be passed on, and the downstream provinces needed to know how much of the natural flow they could depend upon. With the general topography of the southern prairies sloping from the west to the east, Saskatchewan was both downstream and upstream on the important southern streams.

It was obvious that the agreement would have to allow for some use of water upstream while assuring that the rivers were not completely dried up in the downstream jurisdictions. It was concluded that the fairest sharing would be on a 50/50 basis. That is, the upstream province can use 50 percent of the natural flow and must allow 50 percent to flow downstream. On the Saskatchewan River system, Alberta can use up to 50 percent of the flow, Saskatchewan will receive 50 percent from Alberta, plus its own local flow. Saskatchewan can use up to 50 percent of the total water available from Alberta and from local flow and must pass 50 percent on to Manitoba.

The Master Agreement on Apportionment was finalized in 1969 based on equal sharing of the water. However, because of the existing developments and known needs on the South Saskatchewan River several additional special provisions were included:

1. Although the South Saskatchewan River and the Red Deer River enter Saskatchewan separately and join a short distance into Saskatchewan, it was agreed that the flow of the two rivers could be totalled for the apportionment calculation. This allows Alberta greater flexibility on deciding where to develop its water uses within the basin.

2. The Master Agreement specifies that the balance is to be on an annual basis. This allows the upstream jurisdiction to get credit for the release of water from storage in the winter. The Alberta/Saskatchewan Agreement uses the calender year while the Saskatchewan/Manitoba Agreement uses the year from April 1 to March 31.

3. In order to ensure that short-term flows within the year are not too extreme, there is a general "reasonable" provision and for the South Saskatchewan River which Saskatchewan cannot control upstream of Lake Diefenbaker there is a specific provision that the flow must be at least 42.5 m^3/s or one-half of the natural flow to ensure some basic flow in this reach of the river.

4. By 1969, Alberta had developments and commitments to projects which could require 2 590 000 dam^3 of water. It was agreed that Alberta would be allowed to divert this quantity of water even if it exceeds 50 percent of the natural flow. If this provision had been in place from 1912 to 1986 it would have been applied in three years as listed in Table 2.

The Master Agreement establishes the Prairie Provinces Water Board with members from the three Prairie Provinces and Canada to monitor the apportionment.

Because of the impracticality of developing uses for flows that will not be available almost every year, Alberta cannot use its full 50 percent in wet years. In recent years Alberta has passed an average of 83 percent of the natural flow to Saskatchewan. Alberta has never actually used its full 50 percent of the natural flow. The closest that it has come was in 1984 when Saskatchewan received 59 percent of the natural flow which was a very low 5 205 000 dam^3.

Since 1984 Alberta has developed and committed to additional storage and water uses. Water balance studies which provide for these committed projects indicate that by the year 2000, the average annual delivery of water to Saskatchewan will be reduced to 70 percent of the natural flow.

The Government of Alberta presently has no plans for significant additions to the water use and currently considers further developments to be impractical.

Although all of the most economical opportunities for water development in Alberta will be established by the year 2000 and current Alberta policy precludes further significant development, Saskatchewan must allow for the possibility of continued growth of water use in Alberta. Water supply studies were completed for possible far future scenarios with additional water developments in Alberta. Since Alberta's present developments can use the full Apportionment flow in the driest years, uses can only be expanded by using more of the share in wetter years. Since the drought years are the limiting factor for Saskatchewan development potential, additional Alberta developments will not make the driest years worse. Saskatchewan's highest priority needs such as municipal, industrial, irrigation and minimum flows, which are secure in low runoff years now, will continue to be secure in the far future. Saskatchewan's lower priority uses such as hydro-electric generation which take advantage of the extra water when it is available will have extra water less frequently if Alberta uses continue to expand.

TABLE 2	DROUGHT YEAR APPORTIONMENT		
Year	Natural Flow dam^3	Alberta Share dam^3	Saskatchewan Share dam^3
1931	4 970 000	2 590 000	2 280 000
1941	4 820 000	2 590 000	2 230 000
1944	5 140 000	2 590 000	2 550 000

IN SUMMARY:

- Alberta has never used its full 50 percent of the natural flow. The closest was 41 percent in 1984 which was the lowest natural runoff since the 1940s.

- If the driest year on record, 1941, had occurred in the 1980s, Alberta uses would have been very close to 50 percent.

- If the current level of development had been in place from 1912 to 1986, Saskatchewan would have received an average of 80 percent of the natural flow.

- By the end of the century when current development plans in Alberta are implemented the average delivery to Saskatchewan might be reduced to about 70 percent of the natural flow and Alberta will be using its full allocation in about 20 percent of the driest years.

The Master Agreement on Apportionment appears in Appendix B of this document.

4.1.1.3 Conclusions and Recommendations.

1. The Master Agreement on Apportionment ensures that Saskatchewan will always receive an equitable share of the flow of the South Saskatchewan River from Alberta.

2. When planning developments, and water use in Saskatchewan it must be recognized that, in future low flow years, Alberta will be utilizing its full allocation under the Master Agreement on Apportionment.

3. Public education to explain how the Master Agreement on Apportionment permits all of the concerned jurisdictions to rationally manage their resources without unreasonably infringing on their neighbours, is needed.

4.1.2 Issue: Indian Land Claims

This section deals with issues that are relevant to more than one reach of the river.

4.1.2.1 Background. Water resource management must take into account the potential opportunities and complexities that may be created by Indian Reserves. There are four Reserves in the South Saskatchewan River Basin. Two of these, Muskoday and John Smith, are located adjacent to the river. Additional areas could be added as outstanding land entitlements are settled.

4.1.2.2 Analysis. The Reserves interface with the water resource in two ways: water can be a significant contributor to economic and social prosperity and water developments upstream or downstream may be limited by the special status of Reserve land.

On the arid prairie, where water supply is commonly a limitation to the productivity of land for agricultural, industrial and municipal growth, the availability of adequate supplies of water can affect the usefulness of the land. Although only modest use is made of the river by the existing reserves, the availability of this water could open opportunities on existing or future reserve lands.

There has been a tendency for the Reserves which are established under federal authority to avoid submitting to provincial regulations. The legal implications represent a complex constitutional issue which is beyond the immediate water management issue. Since the province, through SaskWater, has responsibility for managing the overall river, it is necessary that SaskWater be fully aware of what happens to the water in the Reserves. Since the Reserves are a minor area compared to the total, their water use is unlikely to significantly impact outside areas, but water developments outside the Reserves could significantly change opportunities in the Reserve. Therefore, SaskWater should have Reserve uses registered in the same way as non-reserve uses are registered in order to protect these uses.

Reserve lands might impact on water resources through the special status of Reserve Lands. Water is a fluid which tends to ignore jurisdictional lines drawn on maps by humans. In order to use the water, developments such as dams and reservoirs may be needed which change the fluid boundary and may interfere with man-made boundaries. Expanded or future Reserves which may be located adjacent to water to take advantage of the opportunities related to the water need not unduly limit other upstream or downstream opportunities if appropriate provisions are included in grants to accommodate the water resource management.

4.1.2.3 Conclusions and Recommendations.

1. The water resource can enhance opportunities for economic and social growth for Indian Reserves.

2. All water developments on Reserves should be registered with SaskWater in order to protect their use.

3. All future Reserve land grants associated with water should include provision to avoid compromising upstream or downstream water developments.

4.2 BASIN-WIDE WATER QUALITY ISSUES

This section covers those water quality issues which are common to most portions of the basin. For example, eutrophication is a common problem to all water bodies in the prairie region and the study area is no different. The basin-wide water quality issues in the study area are as follows:

Quality of Water Coming From Alberta
Eutrophication
Organic Contaminants
Salinity in the South Saskatchewan River
Mercury

Each of the above issues is discussed in some length in the following pages. Background information, analysis, conclusions and recommendations are provided for each issue.

4.2.1 Issue: Quality of Water From Alberta

This section deals with water quality issues that are relevant to more than one component of the basin.

4.2.1.1 Background. Approximately 98 percent of the water available for management in the South Saskatchewan River Basin in Saskatchewan originates in the headwaters upstream in Alberta. This water is used by approximately 40 percent of the people in Saskatchewan for municipal supplies through the systems operated by the three largest cities; Saskatoon, Regina and Moose Jaw; and many smaller towns. Other uses include major irrigation projects, industries, recreation, fisheries and wildlife. The South Saskatchewan River is a high quality source of supply for its users and it is important for the economy and well-being of Saskatchewan that it continue.

4.2.1.2 Analysis. In Alberta, there are roughly a million people, diverse industries and hundreds of thousands of hectares of irrigation development which use the South Saskatchewan River and its tributaries for water supply and discharge of treated effluent. The magnitude and diversity of the economy and social structure of southern Alberta have the potential to significantly pollute the South Saskatchewan River. The economy of southern Alberta has experienced rapid growth and is expected to continue to expand.

The quality of water at the Alberta border is extensively monitored. Analysis of the recorded data indicates that the water arriving from Alberta is of very good quality for all of the uses made of the river in Saskatchewan. Trend analysis on the water quality indicates that the general water chemistry is virtually unchanged relative to historically recorded values.

The major sources of pollution, such as the large cities and industries, are all required to provide substantial levels of treatment of their wastes before discharge to the rivers. The cumulative effect of water from small towns and agricultural development, which are not required to provide similar treatment, could be considerable. The rivers are an important resource within Alberta and protection of the water quality for internal Alberta needs provides Saskatchewan protection from undue damage.

The Master Agreement on Apportionment provides for the Prairie Provinces Water Board to consider and make recommendations on water quality concerns. The Board has adopted water quality objectives for identified transboundary river reaches for both the Red Deer and South Saskatchewan Rivers. In addition to reach-specific objectives to protect existing uses, the Prairie Provinces Water Board is establishing management principles which will ensure that all reasonable and practical measures will be taken to maintain existing quality if it is better than the proposed objectives and to encourage an improvement in water quality.

4.2.1.3 Conclusions and Recommendations

1. Results of the South Saskatchewan River Basin Study should be considered by Prairie Provinces Water Board in establishing the transboundary objectives.

2. The use of ecosystem objectives should be encouraged, in addition to specific constituent objectives, and trend assessments, to provide the proper information for protecting the basin water quality.

3. Monitoring of the water quality at the provincial boundary should be continued, under the supervision of the Prairie Provinces Water Board, and the objectives should be adjusted as appropriate to take into account potential pollutants resulting from upstream developments.

4.2.2 Issue: Eutrophication

This section deals with water quality issues that are relevant to more than one component of the basin.

4.2.2.1 Background. As discussed in the section on Lake Diefenbaker, eutrophication is not a major problem on the largest lake in the study area. However, it is a problem in most of the other water bodies in the basin. In the prairie region most bodies of water from small farm dugouts to the water supply reservoirs such as Duncairn Reservoir in the Swift Current Creek basin and the lakes in the SSEWS system, commonly experience periods of excess algal and weed growth. Eutrophication is most often associated with standing water, but problems may also occur in flowing water at locations such as downstream of municipal sewage outfalls. Eutrophication limits the uses of water. Toxic substances are produced by some algae which are poisonous to people and livestock. Additional limitations include the depletion of oxygen resulting from the decaying of dead plant material, taste and odour which requires expensive treatment in municipal supplies, and physical impacts such as plugged pumps and irrigation nozzles.

4.2.2.2 Analysis. Eutrophication of small prairie water bodies is a common occurrence. Shallow water tends to warm quickly, encouraging plant growth. Natural and man-made nutrients in the soils enrich runoff. Oxygen depletion, which may result under ice cover, permits the recycling of nutrients which would otherwise be permanently trapped in the sediments.

Although much of the cause of eutrophication is natural, human activities can add to the natural process. The nitrogen and phosphorous that is used to fertilize agricultural crops also fertilizes aquatic plants if it reaches a water body. Natural soil nutrients also reach the water through erosion caused by tillage practises. Livestock wastes which are carried to the water add undesirable nutrients. Irrigation and livestock can add nitrates to the ground water and can reach surface water bodies through ground water discharge. Recreational users of water can contribute to the nutrient levels through inappropriate waste disposal and activities that stir up bottom sediments.

Although the water received from Alberta (measured at the Alberta/Saskatchewan boundary), has a relatively high level of phosphorus, it does not exceed current water quality objectives. Most of the phosphorus settles or is consumed biologically by plant growth in the upstream end of Lake Diefenbaker. By the time water is released through Gardiner Dam, its quality is among the highest in southern Saskatchewan.

It should be noted that eutrophication is a natural process through which water is cleansed. Plant growth consumes nutrients and other impurities in the water. Although excess algae is undesirable, it does improve downstream quality.

4.2.2.3 **Conclusions and Recommendations.**

1. Land management practices near the shore of streams and lakes which do not contribute to eutrophication and which reduce or eliminate contributions from elsewhere in the watershed, must be encouraged.

2. Future water developments which may impact on water resources must carefully consider, at the planning stage, the potential to cause or contribute to eutrophication.

3. The public must be informed about the process and effects of enrichment, and how they can help by minimizing the human contribution to the process. This would reduce unrealistic expectations concerning the quality of prairie waters.

4. Monitoring of water bodies must continue in order to document the effectiveness of nutrient-limiting control strategies and to identify areas requiring control strategies.

4.2.3 Issue: Organic Contaminants

This section deals with water quality issues that are relevant to more than one component of the basin.

4.2.3.1 **Background.** Organic chemicals are used in the South Saskatchewan River Basin as they are across the country and indeed around the world. The substances are known to exist in the basin but their direct and indirect effects on water uses are difficult to quantify. Of the chemicals known to be used in the basin, some occur at levels which do not appear to affect uses while others are not directly monitored so their levels are unknown. A toxicity study of basin waters showed that the combined effect of all substances in the water did not appear to adversely affect aquatic life.

4.2.3.2 **Analysis.** Organic compounds originate from sources such as agricultural and urban pest control chemicals, industrial and manufacturing effluents and spills, sewage treatment plants, landfill leachates and storm water runoff. The compounds enter the water by direct application, surface runoff or discharge, and/or by wet (rainfall) or by atmospheric deposition. Organic compounds may also be from natural sources.

Anthropogenic organic compounds, once in surface water, have the potential to impair water for drinking water, livestock, and irrigation purposes, as well as for use by aquatic life.

A wide range of pesticides are routinely monitored in the basin waters. Detectable levels for most are well below Canadian Water Quality Guidelines. Lindane and PCB's are occasionally found at levels exceeding the guidelines. Some pesticides are used in the basin, however, but are not monitored. Similarly, very little is known about the organic compounds which exist in municipal and industrial point sources. Cumulatively, these point sources may have as great or greater impact on the water quality as the seasonal, non-point sources.

Depending upon their solubility, organic compounds are found in water, on sediments, or associated with biota. Special sampling programs monitor each compartment, whereas routine monitoring examines only water. It is feasible, therefore, that compounds are in the environment but are simply not detected in water samples.

4.2.3.3 **Conclusions and Recommendations.**

1. Water quality objectives prepared for the basin should be accepted.

2. Multi-media monitoring should be implemented in the basin, at least on an occasional basis.

3. Ecosystem objectives should be explored as more information becomes available.

4. Effort should be devoted towards quantifying organic compounds from point sources.

5. Agriculture and Environment agencies should co-operatively develop a process and records for articulating what pesticides are used, where they are used, when they are used, how much is used, how they are applied, and what the pesticide use trends are.

4.2.4 **Issue: Salinity in the South Saskatchewan River**

This section deals with water quality issues that are relevant to more than one component of the basin.

4.2.4.1 **Background.** The concentration of dissolved salts in water can limit its usefulness for some purposes. The South Saskatchewan River has a naturally low level of salinity and is an ideal source of water for many users. There is concern that development in the basin may increase the salinity and limit the uses for which the water is suitable.

4.2.4.2 **Analysis.** Water is an efficient solvent which tends to dissolve even relatively stable minerals upon contact. All natural waters have some dissolved solids. A common measure of the mineral quality of water is Total Dissolved Solids (TDS).

Natural and man-made processes contribute to the concentration of Total Dissolved Solids in a river. Ground water is more mineralized than surface water due to the relatively long contact time of the water with the soil and resulting increased time for dissolution of minerals from soils and rocks. Since ground water discharge tends to provide a large portion of the base flow of rivers, rivers tend to have higher mineral concentrations during low flow periods. Evaporation from water surfaces and plant transpiration removes pure water and leaves the minerals in the reduced volume of water, resulting in increased an concentration of dissolved solids in the remaining water.

Most human uses of water tend to contribute to the mineralization. Reservoirs increase water surface area and therefore evaporation; sanitary and industrial uses of water add dissolved minerals; and, irrigation concentrates dissolved substances as plant transpiration depletes the pure water and return flows are exposed to extended duration of soil contact. Reservoirs also change the seasonal distribution of dissolved solids by providing mixing of the annual variations of mineral content, resulting in a more uniform concentration over the annual cycle.

The impact of dissolved minerals in water on various users varies with the composition of the minerals. Modest concentrations of Total Dissolved Solids in water are harmless to most users and are beneficial to many. The water use in the South Saskatchewan River Basin that is most sensitive to dissolved solids is irrigation. Plants cannot draw water into their tissues if the water is too mineralized. Sensitivity to Total Dissolved Solids varies with crop type and with the proportion of sodium. The Canadian Water Quality Guideline as established by the Canadian Council of Resource and Environment Ministers ranges from 500 to 3 500 mg/L of TDS and from 2 to 102 for sodium adsorption ratio (SAR) depending on the plant species. The Saskatchewan objective, which reflects the crops grown in the provinces, is 700 mg/L of TDS and SAR values of 4 to 12.

Monitoring programs measure a wide range of substances that make up the dissolved mineral content of water. It has been found that, in the South Saskatchewan River, no individual salts are at critical concentrations. Chloride, however, should be watched carefully. The Total Dissolved Solids concentration varies from 330 to 415 mg/l and SAR is less than 1.

There is heavy existing and potential development of the South Saskatchewan River in Alberta and Saskatchewan. Much of the potential development is for irrigation which may alter the Total Dissolved Solids concentrations in the river. Concern has been expressed that the continued development might reduce the mineral quality of the water in downstream portions of the basin. Levels are well below those of concern, and no current or foreseeable uses of the water will be limited by its salinity.

As technology advances, better methods of selecting and operating irrigation projects are being implemented. Areas with highly saline soils are now identified and avoided for irrigation development. Water application methods such as sprinklers, which minimize excess return flows, are becoming more common.

4.2.4.3 **Conclusions and Recommendations.**

1. It is recommended that an objective of 500 mg/L TDS and of 3 for SAR be accepted for the basin.

2. Monitoring of the river for salinity should continue. If increasing concentration trends become evident or if the levels approach or exceed these objectives, detailed review of this issue would be triggered.

3. Monitoring of return flows and effluents is needed to ensure that levels do not approach those of concern and that impacts on the mainstem are not significant.

4. Future irrigation development should only proceed after sufficient predevelopment investigations are completed to ensure that unnecessary additional salinity is avoided.

5. Where existing projects are upgraded and renovated, conversion to lower return flow technologies such as sprinklers rather than gravity should be encouraged.

4.2.5 Issue: Mercury

This section deals with water quality issues that are relevant to more than one component of the basin.

4.2.5.1 Background. Prior to the 1960s, the release of inorganic mercury was not recognized as a serious threat. In the 1960s the environmental and human health dangers of mercury, in the form of methyl mercury in fish, became apparent as a result of a major poisoning incident in Japan. In the late 1960s testing in the South Saskatchewan River identified abnormal amounts of mercury contamination.

4.2.5.2 Analysis. Mercury is known to be present in some aquatic biota and sediments in the basin. Aquatic organisms bioaccumulate methyl mercury even though concentrations of mercury in the water column may be extremely low. It has been detected in a small number of water samples from the basin, but the levels are generally well below the Canadian Water Quality Guideline to protect aquatic life.

The source of mercury in the basin, a chlor-alkali plant upstream of Saskatoon, was eliminated in 1981. The concentration of mercury in the sediments has since diminished to levels found elsewhere in the basin. A fish monitoring program carried out by Saskatchewan Parks and Renewable Resources regularly analyzes mercury levels in fish and issues fish-consumption guidelines.

4.2.5.3 Conclusions and Recommendations.

1. The study concludes that although mercury levels continue to be higher than desirable in fish tissue and will continue to decline over time, all reasonable efforts to control point sources have been made.

2. Monitoring for mercury in the fish of the basin should be continued and fish consumption guidelines well publicized until such time as levels are within the Canadian standard and advisories are no longer required.

4.3 ISSUES IN THE SURROUNDING DRAINAGE AREA

The majority of water management issues in the study area relate directly to the mainstem of the river. There are, however, a number of issues which relate to the surrounding drainage basin. These include the following:

Municipal Water Supplies for Communities Away From the River
Soil Salinity
Soil Conservation
Wetlands/Drainage

Each of the above issues is discussed in the following pages. Background information, analysis, conclusions and recommendation are provided for each issue.

4.3.1 Issue: Municipal Water Supplies for Communities Away From the River

4.3.1.1 Background. There are 70 communities within the South Saskatchewan River Basin which have municipal systems. Sixteen of these, including the cities of Saskatoon and Swift Current, draw their water from the South Saskatchewan River, Swift Current Creek or systems supplied from these main rivers. These 16 communities have reliable good quality water supplies. The remaining 54 communities rely on wells or local surface water sources. About half of these communities report problems with undesirable water quality, usually related to taste and odour and the mineral content, and many have to ration water during dry periods.

4.3.1.2 **Analysis.** The 54 communities that rely on local water sources range in size from 16 to 2 100 people with an average size of 328 people. More than half of these communities rely on wells for their raw water supplies.

The arid climate of the region results in inconsistent surface runoff. Surface supplies must include large storage capacity to overcome drought. The surface storage can be expensive and may add to water quality problems as evaporation concentrates minerals and the rich nutrient concentrations of prairie runoff combine with summer warmth to generate plant growth that in turn leads to taste and odour problems.

Over half of these communities use wells in order to take advantage of the natural storage and filtration provided by the ground water system. In order to obtain a reliable supply, deep aquifers, which are less sensitive to short-term climatic variations, must be used. Deeper aquifers tend to contain more highly mineralized water, leading to problems with iron, hardness and other natural mineral pollutants.

There are many difficulties in providing water supplies to very small communities. There is no opportunity to spread basic costs and, as a result, planning and engineering must be kept to a superficial level and the lowest initial cost options are selected. Considering that the area is one of the most drought-prone areas in the province, the need for planning, engineering and relatively high capital costs would be anticipated. Governments, through SaskWater and PFRA, provide some assistance with planning and building water supplies but the basic decisions have been left to the local communities.

One opportunity that might be overlooked in individual community decision-making is the regional supply system. Through regional supply systems, communities around Saskatoon, along the SSEWS system and Eston/Kindersley have access to reliable good quality water. The communities served by the regional systems do not have the frequency or magnitude of problems encountered by the other 54 communities in the study area.

4.3.1.3 Conclusions and Recommendations.

1. Combining as many small communities as possible in regional systems will spread base costs of adequate planning, engineering and infrastructure and could permit improved operation and maintenance which should create better long-term quality and security of municipal water supply.

4.3.2 Issue: Soil Salinity

4.3.2.1 **Background.** Managing the overall fertility of the soils within the drainage basin is beyond the scope of this water management study but one aspect of soil fertility that is directly related to management of the water resource is soil salinity. Soil salinity is a water management issue because water is the key agent that transports the salts that cause salinity and the management of the water can directly impact on the extent and severity of soil salinity.

Agriculture Canada, PFRA, has identified 660 000 acres of severely saline soils and 1 200 000 acres of moderately saline soils in Saskatchewan. These areas have not been defined by drainage area but the South Saskatchewan River Basin is in the portion of the province where salinity is more common due to the arid climate.

Soil salinity can reduce or completely destroy soil fertility causing agricultural production losses. The bare land that is left can be aesthetically undesirable and susceptible to wind erosion.

4.3.2.2 **Analysis.** Soil salinity can have many causes and it is often difficult to define the exact cause in any particular case. A few of the more common causes are discussed below.

Natural soil salinity occurs where the normal ground water level is close to the surface. Capillary action carries water to the surface where evaporation removes the water, leaving the salts in the surface soils. This type of salinity is common around the fringes of sloughs and other water bodies, in depressions and along slopes.

Human activities can add to soil salinity through indirect impacts. Agricultural practises can change the natural balance. Cultivation may remove deep-rooted perennial plants which intercept the ground water. Land which is kept fallow to conserve moisture tends to pass a portion of the extra water to the ground water regime which raises the water table and generates increased salinity where the water table approaches the surface.

Some more direct human causes of soil salinity also occur. Irrigation can add significant quantities of water to the ground water regime and add to soil salinity. Canals and impoundments such as water supply or sewage lagoons can add to the ground water regime through leakage.

Human activities such as water extraction from wells can lower the water table and reduce the soil salinity in local areas.

Through careful planning and design, most modern irrigation projects can be developed without creating soil salinity. The recent developments of major irrigation at Lake Diefenbaker have included comprehensive soil and subsurface investigation to avoid adding to salinity.

Water delivery and retention systems can be designed to prevent leakage or where leakage is unavoidable interceptor drains can be developed to protect against salinity damage. Where small areas of damage are unavoidable, water projects can include land purchase or other forms of compensation to ensure no individual bears the losses unfairly.

In areas where the causes of soil salinity are less directly related to specific human activities, the best solutions are usually related to land management rather than water management. Programs developed under the Canada-Saskatchewan Agreement on Soil Conservation provide technical and financial assistance aimed at reducing soil salinity and other soil problems.

4.3.2.1 Conclusions and Recommendations.

1. The impacts of water management projects on soil salinity should be minimized by:

   limiting irrigation to areas where soil and subsoil conditions are known to be capable of sustaining long term productivity without generating salinity;

   designing water conveyance and water retention works to minimize leakage into the subsoil;

   reducing leakage from existing facilities as a part of normal maintenance and upgrading programs; and,

   where water projects contribute to salinity problems, the projects should include appropriate land purchase or compensation programs to ensure that land owners do not suffer unfair losses.

2. The programs of the Canada-Saskatchewan Agreement on Soil Conservation provide technical and financial assistance to reduce soil salinity.

4.3.3 Issue: Soil Conservation

4.3.3.1 Background. Wind and water erosion of soils impacts on the water resource by physically increasing sediment which fills reservoirs, streams and lakes and by carrying pollutants into these waterbodies.

4.3.3.2 Analysis. Research demonstrates that the quality of agricultural soils in southern Saskatchewan are deteriorating with time as cultural practises encourage wind and water erosion. As organic content of soils break down the processes are aggravated.

The federal and provincial governments have recognized soil erosion as a serious problem and recently entered into joint programs to assist farmers in preventing soil erosion.

4.3.3.3. Conclusions and Recommendations.

1. The policies of the National Soil Conservation Program should be supported since they will benefit the water resource as well as the agricultural industry.

4.3.4 Issue: Wetlands/Drainage

4.3.4.1 Background. The southern prairies of Saskatchewan have a flat, rolling topography. The topography combines with the dry climate to produce a poorly developed natural surface drainage pattern. Much of the prairie drains across short distances into local depressions which capture runoff from a small area and return it to the atmosphere through evaporation. Since no outflow occurs, no natural channels have been eroded from these potholes.

Potholes cause agricultural losses through the loss of the flooded areas to production and the disruption to farming operations created by their discontinuity. The potholes provide an inconsistent opportunity for waterfowl because they are not usually permanent.

4.3.4.2 Analysis. Agricultural drainage has been a widespread activity aimed at developing outlets from many of the potholes in order to bring flooded land into production and to improve efficiency of farming on adjacent lands. Initially, such efforts were undertaken through the individual initiative of land owners. This lead to many conflicts because of augmented downstream flooding problems. The provincial government began providing technical and financial assistance to encourage comprehensive land development leading to adequate outlets so the problem was not simply passed on downstream.

A multidisciplinary, multiagency Provincial Wetlands Committee with drainage expertise and wildlife expertise was established in order to review project proposals. Most agricultural drainage removes shallow, unreliable potholes which have no significant waterfowl value. However some of the project proposals will remove water that is deeper and provides significant waterfowl opportunities. The Wetlands Committee ensures that waterfowl opportunities are not ignored and in some cases opportunities are enhanced when runoff to a number of intermittent potholes can be consolidated in a few more reliable wetlands.

Although technical and financial programs directed most agricultural drainage to appropriate design and planning, some unorganized drainage continued to occur and it became necessary to enact drainage control legislation to provide for drainage which was causing downstream damages. Drainage Control is now a part of the Water Corporation Act. Permits are required before drainage occurs. Anyone damaged by unauthorized drainage can lodge a complaint and if investigation confirms the damages, corrective action, usually the closure of ditches can be required. Appeal processes are provided to ensure fair treatment.

The existing drainage assistance, review and control processes have evolved through experience and detailed study. The existing system emphasizes development of complete drainage projects which include upstream and downstream lands and, through the Wetlands Committee, take into account waterfowl opportunities.

Agricultural drainage is not a major activity in the South Saskatchewan River Basin. It is more of an issue farther east in the province. However, there are a few drainage projects that will require decisions.

Within the South Saskatchewan River Basin there has been significant opportunities to enhance the wetland area which have been developed. The major water supply systems from Lake Diefenbaker have been generally developed with provisions for addition of artificial wetlands. The diversion to the Qu'Appelle River serves large wetlands at Eyebrow Lake, Nicolle Flats, Valeport Flats and along the river. The SSEWS system includes wetlands along Brightwater Creek and at several locations along the canals. Recent major irrigation developments such as Luck Lake have included major wetlands projects. These artificial wetlands are particularly valuable since they are very stable and much less subject to drought than the natural potholes.

4.3.4.3 Conclusions and Recommendations.

1. Existing technical support, financial incentives and legislation provide an adequate framework for agricultural drainage.

2. Comprehensive programs to encourage retention and re-establishment of high quality wetlands should include adequate financial compensation for those who give up potential benefits.

3. Continued development of artificial wetlands in conjunction with other developments such as irrigation should be continued.

4.4 ISSUES UPSTREAM OF LAKE DIEFENBAKER

Upstream of Lake Diefenbaker, the water resources of the South Saskatchewan River are used to meet a variety of needs. These needs include municipal, irrigation and a variety of instream users. Many of these users are affected by water quantity. In fact the major issue in the reach is rate of flow and water level variations. Background information, analysis, conclusions and recommendations for this issue are provided on the following pages.

Water quality issues applicable to the upstream reaches of the South Saskatchewan River are discussed under section 3.5.1. Basin-Wide Issues Associated With The River.

4.4.1 Issue: Rate of Flow and Water Level Variations

This section deals with issues that are unique to the reach of river upstream of Lake Diefenbaker.

4.4.1.1 Background. The flow and water levels upstream of Lake Diefenbaker are variable which results in limited recreation use and extra costs to develop water intakes along the river. Low flows result in difficulties for water intakes, water too shallow for recreational boating and poor operation conditions for ferry crossings. High flows create hazardous conditions for recreational boating, cause erosion to the river banks and channel changes and, in very high floods, make ferry operation unsafe.

4.4.1.2 Analysis. The flow of water in the reach of the South Saskatchewan River from the Alberta border to Lake Diefenbaker is determined by a combination of natural flows and changes to the flow caused by water storage and use in Alberta. The natural flow regime tends to be low in the winter, rise through the spring to peak flows in June and July, then to recede through late summer and fall to the low winter flows. The natural flow regime can vary widely from year to year and in shorter time periods. Consumptive uses of the water in Alberta tend to be heaviest in the summer when irrigation is in progress. Alberta reservoirs also store summer flows. A substantial portion of the storage capacity in Alberta captures summer water for winter release. The flows reaching Saskatchewan have less seasonal variation than they would naturally as storage and use reduce the higher summer flows and releases from storage increase and stabilize the winter flow.

The most desirable range of flows in this reach is from 60 to 150 m^3/s. In this range there are no significant limitations to the river users. At flows from 60 down to 42.5 m^3/s the river is usable but problems with intakes and operation of the Estuary Ferry become progressively worse. At flows below 42.5 m^3/s most users of this reach find the river unacceptable for normal uses. When the flows exceed 150 m^3/s the river is usable but as the velocity of flow increases with rising flow, the river becomes more hazardous. Flows in excess of 400 m^3/s are undesirable because of erosion and the hazard to ferry operations and recreation. At flows in excess of 1 000 m^3/s the river overtops its banks, flooding low valley areas. The open water season from the end of April to the end of October is the recreation and ferry operation season when all of these flow ranges are of interest. In winter the main concern is the water intakes which may not draw sufficient water if the flow is very low. The flow ranges are summarized in the following table:

	Unacceptable (flood risk)
1 000 m^3/s ——	
	Usable with significant limitations (poor recreation, ferries, minor flooding)
400 m^3/s ——	
	Usable with some limitations (negative impacts on recreation)
150 m^3/s ——	
	Preferred
60 m^3/s ——	
	Usable with some limitations (negative impacts on some recreational activities and ferries)
42.5 m^3/s ——	
	Unacceptable (water quality, recreation, intakes and ferries)

Detailed analysis of the average monthly flows for the 75 year period from 1912 to 1986 were completed.

The results are summarized in Table 3.

TABLE 3	UPSTREAM OF LAKE DIEFENBAKER FREQUENCY OF MEAN MONTHLY FLOW OCCURRENCES 1912 to 1986			
FLOW RANGE IN m^3/s	NATURAL CONDITIONS PERCENT	1986 CONDITIONS PERCENT	SHORT-TERM CONDITIONS PERCENT	FAR FUTURE CONDITIONS PERCENT
SUMMER: April to October				
Below 42.5	0	1	0	1
42.5 - 60	0	9	9	18
60 - 150	12	25	38	38
150 - 400	45	36	33	32
400 - 1000	37	26	18	10
over 1000	6	3	2	1
WINTER: November to March				
Below 42.5	9	0	0.3	5
Above 42.5	91	100	99.7	95

Water development in Alberta has reduced the extreme variability of flows in this reach. The summer high flows are much less common and although the flow is generally lower due to water consumption, the regulating impact of the reservoirs in Alberta maintains more reliable base flows as Alberta also attempts to protect its river users from extreme droughts. Saskatchewan is assured of an equitable share of the flow under the provisions of the Master Agreement on Apportionment which is described in section 3.5.1. and Appendix B of this report. Several alternatives to improve the flow or water levels in this reach have been suggested.

In order to change the flow regime, it would be necessary to develop storage upstream in Alberta. The Province of Alberta has substantial storage capacity in the headwaters tributaries which is already stabilizing the flows to some extent. Proposals for a reservoir near the Alberta/Saskatchewan border which could regulate the flow have been considered in past studies (SNBB, 1972). Such a project would involve very high costs in terms of money, changes to the valley environment, and reduced water supply due to evaporation losses and water uses.

The water level fluctuations that accompany flow changes could be reduced by a wide crested weir. Local groups have suggested weirs near Chesterfield Flats and at other locations to stabilize water levels in segments of this reach as possible recreation projects. Analysis by SaskWater indicates that weirs on this large river would have substantial costs and would have a small beneficial effect because they would only reduce, not eliminate the fluctuations. As was the case at the Saskatoon weir, siltation of the pond could be anticipated so it might have a limited useful life. The potential use of a water-based recreational facility in this area might be small due to the distance from population centres.

Some of the difficulties of establishing intakes can be reduced or eliminated if the design is based on the best available information. Future developments and reconstruction of existing developments will benefit from the data generated by this study.

Many of the problems that river users encounter result from a lack of information on the current and anticipated flows. SaskWater has an ongoing program of monitoring upstream flows measured at Water Survey of Canada stations and weather conditions from Atmospheric Environment Service stations and projecting flow forecasts for the Saskatchewan portion of the river. Considerable effort is made to get this information to users who need the data to plan their activities but not all of the potential users take advantage of the available information.

4.4.1.3 Conclusions and Recommendations

1. The flow in this reach can be expected to be within the optimum range of 60 to 150 m^3/s about a third of the time and in the usable range from 42.5 to 400 m^3/s about 80 percent of the time in the open water season. The flow will rarely drop below this range and only rises into the dangerously high ranges for brief periods, usually in the early summer.

2. In the short-term, opportunities to change the flow or water levels in this reach through structural works do not appear feasible. If future water uses and technological changes justify consideration of structural works, the data generated through this study will assist in evaluation of options.

3. Municipalities, irrigators and others who plan developments along this reach should seek professional advice on the feasibility and design of facilities in order to take advantage of the information that is available from past measurements and studies. With appropriate design, most water use facilities can be compatible with the anticipated flow regime. As existing river intakes and recreation facilities are maintained and upgraded, efforts to improve their compatibility with the fluctuating water regime should be incorporated when practical.

4. Programs of SaskWater which generate flow forecasts and disseminate information to water users should be continued and upgraded as technology permits. River users should clearly define conditions that are critical to their use and inform SaskWater in order that appropriate warning and information can be provided.

4.5 LAKE DIEFENBAKER ISSUES

This section deals with the issues surrounding Lake Diefenbaker. As the major reservoir system in the study area, Lake Diefenbaker and its operation is the focal point for many issues. These issues are:

Fluctuating Water Levels
Eutrophication
Shoreline Management
Qu'Appelle Dam Releases

Each of the above issues is discussed in the following pages. For each issue, background information on the origin of the issues is provided, followed by an analysis of the issue, followed by conclusions and recommendations.

4.5.1 Issue: Fluctuating Water Levels

This section deals with issues that are unique to Lake Diefenbaker and its shoreline.

4.5.1.1 Background. Lake Diefenbaker is a reservoir which is used to control and regulate the flow of the South Saskatchewan River. In order to control the flow, the lake level rises and falls as water is stored and released. The lake serves many purposes. The best level for each purpose varies with the time of year. Each lake user would like to see a particular water level regime. Recreation users would like to have stable levels through the summer. Irrigation users would prefer high levels through the irrigation season to ensure that pump intakes are under water and to reduce pumping costs. Aesthetic, fish and waterfowl uses would benefit from more stable levels. For flood control and river regulation, the lake should be lowest in spring in order that it can absorb the normal higher spring and summer flows; and high in the fall so that water can be released to augment the normally low winter flows. For hydro-electric generation, maximum releases in the peak demand months of the winter are desirable.

4.5.1.2 Analysis. The recreation development on the lake has generally been designed to be compatible with the anticipated water level regime. The shoreline is publicly owned and controlled so that recreation development has been established at locations that will accommodate the anticipated water level fluctuations. Subdivisions are set back from the lake. Docks and boat launches have been built to accommodate the fluctuations. A survey of preferred elevations at the existing recreation facilities around the lake (SSRBS Technical Report E.7) identified a wide variety of preferences.

Irrigation projects use the lake as a pumping pond. The level of the lake affects irrigators in two ways: First, if the lake is below the level of the intakes, the irrigators may not be able to draw water or may have to undertake expensive temporary works to gain access to the water. In recent years SaskWater has assisted irrigators in lowering intakes so that the number of intakes out of the water at a given low lake level is less than in the past. Second, the energy required to pump water from the lake is affected by the level of the lake.

A more stable water level would be more like a natural lake which would provide the opportunity for more natural vegetation, fish habitat and waterfowl habitat.

For flood control, river regulation and hydro-electric generation, the lake level must vary in anticipation of the river flows. That is the level must be low prior to the normal high runoff period in the spring and early summer and high prior to the normal low winter flow period. Since the reservoir is large and the release rate is limited by channel and turbine capacities, the changes in level must be made over seasonal periods.

The river flows available to be managed vary from year to year. The flows can only be forecast a short time before their occurrence. Therefore, decisions must allow for a reasonable range of potential future flows. When the lake is drawn down in spring in order to manage anticipated normal summer flows, it will not fill if a drought occurs. If the lake was kept full in winter and spring in anticipation of drought, the water managers would have less ability to manage flood flows.

If the lake could be operated exclusively for the users such as recreation on the lake and irrigation from the lake, it would be operated in a different manner than if it must meet its multiple objectives. Considering only the interests of the lake users such as irrigation, cottages, boating and parks, the following ranges of elevations have been defined:

	Unacceptable, damage to dam and shore
556.86 m (FSL)	
	Usable with some negative impact on beaches and shoreline erosion
556 m ———	
	Preferred
554 m ———	
	Usable with some negative impact on recreation, boating and irrigation pumping costs
551 m ———	
	Usable with significant negative impact on recreation, boating and irrigation pumping
545.6 m ———	
	Unacceptable, damage to the dam

Since recreation and irrigation are open water season activities, these levels are most critical in the April to October period.

Modelling studies of the 75 year period from 1912 to 1986 were carried out for several scenarios. These are summarized in Table 4.

The 1986 Base Case shows the frequency of various lake levels that would have occurred if the water uses and operation patterns that existed in the mid 1980s had been held constant for the 75 year study period. The lake would have been in or above the desirable range about 70 percent of the time during the open water season.

The 2000 Base Case shows that as water uses in Alberta and Saskatchewan increase, by the late 1990s the lake level would less frequently be near full and extreme low levels would be an increasingly frequent problem if operation patterns continue as was normally the case in the 1980s. The Far Future Base Case shows that if upstream water uses continue to increase and no adjustment to operation is used, the lake would be at undesirably low levels most of the open water season.

The water uses that are expected to deplete the flows by the 1990s and that could further reduce flows in the far future will reduce the summer flows of the river, the amount of water available for summer storage at the lake will be reduced. Therefore operation scenarios which provide for less summer storage by increasing the spring lake level were tested.

At the year 2000 level of water uses, a 1 m increase in the spring level compensates for the increased water uses by raising the frequency of high levels higher than those that occurred in the 1980s.

If the far future water uses ever occur, spring levels of Lake Diefenbaker will have to be raised 2 to 4 m in order to obtain summer water levels similar to those obtained in the 1980s.

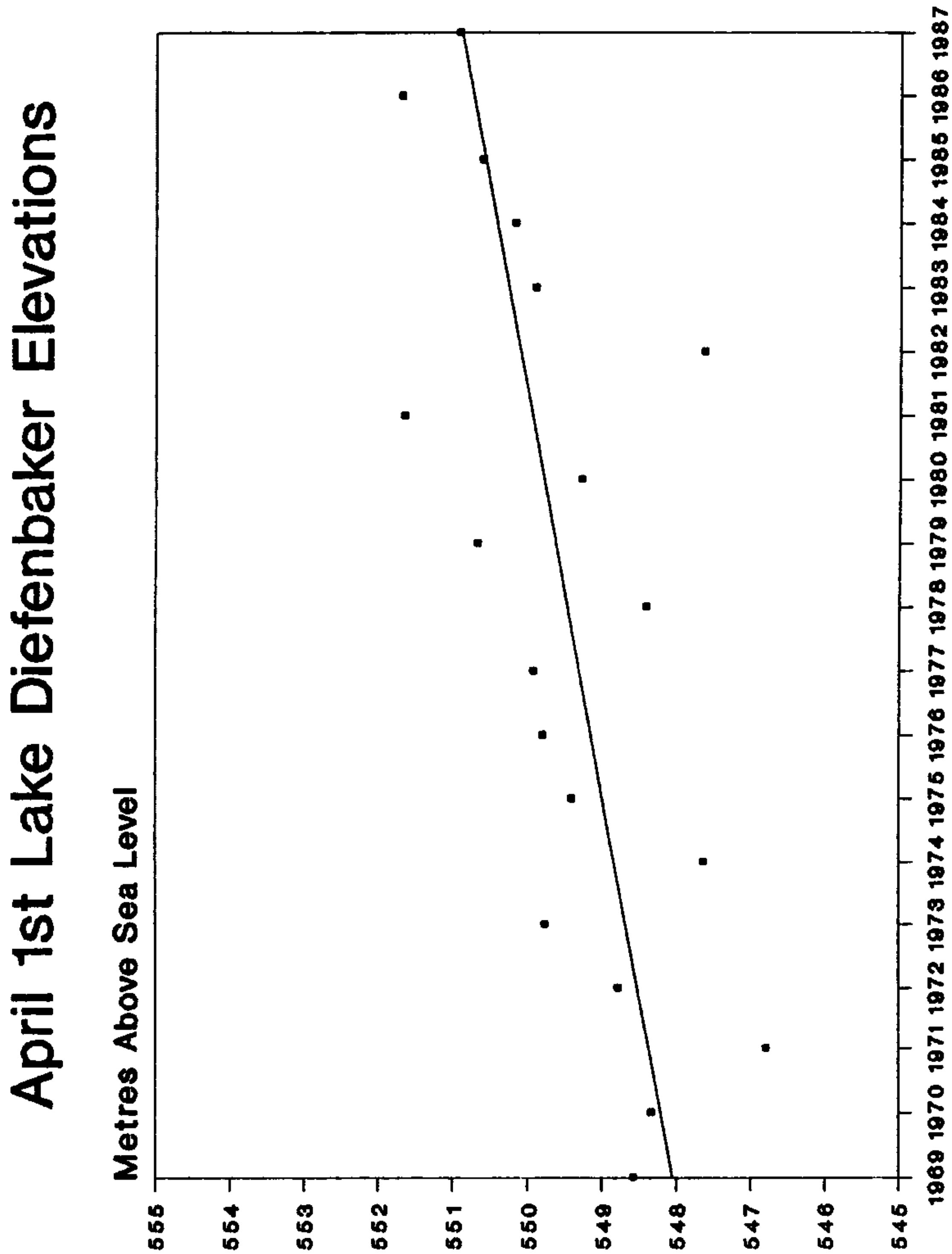
If the lake is operated higher, there may be a greater risk of downstream floods and the frequency of spills which reduce hydro generation may increase. The scenario models evaluated these occurrences and it was found that because the total flows will be reduced, the higher lake levels do not greatly increase the risks of excess downstream floods. Operation at the higher levels increases the generating head on the power turbines and increases production by more than is lost through occasional spills.

Since these analyses demonstrated that the spring levels should generally rise as upstream uses increase, a review of the historic operation was considered. Figure 7 is a plot of the historic April 1 level of Lake Diefenbaker. Although there is a wide scatter of elevations, there is a distinct rise over time.

The computer model used for the studies does not include provision for the runoff forecasts which are a part of the actual operation. The model must therefore fit average conditions where actual operation includes variations that reflect conditions such as mountain snow pack.

TABLE 4	LAKE DIEFENBAKER LEVELS MAY TO OCTOBER Percentage of Months In Each Elevation Range					
Scenario	Above FSL (556.86 m)	FSL 556.0 m	556.0 - 554.0 m	554.0 - 551.0 m	551.0 - 545.59 m	Below 545.59 m
1986 Base Case	0	45	25	27	3	0
1996 Base Case	0	28	29	32	11	0
Far Future Base Case	0	20	18	37	25	0
1996 1 m less drawdown	0	55	26	19	0	0
Far Future 1 m less drawdown	0	28	19	41	12	0
Far Future 2 m less drawdown	0	33	24	41	2	0
Far Future 4 m less drawdown	0	44	44	12	0	0

FIGURE 7 APRIL 1 LEVEL OF LAKE DIEFENBAKER



4.5.1.3 Conclusions and Recommendations.

1. As upstream water use and storage has changed the flow regime, the operation of Lake Diefenbaker has evolved to compensate. This evolution which will mainly take the form of reduced winter drawdown will likely continue into the future as storage and use of summer flows reduce the need for storage at Lake Diefenbaker. Although it will reduce with time, lake level variation will still be necessary for flood control, river flow regulation and hydro generation.

2. Lakeshore facilities for irrigation and recreation should be designed to accommodate the full range of potential lake levels in order that the river regulation capabilities of the reservoir are not compromised by easily avoided artificial limits.

3. Operation should maximize the level during the irrigation and recreation season, without unreasonably increasing the risk of uncontrolled high flows downstream.

4. Forecasting of inflows, long-term seasonal flow variability and all uses of the lake should be considered in the day to day operation of the lake control works.

4.5.2 Issue: Eutrophication

This section deals with issues that are unique to Lake Diefenbaker and its shoreline.

4.5.2.1 Background. Lake Diefenbaker is beginning to show signs of eutrophication. The west end of the lake has elevated nutrient levels relative to the rest of the lake and isolated cases of near shore alga blooms have been noted. The main lake is in a meso- to oligotrophic state. There is concern that with time the enrichment may spread to other areas of the lake. The lake is a source of water for about 40 percent of the province's population and is a major recreational resource. Extra drinking water treatment costs may be required and the recreational potential may be restricted if eutrophication is allowed to progress.

4.5.2.2 Analysis. The trophic state of a lake is related to the concentration of nutrients in the water. It is manifested by algal and macrophyte productivity. Excess plant material can cause problems such as degradation of shoreline aesthetics and odour, and can also cause undesirable conditions for fish due to oxygen depletion which occurs when large amounts of plant material die and decompose.

Plant productivity in a lake is controlled by factors such as temperature, light penetration and availability of nutrients. Nitrogen and phosphorus, the major plant nutrients, originate from both human and natural sources. Phosphorus is the limiting nutrient in Lake Diefenbaker. Detailed studies of the phosphorus balance of the lake, including the development of a trophic model (SSRBS Technical Report D.5), were undertaken to examine sources, behaviour and effects, and to explore alternatives for control actions.

The major source of phosphorus to Lake Diefenbaker is the South Saskatchewan River which receives phosphorus from upstream municipal, agricultural and other activities. Natural sources of phosphorus are thought to outweigh man-made sources. The average annual total phosphorous input to the lake from the river was calculated to be 945 tonnes. Smaller quantities reach the lake from local runoff, in the dust and precipitation that fall on the lake, from human uses of the lake (e.g. swimming and boating), and livestock. Most of the phosphorus is attached to the sediments which is carried by the South Saskatchewan River and deposited in the lake. Approximately half of the phosphorous in the sediments is not biologically available. The other half could theoretically become available if the oxygen content of the water in contact with the sediments were depleted. Oxygen concentrations have generally been high in Lake Diefenbaker and leaching of phosphorous from the sediments is considered to be negligible.

Dissolved phosphorous is immediately available for plant growth. Although dissolved phosphorous is only a fraction of the total phosphorous, averaging about 58 tonnes per year (or six percent of the annual loading from the South Saskatchewan River), it is the most effective in promoting plant growth.

Lake Diefenbaker is a phosphorous sink. That is, more phosphorous enters the lake than leaves. Much of the phosphorous in the river sediments is trapped in the lake. Most of the dissolved phosphorous is consumed by algal growth. Although there is some recycling of plant phosphorous, most ends up settling to the bottom as part of dead plant material. On average, only 16 tonnes of dissolved phosphorous were discharged with the river water at Gardiner Dam compared to the 58 tonnes arriving from upstream.

It was concluded that eutrophication of Lake Diefenbaker is not an immediate threat to any of the Lake Diefenbaker water uses. To ensure that it does not become a problem in the future the following measures are required:

4.5.2.3 **Conclusions and Recommendations.**

1. All development which could accelerate the rate of eutrophication must be discouraged. This includes any activities which may lead to the depletion of oxygen in lake water.

2. It is recommended that a dissolved phosphorous objective of 0.025 mg/L be adopted for Lake Diefenbaker. This is less than half the concentration which could result in eutrophic conditions.

3. The effect of proportionally increasing the flow of the Red Deer River to the lake relative to the flow of the South Saskatchewan River must be investigated.

4. Monitoring the lake chemistry, plant growth and phosphorous balance must continue in order to improve the understanding of the trophic state of Lake Diefenbaker.

4.5.3 **Issue: Shoreline Management**

This section deals with issues that are unique to Lake Diefenbaker and its shoreline.

4.5.3.1 **Background.** The construction of Gardiner Dam and the Qu'Appelle Dam created a lake with 760 km of shoreline. This new lake is located in a region with few natural lakes which could be developed for shoreline recreation. One of the intended uses of the lake was for recreation. Ensuring that this recreational potential is achieved without compromising the other important water supply and flow regulation purposes of the lake has been a continuing issue in the management of the project.

Shoreline development can generate water and noise pollution and result in conflicts among incompatible uses. On this lake, water pollution has not been a major problem due to the sparse development, but regulators have noted that the potential for problems exists as development grows if cottage and boat wastes are not properly managed. Some of the irrigation pump motors are not muffled and, combined with power boats exhausts, have made noise a notable problem in isolated cases. With its long shoreline, Lake Diefenbaker provides opportunity for incompatible users to distance themselves. As use grows, however, conflicts may develop.

4.5.3.2 **Analysis.** While the dams forming Lake Diefenbaker were being built, extensive studies and planning for its development were completed. Studies demonstrated that the new lake would have a very active shoreline as erosion of the valley walls occurs. With water level fluctuations ranging through seven to eight metres most years, the wave action on the shore is not limited to one level. The erosion is occurring over the full range. The beach that would absorb the force of waves on a normal lake will have to form over the full range of elevations to effectively protect this shore. The original valley walls were quite irregular in alignment but water erosion attacks headlands and fills bays. The lake will, in the long-term, carve a more normal shoreline with flat beaches and a smooth alignment. The rate of change was most rapid in the early years and will diminish with time.

During construction, it was recognized that lakeshore developments similar to other prairie lakes, with lake front cottages close to the shore, would not be practical because the erosion would destroy this type of development. Several strategies to protect against this possibility were implemented. First, the land purchased for the lake included generous allowance for erosion so that private land would not be effected. Secondly, legislation and regulations to establish land use control areas called Reservoir Development Areas (RDAs) were passed. SaskWater administers the Reservoir Development Areas which provide for control over land uses near designated shorelines. The Reservoir Development Areas regulations encourage appropriate shoreline development. In order to take advantage of the opportunities that the lake presented, specific areas for development were established. Three provincial parks, several regional parks, boat launches and cottage subdivisions were established. These developments were intended to accommodate the shoreline erosion that was anticipated.

Based on experience at other prairie reservoirs where unauthorized development on the shore has created potential hazards and compromised proper development opportunities, the shore of Lake Diefenbaker has been regularly surveyed to ensure that the land use controls are effective.

In spite of the comprehensive planning and controls, problems have occurred.

The land purchase provided adequate setback between the lake and private land along most of the shore but erosion had exceeded the take line in a few locations by 1979 and small additional land areas were purchased. All significant erosion is now limited to project lands. The cottage subdivision at Coteau Beach which was set well back from anticipated shoreline erosion has been threatened because the beach has extended further than was anticipated. The cottage owners have undertaken bank protection measures to protect their property.

The program of land purchase and land use control has limited shoreline problems to a few isolated areas.

Water intakes along the shore are also affected by the erosion. The unstable conditions have resulted in extra expense for capital and operating costs.

The vast distances and large volume of the lake have kept pollution problems to minor levels. The erosion danger and resulting land use controls have had a secondary benefit in keeping shoreline developments back from the lake so that wastes are less likely to reach the water accidentally. The only bacterial pollution found on the lake have been a few individual samples close to heavy use beaches. Away from obvious sources like the beaches, bacterial levels are very low.

The broad beaches in some areas of Lake Diefenbaker have created a new ecologic opportunity for some species. The most dramatic example is the piping plover which is an endangered species that has used these beaches for intermittent breeding success in recent years.

The water erosion has excavated, sorted and redistributed large volumes of earth. Archaeologic and historic artifacts have been exposed along this new shoreline.

4.5.3.3 Conclusions and Recommendations.

1. The Reservoir Development Areas regulations which control the land use around Lake Diefenbaker should be maintained for the indefinite future in order to ensure that incompatible uses are avoided.

2. The opportunity to expand the Reservoir Development Area considerations to include special ecologic and archaeologic values should be investigated.

3. Water intakes, recreation subdivisions and associated developments must be designed with an allowance for continued erosion and shoreline changes.

4. Lake Diefenbaker has a substantial underutilized recreation potential which could provide desirable economic activity, improved quality of life and reduce the demand on other over-used areas. Continued development of appropriate shoreline recreation should be encouraged.

4.5.4 Issue: Qu'Appelle Dam Releases

This section deals with issues that are unique to Lake Diefenbaker and its shoreline.

4.5.4.1 Background. For a period at the end of the Ice Age the glaciers prevented water from the west from flowing north. The water of the South Saskatchewan River flowed eastward creating the valley that is known as the Qu'Appelle River Valley. The natural interconnection of these two large river valleys was one of the features that helped determine the location for construction of the Lake Diefenbaker project. The Qu'Appelle River Valley provides added storage in the Douglas Arm of the lake and provides an opportunity for the supply of water by gravity release to meet water needs on the Qu'Appelle River.

As early as the mid 1800s, this natural interconnection of the river valleys was noted and the possibility of diverting water to provide a navigable waterway across the southern prairies was proposed. With development of rail transport, the need for a waterway diminished but the possibility of using South Saskatchewan River water to meet the needs of users in the Qu'Appelle River Basin continued to be considered. In the 1920s an attempt to divert water to Moose Jaw by pumping from the river to a canal in the Thunder Creek Valley failed when seepage losses prevented water flow at the downstream end.

By the 1950s water demands in the Regina/Moose Jaw area required decisions on long-term supplies. Studies showed that the only practical supply would be the South Saskatchewan River. In order that the cities could proceed with major investments in water treatment and pipeline projects, the federal and provincial governments guaranteed the cities access to South Saskatchewan River water delivered to Buffalo Pound Lake in the Qu'Appelle River Valley. Canada built a pumped diversion which began delivering water in 1958. A clause in the federal/provincial agreement for construction of Lake Diefenbaker provided for the province to assume responsibility for the supply of water at Buffalo Pound Lake.

In addition to the municipal needs, the water of the Qu'Appelle River which is augmented by diversion from Lake Diefenbaker supports large waterfowl and fish enhancement projects, irrigation, industrial and recreation developments.

Concern has been expressed that the diversion of water to the Qu'Appelle River will adversely affect users in the South Saskatchewan River Basin.

4.5.4.2 Analysis. Since gravity releases began in 1967, the annual volume of water released has ranged from a low of 20 800 dam³ in 1974 to a high of 142 000 dam³ in 1981. The average release has been about 80 000 dam³. The highest diversion volumes coincide with the low runoff years in the Qu'Appelle River. The releases to the Qu'Appelle River have averaged 1.1 percent of the average flow of the South Saskatchewan River at Saskatoon. This water is very important to the Qu'Appelle River system. The average release is equal to about 40 percent of the total flow of the Qu'Appelle River at its downstream end. In some dry years the release has exceeded the total natural flow of the river.

The availability of gravity releases of water has replaced the need to pump water for municipal and industrial supplies, has created the opportunity for irrigation development to proceed with an assured supply, and has provided reliable flows for numerous wildlife, fish and recreation enhancements.

The Qu'Appelle River Basin Study determined that this additional water is very important to water management in the Qu'Appelle River Basin and that certain uses such as the municipal demand and irrigation may increase. However, a major component of the demand has been the evaporation losses from the lakes which will not change with time. The total demand will only grow modestly as a result of increased uses because the return flows from the cities are used for irrigation and for maintaining the lakes. Average annual water release to the Qu'Appelle River is expected to rise by about 22 000 dam³ by the mid-1990s.

Any use or diversion from Lake Diefenbaker, whether to the Qu'Appelle River or to uses in the South Saskatchewan River Basin results in lost opportunities to use the water in other ways. The most direct and quantifiable loss is the loss of hydro-electric generation at three existing power stations in Saskatchewan and one in Manitoba. In the future there may be additional power stations. Each cubic decametre of water could generate about 0.33 mwh of energy at the existing Saskatchewan stations. Depending on the timing of the lost generation this energy could be worth from 3 to 10 dollars per dam³ or from $250 000 to $800 000 per year for the average yearly release. In addition to the economic loss it should be noted that there are environmental losses. The alternative to hydro generation in Saskatchewan is coal or natural gas, which are fuels that are contributing to such environmental concerns as a carbon dioxide build up in the atmosphere.

In the case of diversion to the Qu'Appelle River, a portion of the lost power production could be recovered if the water was released through a small hydro generating facility. The quantity of water is small and the head is less than half that at Gardiner Dam so the capacity would be very limited. The energy would be available when water was needed in the Qu'Appelle River rather than when power was needed on the SaskPower system so the value of the energy would generally be low. This possibility was rejected in the original design because the capital cost was too large for the potential power benefits.

4.5.4.3 Conclusions and Recommendations.

1. The diversion to the Qu'Appelle River has no impact on any of the consumptive uses in the South Saskatchewan River Basin.

2. The water of the rivers of Saskatchewan are managed as a provincial resource to serve the needs of all the people in the most efficient manner.

3. Water from the South Saskatchewan River is essential to the stability and opportunity for growth of the economic, environmental and social systems that use water from the Qu'Appelle River. Therefore continued releases will be necessary to support that region.

4. Water management on the Qu'Appelle River system should make maximum use of the local surface and ground water supplies in order to minimize the need for releases from Lake Diefenbaker. Decisions on diversion to the Qu'Appelle River should take into account the supply conditions on the South Saskatchewan River.

4.6 ISSUES DOWNSTREAM OF LAKE DIEFENBAKER

This section deals with the issues associated with the river downstream of Lake Diefenbaker and Gardiner Dam. The water resources of this reach are the most intensively used in the basin. The water resources support a number of different uses, including hydro-power production, waste disposal, recreation and municipal water supply. This intense use leads to the following management issues:

Downstream of Gardiner Dam
Municipal and Industrial Effluent
Public Access
Instantaneous Flow and Water Level Fluctuations Downstream of Gardiner Dam
Erosion/Sedimentation
Methoxychlor
Flooding

Each of the above issues is discussed in the following pages. Background information, analysis, conclusions and recommendation are provided for each issue.

4.6.1 Issue Downstream of Gardiner Dam

This section deals with issues that are unique to the reach of the South Saskatchewan River downstream of Lake Diefenbaker.

4.6.1.1. Background. The largest consumptive uses of water in Alberta and at Lake Diefenbaker occur in the summer. The highest rates of storage in reservoirs also occurs in the summer. In years of low runoff, the uses and storage of water can result in low flows in the river reach downstream of Gardiner Dam. At times the low flow has caused problems for municipal, private and other water supply intakes along the river. Aesthetics of the river are changed by the low flows, as large areas of sand bars are exposed and if low flows persist for several consecutive years, vegetation becomes established which further changes the river appearance. Boating on the river and ferry crossings are restricted by shallow water depths. Downstream of the confluence with the North Saskatchewan River, the reduced flows cause navigation problems for recreation uses and commercial activities, particularly in the Cumberland Delta Region.

4.6.1.2 Analysis. The natural flow regime of the South Saskatchewan River included wide variations which often occurred over short periods of time. Peak flows in excess of 1 000 m^3/s occurred briefly in early summer and the flow was usually several hundred cubic metres per second in the summer season. These high flows created high velocities and a heavy sediment discharge. The river was of limited use for many of the recreation activities that are currently pursued. Most summers the river would have only been usable by risk oriented adventurers because failure of boat engines or other accidents would have resulted in rapid and dangerous transport downstream.

Construction of the Lake Diefenbaker project has substantially altered the flow as water is now stored during the summer. Present flows are much more tranquil. Heavy recreational use of the river has developed to take advantage of the changed flow regime.

While Lake Diefenbaker was under construction, studies were undertaken to define the limits of operation for the project (Blackwell, 1963). Those studies concluded that although the flows had dropped lower in the past, the project should be operated such that the minimum mean daily downstream flow would be 42.5 m^3/s.

Since 1968, when the project began operation, this low flow limit has been used. This minimum flow criteria has been used in approximately one-third of the 21 years since operation of the project began. In the other two-thirds of the years, the flows were sufficient to meet all the water uses, fill the storage and provide larger releases downstream than the minimum limit.

In the 21 years of operating experience, most of the river users have been able to make physical or operational adjustments to accommodate the low summer flows. All of the river intakes now provide sufficient performance. The ferry crossings generally function except that load restrictions are occasionally necessary. The aesthetic and recreational river uses are changed with mixed results. The lower water levels create some opportunities such as river sand bars for sunbathing and slow water for shallow draft boats but reduce other opportunities such as deeper draft and faster boating.

Flows larger than the current operating minimum would be desirable to improve downstream conditions. The most critical period is the open water season from April to October when the greatest use is made of the river for recreation. Even small increases from the 42.5 m^3/s criteria are useful. Each incremental change provides some improvement up to a point. The greatest improvements occur as flows increase from 42.5 to about 60 m^3/s. At about 60 m^3/s most inconvenience to water intakes and ferries is overcome and the river is attractive to most forms of shallow draft recreation craft. From 60 to about 150 m^3/s, the conditions stay optimum for most users although the higher velocities are unattractive to calm water users and some areas of sandbars which are usable at lower flows for sunbathing are flooded. As flows rise above 150 m^3/s, the conditions for many river users deteriorate. Flow depths and velocities become increasingly more dangerous as the river rises, filling its entire channel and reducing shoreline opportunities. At flows around 400 m^3/s or higher, the river has limited recreational value because it becomes hazardous. Operation of ferry crossings is also impeded.

As the flow increases, the river changes in two ways. The water surface rises and the velocity increases. The amount of change is not the same in all reaches of the river. The width, depth, slope and roughness of the river channel determine the relationship among flow, surface elevation and velocity. Hydraulic studies of the natural river have identified the following typical values are expressed in Table 5.

The section of river in Saskatoon upstream of the weir has the lowest range of levels because the weir tends to reduce the changes in depth.

The relatively shallow draft boats and ferries used on this river become significantly more versatile as a result of the modest depth increases that result from small flow increases. However, as the velocities also increase at the higher flows, tranquil water activities become hazardous.

The flow ranges are summarized in the following table:

	Unacceptable (flood risk)
1 000 m^3/s ——	
	Usable with significant limitations (poor recreation, ferries, minor flooding)
400 m^3/s ——	
	Usable with some limitations (negative impacts on recreation)
150 m^3/s ——	
	Preferred
60 m^3/s ——	
	Usable with some limitations (negative impacts on some recreational activities and ferries)
42.5 m^3/s ——	
	Unacceptable (water quality, recreation, intakes and ferries)

Detailed water balance calculations using the 75 year period from 1912 to 1986 were completed based on various assumed conditions for the South Saskatchewan River Basin Study. These are summarized in Table 6.

This table demonstrates that operation of Lake Diefenbaker has greatly increased the frequency of optimum flows (60 - 150 m^3/s) in the summer from 12 percent to 35 percent of the months and has increased the frequency of usable with some limitations flows (42.5 - 400 m^3/s) from 57 percent to 94 percent. However, as upstream developments continue, if no changes are made to the operating patterns, frequency of flows in the 60 to 150 m^3/s range will diminish and the frequency of low flows in the 42.5 to 60 range will dominate.

For winter conditions, Lake Diefenbaker operation has eliminated the nine percent frequency of extreme low flows below 42.5 m^3/s and future developments will not bring these flows back.

In order to determine how the trend to lower summer flows might be avoided as future developments occur several operating scenarios were tested.

One solution might be to simply raise the minimum flow criteria to 60 m^3/s or even into the middle of the optimum range at 120 m^3/s. These options were modelled and results are provided in Table 7.

The model results indicate that if only the downstream river interests are considered, it would be possible to assure a minimum flow of 60 m^3/s but attempting to go higher to 120 m^3/s would not be possible. If the operators attempted to operate with a 120 m^3/s minimum, too much water would be released from storage and, in extreme droughts, it would not be possible to meet even the present 42.5 m^3/s.

TABLE 5	RANGE OF WATER LEVEL	
Flow m³/s	Increase above 42.5 m³/s m	Range of Velocities m/s
42.5	0	.2 - .4
60.0	.15 - .25	.25 - .5
150.0	.6 - .8	.35 - .7
400.0	1.3 - 2.0	.5 - 1.2
1000.0	2.3 - 3.0	.6 - 1.6

TABLE 6	DOWNSTREAM OF LAKE DIEFENBAKER (SASKATOON) FREQUENCY OF MEAN MONTHLY FLOW OCCURRENCES 1912 - 1986 Current Operating Rules			
Flow Range in m³/s	Natural Conditions Percent	1986 Conditions Percent	Short-term Conditions Percent	Far Future Conditions Percent
SUMMER: April to October				
below 42.5	0	0	0	0
42.5 - 60	0	27	52	79
60 - 150	12	35	23	8
150 - 400	45	32	20	11
400 - 1000	37	6	5	2
over 1000	6	<1	<1	0
WINTER: November to March				
below 42.5	9	0	0	0
42.5 - 400	91	100	100	100

TABLE 7

DOWNSTREAM OF LAKE DIEFENBAKER (SASKATOON)
FREQUENCY OF MEAN MONTHLY FLOW OCCURRENCES
1912 to 1986 Increased Minimum Flow Criteria

	1986 Conditions Percent	Short-term Conditions Percent	Short-term with 60 m^3/s Percent	Short-term With 120 m^3/s Percent	Far Future with 60 m^3/s Percent
SUMMER					
Below 42.5	0	0	0	1	0
42.5 - 60	27	52	0	0.5	0
60 - 150	35	23	74	77	88
150 - 400	32	20	18	14	10
400 - 1 000	6	5	7	6	2
Over 1 000	<1	<1	1	1	0
WINTER					
Below 42.5	0.0	0.0	0.0	0.5	0.0
42.5 - 400	100.0	100.0	100.0	99.5	100.0

In order to assure even a minimum flow of 60 m^3/s other users would have to lose benefits. The lake level would have to drop during droughts. The future potential for development of irrigation, industry and municipal uses would be limited. Once Alberta developments reach their apportionment limit, Saskatchewan will have the opportunity remaining to develop 130 000 ha of irrigation or over 600 000 dam^3 of municipal and industrial water use in addition to current commitments while meeting a minimum flow limit of 42.5 m^3/s. However, if the minimum flow limit was 60 m^3/s this potential additional development would drop to about 24 000 ha of irrigation or about 100 000 dam^3 of water for municipal and industrial uses.

In effect, providing an assured flow of 60 m^3/s would require so much water that in drought years other opportunities for water development would be seriously limited.

Since raising the assured low flow significantly from 42.5 m^3/s has serious consequences for all other users, investigations were directed toward methods of increasing the frequency of desirable flows. Other jurisdictions with similar problems have found that setting a desirable objective which is met most of the time and having a lower absolute minimum that is only permitted in extreme droughts helps to improve flow conditions. Although it is not a formal policy, Saskatchewan has used this system in managing Lake Diefenbaker. The flow is only allowed to drop to 42.5 m^3/s when upstream flows and lake levels are very low. Alternatives to increase the frequency of desirable flows by operating Lake Diefenbaker at higher spring levels were studied. If more water is in Lake Diefenbaker in spring it should be possible to fill the lake and released greater flow in the summer even in dry years. This is summarized in Table 8.

This strategy only modestly improves the frequency of optimum flow conditions while it increases the risk of flood flows slightly. Since the flood flows can be managed to a certain extent by streamflow forecasting which cannot be studied with the present model, a modest increase in the normal spring lake level would likely have a net beneficial impact on the downstream reach.

As mentioned in the previous section there has been a trend toward higher spring lake levels and the findings relative to downstream flows suggests that this trend should continue as upstream uses are expected to reduce the volume of water available.

Proposals that a brief flushing flow in the spring should be undertaken to partially simulate natural flow patterns were evaluated but it was found that this could disrupt uses which are taking advantage of the new regime. Goose nests along the river would flood. A brief period of flow would not scour the river more than the high winter releases. The high release would use water which could provide more benefit as a small increase over the whole summer.

There has been some confusion regarding where the flow criteria should apply. The studies have found that the flow ranges discussed above are similar throughout the reach but that the largest concentration of river uses is at Saskatoon. If the flow criteria is applied at the release from Gardiner Dam, the uses between the dam and the city and the city municipal intake which is upstream of the city will reduce the flow through the critical city reach. The hydrometric station at Saskatoon is between the city intake and city effluent so it measures the lowest flows in the reach.

4.6.1.3 Conclusions and Recommendations.

1. Continue and enhance programs to inform the river users that, in spite of the presence of Lake Diefenbaker, the river can be expected to vary in flow and river uses must adapt to this natural variability.

2. The flow should continue to be kept within the optimum range of 60 to 150 m^3/s throughout the summer months whenever practical.

3. In extreme drought or flood events when the optimum range is impractical, the public should be informed of excursions from the range in advance and with an explanation of the conditions that are expected to cause the excursion.

4. The flow criteria should be defined for a specific location such as at the Saskatoon gauging station in order to ensure that increasing consumptive uses upstream of the city do not reduce the flow excessively in this high use reach.

4.6.2 Issue: Municipal and Industrial Effluent

This section deals with issues that are unique to the reach of the South Saskatchewan River downstream of Lake Diefenbaker.

TABLE 8	DOWNSTREAM OF LAKE DIEFENBAKER (SASKATOON) FREQUENCY OF MEAN MONTHLY FLOW OCCURRENCES 1912 to 1986 Increased Minimum Flow Criteria			
	Late 1980s Conditions Percent	Late 1990s Conditions Percent	Late 1990s with 1 m Lake Level Percent	Late 1990s with 2 m Lake Level Percent
SUMMER: April to October				
Below 42.5	0	0	0	0
42.5 - 60	27	52	47	47
60 - 150	35	23	26	26
150 - 400	32	20	19	19
400 - 1 000	6	5	7	7
Over 1 000	<1	<1	1	1

4.6.2.1 **Background.** The South Saskatchewan River downstream of Gardiner Dam receives municipal and industrial effluent from small communities and the city of Saskatoon. Storm water runoff and snowmelt from urban areas also add substances such as road salts, grease and animal wastes to the river. The effluent and runoff cause noticeable changes to the water quality at Saskatoon and raise concerns that subtle changes may also be occurring. Water users are concerned about the short and long term health of the river in the Saskatoon reach and in areas downstream.

4.6.2.2 **Analysis.** Most effluents differ greatly in quality from the quality of the receiving water. Zero discharge of undesirable substances remains a prohibitively costly practice. Pollution control strategies recognize the assimilative capacity of fresh waters and make use of it to the extent possible. Problems arise when nondegradable wastes are released to the river system along with the substances which can be assimilated.

The quality and quantity of the effluent and the quality and quantity of the receiving water are considered in determining the level of required treatment before effluent is discharged to a river. Water quality objectives, which define the quality necessary for specific water uses, are consulted to determine the acceptable quality of effluent which can be released. Typical releases from small urban sewage lagoons are made in spring and fall. The city of Saskatoon releases treated effluent to the river year-round. The critical period is in summer due to the low flows which occasionally prevail at that time of year. Saskatchewan Environment and Public Safety has adopted the lowest flow that can be expected over a seven day period in a 1:10 year drought, as the minimum treatment for municipal effluent. Operation of Lake Diefenbaker has assured that the river received at least 42.5 m^3/s of water to meet the needs of riparian users, ferry crossings, recreation and other uses. This rate of flow has been used in the establishment of municipal effluent treatment requirements for communities discharging to the river.

Small communities along the river provide secondary treatment of their effluent and discharge to the river without significant impact. The city of Saskatoon has historically been able to rely on the assimilative capacity of the river. However, the increasing pollution loading as the city has grown and the increasing public awareness of the need to protect the environment has lead to substantial investment by Saskatoon in recent years to upgrade effluent treatment. Further improvements are planned.

A computer model was developed which calculates the river water quality under specified flow conditions and quantity of pollutants. Using the model, the impact of changes in effluent quality and quantity can be estimated in the river.

Although sewage treatment costs might be less if the minimum flow of the receiving stream was increased, this possibility was not considered. It is felt that the effluent should be treated to the highest degree possible without interfering with other uses of the river.

4.6.2.3 **Conclusions and Recommendations.**

1. The city of Saskatoon, industries, smaller towns and Saskatchewan Environment and Public Safety should continue their efforts to improve the quality of effluent reaching the river.

2. Where practical, efforts should be made to minimize the pollution reaching the river in urban runoff from snow and rain. Snow dumps should be away from the river and storm water retention ponds that captures suspended sediments and associated pollutants should be considered.

3. Continued monitoring of the quality of the river and effluents is required to ensure the most effective efforts to reduce pollution are implemented.

4. Urban water management strategies which encourage recycling of water, effluent irrigation, demand management, and opportunities for zero discharge should be promoted.

5. Water quality objectives proposed by the study should be used in the development of municipal and industrial effluent regulations.

4.6.3 Issue: Public Access

This section deals with issues that are unique to the reach of the South Saskatchewan River downstream of Lake Diefenbaker.

4.6.3.1 **Background.** The river is a public resource but the land along the river is mostly privately owned. Conflicts arise between the interests of people who would like to take advantage of the recreation opportunities that the river provides and the land owners who are suffering damages from the misuse of their lands.

4.6.3.2 **Analysis.** In most cases, the land owners and recreation users would not be in conflict if everyone would respect the land, but because some people do not understand the responsibilities that go with use of private property, damages to crops, litter and nuisance damages have resulted in many land owners closing their land and preventing access to the river. As private land is closed, the pressure on remaining public land such as road allowance rights of way becomes intense. Traffic damage to fragile shore vegetation, litter and high volumes of traffic on rural roads result. Trespassing and property damages are also problems.

In certain reaches, particularly in and near Saskatoon, the problem is controlled by the dominant public ownership and control of the river environment by the city and Meewasin Valley Authority (MVA). Outside of the Meewasin Valley Authority boundaries where the concentrated city population generates heavy demand, there is a fringe of active conflict. In similar situations in other jurisdictions recreation corridors have been established along reaches of rivers where the recreation demand is high. Such a recreation corridor could provide for appropriate, non-conflicting uses and a buffer for pollution control. A level of control and government involvement less intense than that required through the city would likely be preferred.

4.6.3.3 **Conclusions and Recommendations.**

1. A combined strategy to enhance appropriate access to the river might include:

   a) Encourage the development and maintenance of sufficient suitable parks and recreation site facilities;

   b) Land use controls by Municipalities; and

   c) Physical controls to prevent inappropriate access.

2. The possibility of establishing a recreation corridor along the river through joint, co-operative efforts of the municipalities and land owners might be considered.

4.6.4 Issue: Instantaneous Flow and Water Level Fluctuations Downstream of Gardiner Dam

4.6.4.1 **Background.** During certain periods, the rate of release of water from Lake Diefenbaker through Gardiner Dam varies sharply within very short time periods. The rapid rate of change in flow causes rapid changes in water level and velocity of flow. In the early years of operation of the project, operators of river intakes encountered difficulty accommodating the variations but as they gained experience the problems have reduced. These permanent river users have been able to accommodate the fluctuations but casual users such as occasional canoers and hikers who are not familiar with the river variations sometimes encounter difficulties. The sand bars can become islands, stranding the unwary hiker, or channels which were navigable can become too shallow a few hours later.

4.6.4.2 **Analysis.** In order to use the water available to the greatest advantage for hydro-electric generation, SaskPower usually varies the rate of release over a wide range during the day. This is done for three reasons:

First, the value of energy varies. At night when the demand is low, the lowest cost fuels are used and higher cost fuels are used as little as possible. If a limited water supply for generation is available, its most effective use will be to displace the highest priced fuels which would have been used in the peak demand periods during the day.

Second, operation of hydro turbines is more flexible than the large lignite-fired turbines on the SaskPower system. Their output can be varied easily and efficiently in short time periods. Therefore, their rate of power output is varied in response to fluctuations in the customer load more frequently than the large thermal generation units.

Third, the turbines function most efficiently at a load that is near their capacity. Each of the three turbine units can most efficiently release approximately 100 to 130 m^3/s. When the flow available for release is less than 100 m^3/s, the release will be made for less than 24 hours at an efficient turbine load to obtain the desired daily average.

As a result, flows downstream of Gardiner Dam are highly variable when the rate of release is below the capacity of the Coteau Creek Generating Station. Water levels in the river fluctuate widely. The largest fluctuations occur close to the dam and are attenuated with distance downstream. In order to monitor this and other impacts of the project, water level recorders have been established on the river.

Water level variations which are 0.5 to 1 m immediately below the dam attenuate as the water flows downstream. At Outlook the variation is slightly reduced. In the Pike Lake area the variation is down to 0.25 to 0.5 m and at Saskatoon it is a modest 0.1 m or less. At the downstream end of the river, near St. Louis, the hourly variations are barely measurable.

The problems of changing hourly flows tend to be most noticeable in the summer months when the greatest use is being made of the river and the average flows tend to be below the power station capacity. In winter, the releases are usually close to the plant capacity and fluctuations are minor.

Mitigating these variations would be very difficult. The turbines cannot efficiently release the low end of the flow regime and the water would have to be released through the riparian outlet with no energy harvested if no fluctuation was allowed. This would result in wasted economic value of the falling water and indirectly would be environmentally wasteful as additional fossil fuels would be required at other generating facilities to meet the demand. At higher average release rates, the energy would be competing with low cost fuel much of the time. The SaskPower system would have to pick up the fluctuating demand elsewhere at higher economic and environmental cost.

A small reservoir could be built downstream to balance the short-term variations but this is not likely an economical or environmentally efficient option. A small turbine and generator could be installed to pass low flows efficiently but this would not solve the power demand timing conflict.

Although the sharp variations in flow are undesirable in the segment of the river immediately downstream of Gardiner Dam, they are necessary to take advantage of the low cost and environmentally attractive hydro-electric generation opportunity provided by this dam and reservoir.

4.6.4.3 Conclusions and Recommendations.

1. As future developments are planned, opportunities to reduce these hourly fluctuations should be considered.

2. In the short-term, the flow variations should be allowed to continue in order to most efficiently harvest the economic and environmental value of the hydro-electric energy.

3. A co-ordinated program of public information should include explanations of the reason for the variations, the potential dangers and the best methods to avoid problems.

4.6.5 Issue: Erosion/Sedimentation

This section deals with issues that are unique to the reach of the South Saskatchewan River downstream of Lake Diefenbaker.

4.6.5.1 **Background.** The South Saskatchewan River carried a large load of sediment through its Saskatchewan reach prior to development of the Lake Diefenbaker project. The river had a natural meander pattern that slowly progressed with time, eroding material from some areas and depositing it in others. Erosion and sedimentation processes make development of works such as intakes and transportation facilities along the river difficult.

4.6.5.2 **Analysis.** Man-made developments have changed the erosion and sedimentation regime of the river. Water storage and use projects in Alberta reduce the total flow and the variability of the flow, which reduces the amount of sediment reaching Saskatchewan. The water level control weir at Saskatoon has changed this river reach by fixing a formerly transient river reach and by slowing the flow so that sediment tends to accumulate upstream of the weir.

The largest change was the construction of Lake Diefenbaker (SSRBS Technical Report C.8). With its large size, the lake traps all of the sediment that arrives from upstream. The released water is clear of sediment and has an enhanced erosion capability as a result. The lake also reduces and attenuates the flow so its erosion force is reduced. A survey program to monitor the sedimentation in the lake and downstream erosion was started in 1964 and has continued since that time. This program shows that the net effect of the lake has been a noticeable downward erosion of the channel immediately downstream of the dam and a sharp reduction in the rate of changes along the rest of the river reach. In the lake itself sediment is accumulating in the upstream end but the rate is so slow that no significant impact will develop for several hundred years.

Although the rates of erosion and sedimentation have slowed in general, there will continue to be local problems where the river cuts into private property, which may require remedial efforts. However, such efforts must take into account impacts on other sections of the river. Erosion and sedimentation are very complex natural processes. Any action at one place will inevitably have effects along the whole reach. Therefore, river control works must be designed on a broader basis than the apparent local problem. Efforts to control the river meanders using inappropriate methods can precipitate damages to other lands, cause pollution and waste money if not properly designed.

4.6.5.3 Conclusions and Recommendations.

1. Continued monitoring of the river regime will be required to determine the causes and trends in river geometry changes.

2. Shoreline developments and other uses of the South Saskatchewan River must take the variable nature of the river into account through appropriate design of each project.

3. River training works, intakes and other shoreline developments require comprehensive designs taking into account the changing river and impacts beyond the immediate locations of the works.

4. Nonstructural options which avoid conflicting with the natural tendency of the river meanders to change with time should be used where practical rather than trying to force the river to an unnatural stable regime.

4.6.6 Issue: Methoxychlor

This section deals with water quality issues that are relevant to more than one component of the basin.

4.6.6.1 Background. The South Saskatchewan River is an ideal breeding location for black flies, which inflict significant losses on cattle herds. Treatment of the river with methoxychlor is regularly undertaken to control the black fly population. Methoxychlor was found to be adversely impacting on non target organisms and persists in the river system longer than anticipated. Its use is being reviewed.

4.6.6.2 Analysis. Methoxychlor is relatively insoluble in water and is therefore found in the aquatic environment strongly associated with suspended and bed sediments. Studies in the basin have found detectable levels of methoxychlor in sediments, aquatic plants, clams, crayfish and minnows. Contamination of biota occurs by direct application and by desorption from sediments and plants over the longer term. Bioaccumulation factors are low as higher organisms are able to metabolize methoxychlor. Other methods of black fly control are being investigated.

4.6.6.3 Conclusions and Recommendations.

1. Careful selection of chemical control of undesirable organisms is required to ensure that the impacts are fully known in the short- and long- term.

2. Consideration should be given to non-chemical control of black flies.

4.6.7 Issue: Flooding

This section deals with issues that are unique to the reach of the South Saskatchewan River downstream of Lake Diefenbaker.

4.6.7.1 **Background.** Certain urban developments in Saskatoon and rural developments along the river valley may be subject to flooding in periods of high flow. The Lake Diefenbaker project reduces the flood frequency and severity but does not eliminate the risk of floods.

4.6.7.2 **Analysis.** Under the Canada/Saskatchewan Flood Damage Reduction Program (FDRP), detailed mapping of the flood hazard at Saskatoon has been completed and an inventory of structures in and near the flood plain has been assembled. A study of the hydraulic characteristics of the river through the city was also completed, as was a study of the flood hydrology of the river based on operation of the Lake Diefenbaker project as it was operated prior to 1985. In 1985, evaluation of the performance of Gardiner Dam determined that certain restrictions on the allowable rate of fill at Lake Diefenbaker which had been necessary in the early years of operation could be lifted and the operation criteria during floods was significantly altered from those used for the Flood Damage Reduction Program studies. The updated flood hydrology was not available under the Flood Damage Reduction Program, therefore, an update study was undertaken under the South Saskatchewan River Basin Study (SSRBS Technical Report C.8).

At Saskatoon, as many as 270 buildings in the natural flood plain of the river could be subject to flooding in an extreme flood event. If Lake Diefenbaker was not available to attenuate floods and an extreme flood such as the 1:500 year event were to occur with existing development in place, the damage could be in the order of $8 million. In smaller floods, the damage would be less. The average annual damage potential was estimated at $320 000. Lake Diefenbaker reduces the flows in all floods, eliminating the flood hazard in low to moderate flood years. Under current operating rules, the extreme flood hazard would be reduced to 140 buildings and $4.4 million. The average annual damage would be $125 000. Although the impacts have not been studied in detail, there could also be reduction in the flood potential resulting from reservoirs in the Alberta headwaters area.

In the past, land in the river valley in Saskatoon was reclaimed from the river by raising the ground level with fill. Studies have determined that this practise of channel infilling can significantly reduce the flow capacity of the river causing increased water levels in upstream reaches.

Future operation of Lake Diefenbaker might be adjusted to retain more water in storage to improve the water supply at the lake and for more reliable downstream flow augmentation. If the lake was operated at higher levels, some of its flood control capability would be lost. The flood routing studies demonstrated that for each metre of increase in the spring level of Lake Diefenbaker, the average annual damages at Saskatoon would be increased by $15 000. That is, about 7 percent of the flood control benefit of the lake would be lost.

In addition to the city flood damage potential, there is some potential for rural flood damages. Using stage versus discharge information developed for the river, air photos and small-scale mapping an estimate of the impact of floods on agricultural areas was developed.

Agricultural flood damages along the river downstream of Gardiner Dam are less sensitive to the operation of the project. For most of the river reach the valley is narrow and has limited agricultural development. The reach from Pike Lake to Saskatoon is the only section with large areas of farm land adjacent to the river. Agricultural flood damage tends to relate to the duration of flooding. The flood routing studies for Lake Diefenbaker showed that the lake can significantly reduce the flood peaks by storage, but that in large floods the affected on the longer duration flood flows is small.

There are recreation facilities such as the golf course and regional park at Outlook which can also be damaged by floods.

SaskWater has an ongoing program of flow forecasting that is an important input to the operation planning for Lake Diefenbaker. The flow forecasts are important to flood damage control for two reasons. First, the forecasts permit the operators to most effectively utilize the storage capacity of the project to reduce the physical extent and impact of the floods. Second, forecasts of the flow can permit those impacted by the flooding to mitigate the flood damages by emergency action.

4.6.7.3 **Conclusions and Recommendations.**

1. Operation of Lake Diefenbaker must continue to provide for a reasonable level of flood control capability.

2. Although the Lake Diefenbaker project has reduced the flood potential, there is still a flood hazard associated with the South Saskatchewan River valley and land uses compatible with the hazard should be the only permitted uses.

3. Flow forecasting and the dissemination of forecast information to the affected public should be continued and if possible enhanced as knowledge of the physical processes develops.

4. The process of flood plain designation as set out under the Canada/Saskatchewan Flood Damage Reduction Program should be completed for the city of Saskatoon in order to ensure that development of the flood plain only includes appropriate uses.

5. The channel cross-section that nature has developed to carry the flood flows should not be diminished through channel infilling.

4.7 SWIFT CURRENT CREEK BASIN ISSUES

Swift Current Creek is the only major tributary to the South Saskatchewan River in the study area. In comparison to the mainstem of the South Saskatchewan River, the water resources of Swift Current Creek are relatively small and very intensively used. The issues related to Swift Current Creek are generally related to this intense use. The issues are:

Swift Current Municipal Water Supply
Irrigation Water Supply
Flooding
Shoreline Management

Each of the above issues is discussed in some length in the following pages. Background information, analysis, conclusions and recommendations are provided for each issue.

4.7.1 Issue: Swift Current Municipal Water Supply

4.7.1.1 Background. The city of Swift Current relies upon releases from Duncairn Reservoir to Swift Current Creek for a reliable water supply for the city.

4.7.1.2 Analysis. The city of Swift Current was using 3 160 dam^3/year of water in 1986 and is expected to require about 3 190 dam^3/year by the year 2000 and the city water requirements can be expected to continue to grow slowly.

Duncairn Reservoir is a multipurpose reservoir which provides water for irrigation, downstream riparian users and municipal uses and the lake is used for recreation and sport fishing. The operation has always given a high priority to the city supply and maintenance of a steady base flow in the creek channel for riparian users. Water balance studies have demonstrated that Duncairn Reservoir can assure the city and riparian users a supply as long as no irrigation use occurs when the lake is below elevation 803.72 m. At this level the storage capacity is 52 000 dam^3 or about half of the total capacity of Duncairn Reservoir.

Swift Current draws its water from a small 420 dam^3 reservoir on the creek in the city. This small reservoir is supplied from Duncairn Reservoir.

In order to convey water from Duncairn Reservoir to the city reservoir, a release rate of 0.57 m^3/s is necessary from November to February to keep the creek from freezing solid. This requires a release of 5 870 dam^3 of water to meet a city need of about 720 dam^3. The excess water flows to Lake Diefenbaker meeting riparian needs along the channel. In the summer the release rate is reduced to a minimum of 0.28 m^3/s. The eight month release in summer is 5 990 dam^3 while the city use is about 2 440 dam^3. The excess maintains a live stream downstream which provides stock water for riparian lands and some excess reaches Lake Diefenbaker.

Although the present operation assures the city supply, the other major use, the irrigation projects, suffer shortages in about 25 percent of the years and development of additional irrigated area is not permitted. Several possibilities exist for reducing the effect of city use on the irrigation water supply.

1. A pipeline from Duncairn Reservoir to the city of Swift Current would reduce the winter release requirement and some of the summer losses. Although some of the excess release is needed for livestock water along the creek, it is likely that a pipeline to Duncairn Reservoir could reduce the water requirement by over 5 000 dam^3 per year which could be used to reduce the frequency of irrigation shortages or to irrigate an additional 1 700 ha of land.

   A pipeline would provide the city with a more consistent quality of raw water and might reduce treatment costs and improve the supply to the residents.

   A pipeline to Duncairn Reservoir is estimated to cost about $6 700 000. Operation costs would be low since the water in the pipeline could flow by gravity.

2. A pipeline from Lake Diefenbaker to the city of Swift Current would not only reduce the channel losses but it would add new water to the local supply. Since the city sewage effluent is used for irrigation, the total basin supply would be enhanced. The pipeline distance would be about 50 percent larger and a pump and intake would increase the total cost substantially. A vertical lift of about 200 m would be required which would require operation costs in excess of $50 per dam^3 of water. The irrigation supply would be enhanced by at least 10 000 dam^3 per year which could firm up existing supplies or add 3 400 ha of irrigated area.

3. The present operation of Duncairn Reservoir reserves 52 000 dam^3 of the reservoir for non-irrigation uses. The city water supply does not require this level of reserve. Water balance studies indicate that a 2 m increase in the range of Duncairn Reservoir would reduce the shortages to irrigation to less than half of their present frequency and would increase the average annual water supply to irrigation by about 1 000 dam^3. However, the city municipal supply is not the only user of this reserve capacity. It also assures that the lake remains a viable recreational opportunity and supports the sport fishery in the lake.

4.7.1.3 Conclusions and Recommendations.

1. The municipal water supply must remain a high priority for the operation of Duncairn Reservoir. An adequate reserve must be retained in the lake at all times to assure the city water supply.

4.7.2 Issue: Irrigation Water Supply

4.7.2.1 **Background.** Over 7 500 ha of irrigation development depends on the natural runoff of Swift Current Creek, Rushlake Creek and the reservoirs and canals constructed by PFRA since 1942. The system provides sufficient water for full irrigation most years but in about 25 percent of the years rationing occurs, resulting in reduced productivity. Additional land could be irrigated if more water was available.

4.7.2.2 **Analysis.** The annual water supply available is summarized in Table 9.

Irrigation usage requires over 16 000 dam^3 of water per year. Releases to the city of Swift Current require an additional 11 800 dam^3 of water per year and other small projects use modest amounts of water. The total water use of about 38 000 dam^3 per year exceeds the supply in low flow years.

Since 1942 a system of canals and reservoirs has been built. The main live storage capacities are listed in Table 10.

The reservoirs provide two major benefits. They capture spring snowmelt runoff and make it available for use in the growing season and they capture excess flow in wet years for use in subsequent dry years. Although the reservoirs stabilize the supply, they do not totally overcome shortages.

TABLE 9	SWIFT CURRENT CREEK BASIN RUNOFF VOLUMES		
	dam³ Minimum	Average	Maximum
Swift Current Creek Above Duncairn Reservoir	13 500	58 600	190 000
Swift Current Creek Below Duncairn Reservoir	7 100	27 100	96 000
Rushlake Creek	130	9 100	32 000
Other Local Runoff	170	13 000	49 000
Total	20 900	107 800	367 000

TABLE 10	SWIFT CURRENT CREEK BASIN RESERVOIRS
	dam³
Duncairn Reservoir	52 000
Highfield	14 000
Herbert	2 000
Total	66 000

Water balance calculations for the 75 year period from 1912 to 1986 indicated that shortages can be expected in about 25 percent of the years. An important feature of the Swift Current Creek and Rushlake Creek hydrology is the relatively stable low flows. These creeks arise on the slopes of the Cypress Hills and although the flow varies sharply from year to year, these creeks do not encounter the near zero flows that sometimes occur on other creeks in this region. Therefore, even in the driest years, there is still sufficient water for the critical municipal use with some excess available to be shared among irrigation projects. This availability of at least partial irrigation is particularly important in this region where perennial forage crops are grown. A partial irrigation will ensure that the root systems remain viable so that the loss is limited to reduced production in the year of the short supply. A total water supply failure to forage crops could result in root damage that not only reduces the current year production but also inhibits future production.

Irrigation development in this region could use two types of improvement: improved reliability of supply and increased overall supply. These improvements could be achieved in several ways:

1. Improving the efficiency of water use by eliminating delivery losses could provide additional water for use. The quantities of water that could be saved are relatively small but possibilities of reducing canal seepage have been considered. The cost of rehabilitating canal systems strictly for more efficient delivery is not practical but as the system components are maintained and redeveloped in the normal operating cycles, it might be possible to include improved delivery efficiencies.

2. Reducing the competing needs for water could free up water for irrigation. The main user, the city of Swift Current, cannot stop using water but as discussed in an earlier section the demand on Duncairn Reservoir could be reduced by pipelines from Duncairn Reservoir or from Lake Diefenbaker. Irrigation benefits could not justify these developments but could contribute significantly.

3. Increasing the storage capacity available to carry water from wet to dry periods could stabilize and increase the usable supply.

Since major investments are needed for these types of development, they can only be considered in the long-term.

A large portion of the irrigation in this area is of the gravity or backflood type that requires larger volumes of water and is less efficient. Conversion to more efficient sprinklers could improve the water supply. However, the higher capital investment required for sprinklers may be difficult to justify when the supply is subject to occasional shortages.

The water balance calculations show that the storage capabilities of Duncairn Reservoir and Highfield Reservoir are not fully utilized by the present operating policies. The operating range on Highfield Reservoir could be widened without endangering any other users. The supply would be modestly enhanced.

Water supply studies indicate that, with the present limit that terminates irrigation when the water level on Duncairn Reservoir drops below 803.72 m, the existing irrigation projects can expect modest shortages in approximately 35 percent of the years and less than 50 percent of the normal months of supply in about 20 percent of the years. If the limiting level was lowered to 802.72 m, the frequency of modest irrigation shortages would be reduced to 15 percent of the years and of severe shortages to 10 percent of the years. Table 11 shows the probability of Duncairn Reservoir being in a specified elevation range.

The irrigation operators have indicated that although full irrigation water supplies are important, in the case of short supplies, at least a partial irrigation would be extremely useful in order to provide some income boost every year and to ensure survival of perennial plants for future production. An alternative operating scenario was tested in which the present 803.72 m water level limit was used for full irrigation but a limit of 802.72 m was used for 50 percent irrigation. That is, the water from 803.72 to 802.72 m would be reserved for the spring irrigation only. Water below 802.72 m would be reserved for city of Swift Current, fish and recreation. In this case modest shortages would occur in 29 percent of the years.

Highfield Reservoir operating ranges could also be widened by about a metre. This would also improve the reliability of the water supply but because of the small size of this reservoir, the differences are less dramatic.

The suggested changes would not place the city of Swift Current's water supplies at risk.

TABLE 11	DUNCAIRN RESERVOIR LEVELS PROBABILITY IN PERCENT OF LAKE LEVEL BEING IN SPECIFIED RANGE		
Range	Irrigation Minimum 803.72 m	Irrigation Minimum 802.72 m	100 Percent Irrigation Minimum 803.72 m Partial Irrigation Minimum 802.72 m
803.72 - 807.72 m	79	71	75
801.0 - 803.72 m	21	27	25
790.8 - 801.0 m	0	2	0
less than 790.0 m	0	0	0

Increasing the operating range on these reservoirs would reduce their value for other uses such as fish and recreation. Highfield Reservoir is not a high use recreation area and fishing is only an occasional activity so the operating ranges are not critical to these uses on this reservoir. Although Duncairn Reservoir was primarily built to provide reliable water for the city of Swift Current and irrigation, it has become a significant local recreation and fishing area. Increased irrigation use would make the lake less desirable for these secondary uses.

Fisheries managers indicate that the lower levels would be undesirable but would not destroy the fish populations. There would be sufficient survival to ensure repopulation after drought events.

It has been noted that the delivery of water to these irrigation projects has consistently exceeded the licensed quantity. A large portion of the surplus delivery relates to the gravity irrigation systems which require extra water to flood the fields. This water is returned to downstream users, but some of it is actually the result of excess use.

SaskWater has stopped issuing new approvals for irrigation in this area. This has been necessary because all of the irrigation would become uneconomical if irrigators experienced more frequent years of rationing.

4.7.2.3 <u>Conclusions and Recommendations.</u>

1. Existing irrigation is fully utilizing the local water supply and available water storage facilities.

2. In order to protect the economic viability of the existing irrigation in the basin the moratorium on irrigation development should be continued unless alternative supplies are developed. This prohibition need not apply to areas which do not normally contribute runoff to the main channels.

3. As maintenance and rehabilitation of the existing system is carried out, consideration of measures to reduce losses and improve efficiency should be incorporated where practical.

4. Where practical, on farm irrigation efficiencies should be improved through demand management strategies.

5. The operating range on Highfield Reservoir could be widened to include the full physical limits of the works without adversely affecting any other uses.

6. In the event of extreme drought, water from Duncairn Reservoir should be used to provide the first irrigation even if it means drawing the lake below the established minimum of 803.72 m, but in no case should water be drawn for irrigation from below 802.72 m. It is important to note that this proposed operation change would only apply to an absolute minimum release of water to provide for a single spring or early summer application of water.

4.7.3 <u>Issue: Flooding</u>

4.7.3.1 <u>Background</u>. A portion of the city of Swift Current was developed on the floodplain of Swift Current Creek. Most of the floodplain is in recreation land uses which are compatible with the flooding. A portion of the floodplain as defined by the Canada/Saskatchewan Flood Damage Reduction Program, is occupied by 263 homes and 12 commercial buildings which could be affected in extreme runoff events.

4.7.3.2 <u>Analysis</u>. The only flood that caused major flood problems occurred in 1952 when a flood peak of 167 m^3/s resulted in evacuation of 139 families from the floodplain. A similar flow in 1917 apparently did not flood any buildings because the floodplain had not been developed at that time.

Under the Canada/Saskatchewan Flood Damage Reduction Program detailed studies of the hydrology (PFRA, 1981) and hydraulics (PFRA, 1988) of Swift Current Creek and of the potential for flood damages have been completed. Some of the results are summarized below.

The hydrology study considered 67 years of recorded data and included detailed evaluation of the impact of Duncairn Reservoir on flood flows. It was found that, in most years, Duncairn Reservoir can fully control floods from the 75 percent of the drainage basin upstream of the dam but in extreme floods the lake has little flood control value. The estimated flood potential is summarized in Table 12.

The 1952 flood peak of 167 m^3/s was more extreme than would be expected in the 67 years of record, being equal to about the 1:75 year event.

Because Duncairn Reservoir captures virtually all of the runoff from upstream in normal and low flow years and provides a major reduction in the flood peak in the more common floods, there is a tendency to assume that it will always control floods. As shown above, Duncairn Reservoir does reduce larger floods somewhat but the proportionate reduction is less in large floods. Although they will be rare, floods larger than the 1952 event are possible, and since most of the developments that were damaged in that flood are still in the floodplain, severe damages could occur.

Hydraulic calculations to determine water levels corresponding to the various flood flows were completed and an inventory of flood prone property (IBI-ECOS, 1981) was assembled. This information is summarized in Table 13.

Duncairn Dam has eliminated about 45 percent of the damage potential but in extreme flood years, there will still be some damage.

The possibility of operating Duncairn Reservoir to achieve greater flood control was reviewed. It was found that in the common flood events Duncairn Reservoir captures all upstream runoff and peak flows. In extreme floods the volume of Duncairn Reservoir has little influence on flood flows. Therefore, additional flood control through operation of Duncairn Reservoir is not possible.

A 1981 study of options for managing the flood hazard at Swift Current found that since damages occur infrequently and there is little risk of injury, major investments to control flows or relocate structures are not practical. The management plan emphasized efforts to avoid further flood damage susceptible development through zoning and regulation; flood forecasting, warning and emergency action to minimize risk to existing developments; and modest channel and diking work to protect developed areas where low costs are required. The city of Swift Current has not fully adopted the Flood Damage Reduction Program approach to reducing flood damage but through partial adoption of the main components, much of the potential for controlling developments in the floodplain has been achieved.

4.7.3.3 Conclusions and Recommendations.

1. Maintenance and enforcement of the floodplain zoning established by the city of Swift Current will prevent municipally controlled developments in the flood hazard area.

2. Designation of the floodplain under the Canada/Saskatchewan Flood Damage Reduction Program would reinforce the municipal control and ensure that federal and provincial activities stay clear of the floodplain.

3. Operation of Duncairn Reservoir must continue to recognize the flood control potential of the reservoir.

4.7.4 Issue: Shoreline Management

4.7.4.1 Background. Within the Swift Current Creek drainage basin there are two lakes with substantial recreation development along the shoreline.

Lac Pelletier is a natural lake which has been raised and stabilized by a low control dam. The lake was developed mainly for recreation use and the level is relatively stable so a natural shoreline has permitted development of the shoreline with no major problems.

Duncairn Reservoir was created by the construction of Duncairn Dam by PFRA in 1942. The lake was created to stabilize water supplies for the city of Swift Current and for irrigation water supply. A secondary opportunity to use the lake for recreation and sport fishing has been generated. In order to serve its primary uses, the lake level must fluctuate as water is stored and withdrawn. The fluctuating shoreline creates difficult shoreline development.

TABLE 12 SWIFT CURRENT FLOOD POTENTIAL

Probability in Any One Year	Flood Peak Regulated m^3/s	Natural m^3/s	Regulated as Percent of Natural
1:10	82	135	61
1:50	153	230	67
1:100	193	270	71
1:500	334	384	87

TABLE 13 SWIFT CURRENT FLOOD DAMAGE POTENTIAL (1981)

Probability in Any One Year	Natural Conditions Dollars	Existing Conditions Dollars
1:10	270 000	163 000
1:50	600 000	317 000
1:100	800 000	445 000
1:500	1 200 000	1 080 000
Average Annual	53 000	30 000

4.7.4.2 Analysis. Recreation development can be undertaken on water supply reservoirs without compromising the primary purpose of the lake if it occurs in appropriately designed subdivisions. Recreation developments on reservoirs must be designed to accommodate fluctuating water levels and to prevent contributions of pollutants to the water. Provisions such as a buffer zone along the shore are necessary because the new, unnatural shoreline will erode and because reservoir levels vary as water is stored or used.

At Duncairn Reservoir there are two types of cottage developments. The Reid Lake Cottage Owners Association have developed an appropriately designed subdivision in Section 9-12-16 W3 where the cottages are safely separated from potential flood or erosion damages and wastes can be managed. In addition, there are about 75 cottages which have been constructed on public land without either title or lease. These cottage owners are trespassing. This trespass creates serious legal and administrative problems and compromises opportunities for operation of the lake.

In the 1940s when this lake was developed, it was common practise to obtain the absolute minimum land needed to contain the dam and normal water surface. No special effort was made to control how shoreline developments progressed. Experience with the haphazard cottage development at Duncairn Reservoir and other prairie reservoirs changed this practise. Land control is now normally obtained to a higher elevation to contain all future erosion and flood levels. On large, important reservoirs like Duncairn Reservoir, only designed subdivisions with adequate buffer provision would be permitted. By today's standards Duncairn Reservoir would be protected by zoning controls and regular inspection under the Reservoir Development Area Regulations to prevent trespassing.

Since Duncairn Reservoir shoreline cottage developments occurred before the current standards, the reservoir managers have been working toward correcting the problem. Field surveys in 1989 indicated that about half the right-of-way was established below the top of the dam with some private lands as close as 0.5 m above FSL. Some flooding above the existing right-of-way would occur in floods of 1:50 year or greater magnitude. The legal implications of cottages that have been built on the public right-of-way are under investigation.

4.7.4.3 Conclusions and Recommendations.

1. Right-of-way for the Duncairn Reservoir project is inadequate by modern standards.

2. The cottages which are trespassing on public right-of-way are:
   - creating an undefined and potentially high liability risk;
   - at significant risk of damage in flood events;
   - compromising the reservoir operators flexibility to use this lake for its legitimate water supply and flood control purposes; and
   - unfair to the legitimate cottage owners who have accepted the necessity for a reasonable buffer along the lake shore.

3. A program to bring shoreline management up to modern standards should be established. Such a program should be based on more detailed study of the problem and involvement of the local residents, cottagers, water users and municipal authorities and should include:
   a) expanded right-of-way to modern standards;
   b) zoning controls to prevent further inappropriate development;
   c) design and development of additional organized subdivisions if needed to meet demand; and,
   d) removal of existing inappropriate development.

4.8 SASKATOON SOUTHEAST WATER SUPPLY (SSEWS) SYSTEM ISSUES

The SSEWS system is a unique system with its own particular management issues. As a completely engineered system for delivering water to a wide variety of users, the issues relate to the capacity of the system. The issues are:

Water Supply "Shortages"
Water Quality-Salinity

Each of the above issues is discussed in some length in the following pages. Background information, analysis, conclusions and recommendations are provided for each issue.

4.8.1 Issue: Water Supply "Shortages"

The South Saskatchewan River Irrigation District (SSRID) #1 and the Saskatoon Southeast Water Supply (SSEWS) system draw water through a series of pumps, canals, reservoirs and pipelines to serve irrigation, wildlife, industries, municipalities, domestic and recreation users. The South Saskatchewan River Irrigation District and the SSEWS system share common facilities at the upstream end and for this report have been combined under the heading SSEWS.

4.8.1.1 Background. These water supply facilities were built in the late 1960s and have been modestly expanded in subsequent years. The water use on the system has steadily grown over the years. Prior to 1984 no significant water supply shortages were encountered. In 1984 and 1986 the growth in the area of the largest use, irrigation, combined with hot dry weather, which generated a very high demand for irrigation water resulted in peak demands which exceeded the system capacity for a short period in the summer. All of the irrigators upstream of Blackstrap Lake were required to stop irrigating for a brief period in each of these years. As a result, irrigated crop production was less than the potential production. This loss of potential production directly affected the irrigation farms and the lost income indirectly affected secondary economic spinoffs. A potentially greater, but less quantifiable, impact of the shortages could have developed if future irrigation potential along the system was discouraged.

In addition to the economic costs of water shortages, there are significant social implications. The SSEWS and South Saskatchewan River Irrigation District comprise a government funded water delivery system, sourced at Lake Diefenbaker. Users tend to have a high expectation of the reliability of the supply and a proportionately high level of disappointment when failures to meet that high expectation are encountered.

4.8.1.2 Analysis. In 1986 SaskWater engaged Water Resource Consultants Ltd. to conduct an assessment of the system conveyance requirements. It was determined that the critical sections of the system were the pump capacity and main canal rehabilitation. By 1988 the capacity of the pump station had been increased. A major rehabilitation of the main canal has not been undertaken but maintenance has provided adequate flow capacity.

Water supply model studies conducted for the South Saskatchewan River Basin Study have determined that the system can meet the normal demands placed on it at the current level of development. The system can also meet normal demands with anticipated modest increases in irrigated area over the next few years. The system is meeting demands that are near to its maximum capacity and there is little flexibility. The operation must take advantage of the full open water season, specially in the spring, in order to fill the reservoirs before the peak demand season because the canal cannot meet the peak demands. The system operators have extended the spring operating season in recent years.

Additional uses in the upstream end of the system will require expansion of the main canal or increased storage capacity. Additional storage opportunities are not evident in this area but it is possible that additional use of the soil as a storage medium could be achieved if water was applied early in the season before the hottest weather occurs. This would allow plants to draw on this reserve rather than on water delivered in the peak season.

If further irrigation development occurs, there will be brief periods in hot dry years when the demand is extreme, when the system capacity will be insufficient and the irrigators will have to ration water. If irrigation continues to expand, the frequency and degree of shortages will increase. Failures to meet the irrigation demand will discourage further expansion of irrigation.

In the past, system expansions have occurred in response to needs that became apparent as a result of shortages. The Water Resource Management Model as calibrated for the South Saskatchewan River Basin Study, and future upgraded versions of water management models of the system will permit refined planning of system expansions with improved knowledge of risks, frequencies and magnitude of shortages.

4.8.1.3 Conclusions and Recommendations.

1. The existing system and operation policies can adequately meet all existing system demands.
2. An additional 1 900 ha of irrigation can be developed from Blackstrap Lake and downstream to take advantage of the capacity of the existing system to deliver water.
3. A further 3 000 ha of irrigation can occur in the South Saskatchewan River Irrigation District and upstream end of the SSEWS without major capital expenditures.

4. Opportunities to make full use of the storage potential of the soil to reduce the impact of shortages in the delivery capacity should be considered.

5. Major irrigation growth will not be possible unless the limitations imposed by the Main Canal are removed.

4.8.2 Issue: Water Quality-Salinity

This section deals with issues in the area served by the SSEWS system.

4.8.2.1 Background. The water quality problem that is most unique to the SSEWS system is the high concentration of dissolved solids in the water. A common measure of water salinity is total dissolved solids (TDS).

The main source of water in the system is Lake Diefenbaker. Modest natural runoff is also added to the system reservoirs. The Total Dissolved Solids concentration in the surface water entering the system is rarely higher than 400 mg/L and averages less than 350 mg/L. The water in the upstream end of the system reflects this good quality source. As water moves downstream in the system the concentration of Total Dissolved Solids increases due to:

1. evaporation from the water surface, leaving the dissolved solids in a reduced volume of water;

2. accumulation of soluble salts from the soils of the canals and reservoirs; and

3. ground water discharge, containing higher concentrations of Total Dissolved Solids than the surface water, to the canals and reservoirs.

In addition to the these progressive increases in Total Dissolved Solids, the formation of ice in the winter results in a temporary increase in the Total Dissolved Solids. Ice tends to reject the dissolved solids as it freezes so that the reduced volume of water under the ice has a higher concentration of Total Dissolved Solids. The effect of this process is particularly noticeable in shallow reservoirs where the ice constitutes a large portion of the total water mass.

High concentrations of Total Dissolved Solids can adversely affect the use of the water for irrigation. Plants extract the pure water and leave the minerals in the soil at an increased concentration. If the Total Dissolved Solids concentration becomes too high, the plants can not extract their water requirements from the soil and production suffers. Total Dissolved Solids concentrations of 500 mg/L have no impact on most irrigated crops. Concentrations from 500 to 1 500 mg/L have impacts on sensitive crops and irrigation with water having Total Dissolved Solids concentrations higher than 1 500 mg/L requires special management to ensure long term viability. Most of the irrigation development on the system is located in the upstream reaches where no salinity problems occur, but some existing and potential irrigation is downstream where there could be limitations due to high salinity.

High levels of Total Dissolved Solids are also not desirable for municipal and domestic uses. In Saskatchewan an objective of 1 500 mg/L has been set while some jurisdictions try for lower concentrations.

4.8.1.2 Analysis. Broderick and Brightwater reservoirs receive and discharge large quantities of good quality water from Lake Diefenbaker every year. Their evaporation losses are small compared to the total volumes and there is little ground water inflow or accumulation of salts from the soil. The only noticeable Total Dissolved Solids deterioration in these reservoirs is the seasonal concentration increase due to ice exclusion. The summer concentrations of less than 350 mg/L are raised to over 400 mg/L in the winter. No uses of the water are affected by this quality.

Prior to development, Blackstrap Lake was a valley which received water from ground water discharge but little surface runoff. The high rate of evaporation in the region resulted in loss of the water to the atmosphere and an accumulation of salts in the soils. Water development in the system downstream of Blackstrap Lake requires relatively low volumes of water. The soils, the ground water discharge, the evaporation from the lake, and the low volume of flow combine to sharply change the Total Dissolved Solids at this lake. In recent years the summer Total Dissolved Solids concentrations in the south (upstream) end of Blackstrap Lake have been between 500 and 600 mg/L. In the north end of the lake the Total Dissolved Solids concentration has increased to over 700 mg/L.

The concentrations continue to increase downstream. In Bradwell and Zelma reservoirs the Total Dissolved Solids has been close to 1 000 mg/L in the summer and about 1 200 mg/L in the winter. Dellwood Reservoir receives more of its supply from the natural flow of Dellwood Brook in wet years and its Total Dissolved Solids level fluctuates. In wet years the concentration drops to relatively low values but in dry years when the supply is by canal from Zelma Reservoir, the Total Dissolved Solids level rises to similar values to those found in the system.

Little Manitou Lake is a natural dead end lake which has accumulated very high Total Dissolved Solids (100 000 to 200 000 mg/L) values due to natural evaporation over the millennia. Diversion of water from the SSEWS system tends to dilute this lake.

Model studies and trend analysis of the available water quality data (SSRBS Technical Report D.7) determined that the Total Dissolved Solids levels have been reducing with time as the natural soil salinity has been flushed from the system and as through flows have increased with the development of additional uses. In the late 1970s Zelma, Bradwell and Dellwood reservoirs had Total Dissolved Solids values in the 1 500 mg/L range in the winter but through the 1980s the Total Dissolved Solids levels have improved. Although the levels are higher than desirable, no uses are directly limited except that irrigation should be restricted to compatible soils and crops in the downstream reaches of the system.

CONCLUSIONS AND RECOMMENDATIONS

1. Monitoring of Total Dissolved Solids levels in the SSEWS should continue in order to trace changes over time.

2. Crops which are compatible with the area soils and which are tolerant to high Total Dissolved Solids waters should be considered for SSEWS.

5.0 LONG-TERM PLANNING STRATEGIES

5.1 PLANNING HORIZON

The long-term planning horizon was set at the year 2020, 30 years after completion of the study. In this length of time, substantial changes to the water management infrastructure could be in place.

As mentioned in the discussion of the Framework Plan in Chapter 2, the long-term strategies are not intended to pre-empt future decisions. No single development strategy is emphasized. Instead, the study considered a range of alternative scenarios which include current development trends and various alternative trends. Since it is not practical to judge which alternative future generations might prefer, an important consideration is the determination of how flexible future opportunities will be.

The evaluation criteria described in section 3.4.3 were used in reviewing the various scenarios. Appendix C lists the results of the scenarios for each of these evaluation criteria. In the following text, the findings are generally discussed in relation to a few key criteria. For more detailed data, the reader can review the tabulated values in Appendix C. The text discusses major effects like the frequency of desirable levels on Lake Diefenbaker, frequency of desirable flows downstream of Gardiner Dam and annual electric power production, all of which are important, but additional factors such as whether excursions from desirable ranges are above or below optimum and whether power is produced in winter or summer can be obtained from the appended tables.

5.2 MAINSTEM SCENARIO DEVELOPMENT

Unlike the short-term planning, which focused on issues, the long-term planning was intended to provide information on the relative impacts of emphasizing various types of development. The developments would not be restricted to those that currently exist since, in the intervening 30 years significant changes could occur.

Since a large number of water quantity scenarios were studied, a numbering system was set up to identify individual scenarios. The first long-term scenario was M20BASE; where M stands for Mainstem, 20 designates the year 2020 conditions and BASE indicates that changes in operation beyond the year 2000 are ignored. Each of the long-term scenarios after the base case share the M20 prefix in their number but they have a four digit designation that indicates the Case (C) number and Run (R) number.

5.2.1 Base Case Scenario (M20BASE)

The first scenario provided for the continuation of past trends into the future. This scenario was intended to provide a benchmark against which other development scenarios could be compared. The off-stream uses, including municipal, industrial, irrigation and diversions to recreation and wildlife projects, were assumed to continue to grow at a rate similar to the average rates of the recent past. No new dams, reservoirs, sewage treatment facilities or other major developments were included.

For the Base Case Scenario, it was assumed that the results and findings of the short-term planning would be implemented by the year 2000 and operations would continue in a similar manner until the year 2020. For example, it was assumed that shortages at irrigation projects around Lake Diefenbaker caused by inadequate intakes, would be corrected. The typical annual operating range of Lake Diefenbaker which is expected to average about one m less by the year 2000 was assumed to remain the same until the 2020 in the Base Case Scenario.

5.2.1.1 **Water Demand.** The largest change in the water supply over the next 30 years is expected to occur upstream of the study area in Alberta. As described in the South Saskatchewan River Basin Study Water Quantity Technical Appendix, the average natural flow of the South Saskatchewan River entering Saskatchewan is 9 200 000 dam^3 per year. Developments prior to 1986 had reduced that average to 7 200 000 dam^3 or 78 percent. Developments currently planned are expected to reduce the average flow to 72 percent by the year 2000 and to 67 percent in the long-term. In the critical drought years when the natural supply is about half the average, Alberta uses will reach the limit under the Master Agreement on Apportionment.

The largest manmade flow reduction in Saskatchewan results from lake evaporation which averages about 267 000 dam^3 per year. Since the Base Case Scenario did not include any new reservoirs, lake evaporation would not significantly change from current conditions.

The use that has changed most rapidly in recent decades is irrigation. Irrigation demand has averaged about 170 000 dam³ per year in recent years and is expected to rise to about 248 000 dam³ per year by the year 2000 as a result of projects currently under way. If trends continue, irrigation use could reach 425 000 dam³ per year by the year 2020. Most of this potential growth would likely draw water from Lake Diefenbaker.

Municipal demand, industrial demand and releases of water to the Qu'Appelle River combined use about 140 000 dam³ per year and are projected to grow to 178 000 dam³ by the year 2000 and 225 000 dam³ by the year 2020. A portion of the water withdrawn for these demands is returned to the rivers as treated effluent.

Saskatchewan's uses were about six percent of the average natural flow in recent years and are expected to increase to about 8 percent in the short-term and 10 percent in the long-term.

For more details on water demands and water uses in the study area, the reader is referred to the South Saskatchewan River Basin Study Water Use Technical Appendix.

5.2.1.2 <u>Findings</u>. Appendix C lists the water supply model results for the evaluation criteria discussed in section 3.4.3.

Although the total flow reaching Saskatchewan will be diminished by Alberta uses, the flow pattern will be less erratic than in the past. Where the summer flow upstream of Lake Diefenbaker was only in the desirable range about 25 percent of the time in recent years, it is expected to rise to 34 percent in the short-term and 38 percent in the long-term as Alberta regulates the flow to improve instream conditions for recreation and fish.

The frequency of water levels on Lake Diefenbaker above the minimum desirable summer level would decrease from 70 percent in the past to 61 percent in the long-term.

The reduction in the volume of flow due to upstream uses would substantially increase the frequency of low flows downstream of Gardiner Dam. Under current conditions, the flow is below the desirable summer range about 27 percent of the time, in the desirable range about 34 percent and above in 39 percent of the time. In the long-term base case scenario, the frequency of below desirable flows rises sharply to 48 percent, the frequency in the desirable range drops to 26 percent and the frequency above drops to 26 percent of the time.

The portion of annual Alberta flow that reaches the downstream end of the South Saskatchewan River which was typically 94 percent in the recent past would drop to 87 percent in the long-term.

The reduction in the volume of flow caused by Alberta and Saskatchewan water uses would reduce the hydro-electric generation. Average annual power production at Coteau Creek Power Generating Station would be reduced 23 percent from current conditions and the average winter generation would be reduced 27 percent. The firm annual power would be reduced 32 percent and the firm winter power would be reduced by 45 percent.

Because the flows of the North Saskatchewan River were assumed to be unchanged, the hydro-electric generation on the Saskatchewan River would not be as greatly reduced. The reductions would be slightly less than half of the reductions at Coteau Creek Power Station.

5.2.2 <u>Demand Management Scenarios (M20C1R1 and M20C1R2)</u>

The second group of scenarios considered the impacts of two potential levels of reduced demand for off-stream uses.

5.2.2.1 <u>Water Demand</u>. Where water is scarce and expensive, users take less water. That is, the demand for water can be managed to reduce total consumption.

Through the use of water saving devices in homes and commercial buildings and careful management of lawn and garden irrigation, per capita municipal and industrial water needs have been reduced as much as 40 percent in some cases.

The largest off-stream demand, irrigation, can be reduced through high efficiency technologies. Conveyance of water in watertight pipelines instead of canals, which has become common in recent years, can reduce seepage and evaporation losses. Sprinkler systems which deliver water uniformly throughout the irrigation season make better use of the water than less sophisticated surface flooding methods. In some areas where high value crops are grown with very expensive water, The largest off-stream demand, irrigation, can be reduced through high efficiency technologies. Conveyance of water in watertight pipelines instead of canals, which has become common in recent years, can reduce seepage and evaporation losses. Sprinkler systems which deliver water uniformly throughout the irrigation season make better use of the water than less sophisticated surface flooding methods. In some areas where high value crops are grown with very expensive water, systems have been developed to deliver water to the plant root system through individual small pipes referred to as drip systems, so no loss to evaporation occurs.

In the study area, there are large areas where water delivery is by canals with their associated losses. Substantial areas are provided water by inefficient surface flooding. The large systems developed in recent years have used pipelines for delivery and most fields are served by sprinkler systems. However, losses to the atmosphere are still high compared to the drip systems used elsewhere.

At present, high costs and relatively low product prices make the best technologies for demand management impractical. This situation may change in the long-term. It is not practical to predict the limit for water savings by future demand management programs. Therefore, scenarios with two levels of demand management, 40 percent and 20 percent, were studied. That is, all off-stream water uses were reduced by these percentages.

Other uses were assumed to continue as in the past and water losses through evaporation would also continue.

5.2.2.2 Findings. Since conservation in the study area will not change water use in Alberta, conditions upstream of Lake Diefenbaker would not be significantly changed.

The 40 percent and 20 percent conservation scenarios increase the frequency of summer levels of Lake Diefenbaker above the minimum desirable from 61 percent in the Base Case to 63 and 62 percent of the time respectively.

The reduced water use improves the frequency of desirable summer flows downstream of Gardiner Dam from 26 percent in the Base Case to 28 percent and 27 percent with demand management. The percentage of the Alberta flow that typically reaches the downstream end of the South Saskatchewan River would increase from 87 percent in the Base Case to 91 and 89 percent with demand management.

Reduced water use results in improved hydro-electric generation. Average annual power production would be increased 6 percent and three percent by the 40 percent and 20 percent demand management scenarios respectively. Most of the extra power could be available in the critical winter period when average energy production would be enhanced 9 percent and 5 percent by the demand management scenarios. Because of the extra water available for storage, the firm power generation would be enhanced 15 percent and 5 percent. Energy generation downstream on the Saskatchewan River would also be enhanced.

5.2.3 Irrigation Scenarios (M20C2R1 and M20C2R2).

If recent trends continue, the largest change to the water resource will result from water use for irrigation. Since this is the major off-stream use, further study of this use was undertaken. The Base Case Scenario provided for continued growth of irrigated area at a rate similar to the average in recent decades. Two additional irrigation scenarios were investigated.

The high irrigation scenario assumed that the rate of growth in irrigated area from the year 2000 to 2020 might parallel the brief periods of rapid expansion that have occurred in the past. The high rate of growth might be associated with high commodity prices, high government support or a combination of the two. Since most of the potential for irrigation is at Lake Diefenbaker, only projects using this source of water were adjusted. Irrigation along other parts of the river were assumed to be the same as the Base Case Scenario.

The low level of irrigation scenario assumes that the irrigated area around Lake Diefenbaker might not change from the year 2000 to 2020. This low growth in area could reflect low government support, low commodity prices or a combination of both.

5.2.3.1 Water Demand. The high growth scenario assumed an extra 18 000 ha of irrigation from Lake Diefenbaker over the Base Case Scenario which would require an additional 86 000 dam^3 per year of water. The low growth scenario assumed a reduction of 21 000 ha of area from the Base Case Scenario which would reduce the demand by about 94 000 dam^3/year. All other demands were held at the Base Case level.

5.2.3.2 **Findings.** Since the changes in irrigation are assumed to occur at Lake Diefenbaker, no impact would be felt upstream of the lake.

By coincidence, the low irrigation scenario results closely resemble the 20 percent demand management scenario. The total reduced volume of use was nearly the same in both scenarios although the method of achieving the reduction was different.

The high irrigation scenario results in a 5 percent increase in the frequency of undesirably low levels on Lake Diefenbaker and a 50 percent increase in the frequency of extremely low lake levels compared to the Base Case.

The extra water use in the high irrigation scenario results in a 6 percent increase in the frequency of undesirably low flows downstream of Lake Diefenbaker and reduces the typical percentage of the Alberta flow reaching the downstream end of the South Saskatchewan River from 87 percent in the Base Case to 85 percent.

The higher rate of water withdrawal results in the lowest hydro-electric generation of all the scenarios studied. The average annual generation at Coteau Creek Generating Station is reduced by 2 percent from the Base Case. Generation on the Saskatchewan River would be reduced about 1 percent.

5.2.4 Instream Water Use Downstream of Gardiner Dam (M20C3R1)

The instream water use scenario is intended to show the effects of maintaining a minimum flow downstream of Lake Diefenbaker above 60 m^3/s. This would improve conditions for instream uses such as recreation.

5.2.4.1 **Water Demand.** The off-stream water uses were the same as the Base Case Scenario.

5.2.4.2 **Findings.** This 41 percent increase from 42.5 to 60 m^3/s represents an added summer volume of 276 000 dam^3 of water. In dry years this would be a significant portion of the total available supply.

Placing greater emphasis on maintaining higher downstream flows would result in less water being stored in Lake Diefenbaker over the summer. The frequency of desirable or higher levels on Lake Diefenbaker in the summer would be reduced from 61 percent in the Base Case to 55 percent of the time. The frequency of extremely low levels (more than 8.6 m below FSL) would more than double from under 5 percent of the time in the Base Case to over 10 percent.

There is sufficient water to permit the elimination of periods of less than desirable flows downstream of Gardiner Dam. This flow would, however, be at the bottom of the desirable range (60 m^3/s) most of the time.

Since the lake level would be lower, evaporation losses would be less and the average downstream flow would be slightly greater.

The generally lower lake level would also reduce the frequency of spill from the lake so that more of the water would pass through the generating turbines to produce electricity. The model results indicate a 6 percent increase in energy production at Coteau Creek Generating Station. However, a part of this difference results because the water balance model had no provision for the operating adjustments which are made on the basis of forecast flows. The actual operation would avoid some of the modelled spill events in other scenarios.

5.2.5 Additional Hydro-electric Reservoirs

In the past, three additional reservoirs have been proposed downstream of Lake Diefenbaker. These reservoirs would be mainly for hydro-electric generation. The sites are near Dundurn and St. Louis on the South Saskatchewan River and near The Forks on the Saskatchewan River. The proposed reservoir near The Forks was included in all of the long-term scenarios. For this study it was assumed that these reservoirs would be operated as run of the river ponds. That is, they would not significantly alter the flow pattern.

5.2.5.1 **Water Demand.** The off-stream water uses were the same as the Base Case Scenario.

5.2.5.2 **Findings**. The annual hydro-electric output of the South Saskatchewan River could be increased by an average of 885 000 Mwh, an amount roughly equal to the current average annual output from Coteau Creek Generating Station.

The hydro-electric output of the Saskatchewan River could be increased by 2 340 000 Mwh, an amount about equal to 85 percent of the output of the Nipawin and E.B. Campbell Power Stations.

The additional reservoirs on the South Saskatchewan River would result in increased evaporation which would reduce the average flow about 2 percent over the Base Case.

5.2.6 One Metre Reduction in Normal Winter Drawdown (M20C5R1 to M20C9R1)

The short-term planning process showed that there would be advantages in reducing the normal winter drawdown on Lake Diefenbaker as upstream uses reduce the volume of water available for management. This slow increase in the spring level has been occurring and is expected to be about one metre higher by the year 2000. The long-term Base Case Scenario and the other long-term scenarios discussed previously in this chapter included allowance for that one metre increase but did not provide for continuation of this trend beyond the year 2000.

Since upstream flow reductions and uses from Lake Diefenbaker are expected to continue to increase after the year 2000, further reduction of the winter drawdown would be expected to produce beneficial results. Therefore a series of scenarios similar to those described above was studied with an additional one metre increase in the normal spring lake level superimposed.

5.2.6.1 **Water Demand**. The off-stream water uses were the same as the Base Case Scenario or the relevant scenarios discussed earlier.

5.2.6.2 **Findings**. With the Base Case demands, a one metre reduction in the normal winter drawdown would result in an increase in the frequency of summer levels on Lake Diefenbaker above the minimum desirable occuring. The frequency of desirable summer levels would rise from 61 percent in the Base Case to 68 percent of the time.

Downstream of Lake Diefenbaker the frequency of desirable summer flows would be increased from 26 percent to 32 percent of the time.

The increased operating head would result in a very small increase in total power output (less than 1 percent) but because of the reduced winter drawdown, the more desirable winter power generation would be reduced by about 1 percent.

5.2.7 Improved Lake Levels (M20C10R1)

Lake Diefenbaker was designed and has been operated as a flow regulation reservoir. It is drawn down over the winter when natural flows are low and filled in the summer when natural flows are high. By careful design and control, recreation developments compatible with the wide range of operating levels have been developed but it has been suggested even better recreation opportunities would be possible if the lake was operated at a more stable level. This scenario investigates the possibility of reducing the normal winter drawdown by three metres, that is, the one metre that is expected by the year 2000 plus three additional metres.

5.2.7.1 **Water Demand**. Off-stream water uses were the same as the Base Case Scenario and all of these off-stream uses were unaffected by this operating scenario.

5.2.7.2 **Findings**. The frequency of desirable summer levels of Lake Diefenbaker would be increased by almost 50 percent and, of the time outside the desirable range, only 6 percent would be below the desirable range. The recreation facilities around the lake would require adjustments to accommodate these higher levels but once adjusted, the recreational potential would be substantially higher.

Because the summer storage would be less, the summer flows would be substantially higher. Occurrences of less than desirable flows would be about half as frequent and desirable flows would occur about 50 percent more often than the

Because of added spills at Gardiner Dam, power generation downstream on the Saskatchewan River would be reduced about 1 percent. Average annual winter generation would be reduced 10 percent.

5.2.8 Improved Water Quality

As discussed in detail in the chapter on Short-Term Strategies, the South Saskatchewan River is a high quality source of water for users in Saskatchewan. The water quality objectives and monitoring identified for the short-term will have to continue and be updated as technology permits in the long-term.

One issue, the sharp drop in water quality that occurs due to urban runoff and effluent at Saskatoon, will only be partly corrected by planned treatment improvements in the short-term. In the long-term, additional treatment improvements could be added. The greatest impact on the river is the abrupt increase in the concentration of phosphorous, a key plant nutrient. With the increasing awareness of environmental quality and advancing technology, by the year 2020 treatment to remove phosphorous from effluent may be normal municipal practise.

Since this is not a water quantity problem, the Water Resource Management Model model results in Appendix C cannot be used for analysis. Instead, the South Saskatchewan River Water Quality Model was applied. Two simulations were completed.

In the first simulation it is assumed that the city of Saskatoon discharge would continue to grow in proportion to the water use growth to the year 2020 and that the level of treatment would be limited to the improvements currently planned. A second simulation was modelled assuming that the city implements a high level of phosphorous removal. In spite of the increase in the volume of effluent from the city by the year 2020, a 50 percent reduction in the concentration of phosphorous in the river downstream of Saskatoon could be achieved.

5.3 SSEWS Scenario Development

The SSEWS system is a manmade water delivery system that was designed to meet the demands placed on it. As these demands have grown, the system has been upgraded to meet the demand.

The SSEWS scenarios were numbered in a manner similar to the mainstem but with the designation SE in the prefix.

5.3.1 Base Case (SE20BASE)

5.3.1.1 **Water Demand.** The Base Case Scenario tested the ability of the system to supply water to the anticipated demands by the year 2020. The municipal demands which were 462 dam^3 in recent years are expected to rise to 613 dam^3 by the year 2000 and 860 dam^3 by the year 2020. Industrial demands which averaged 2 676 dam^3 in recent years are projected to rise to 3 557 dam^3 by the year 2000 and 3 950 dam^3 by the year 2020. Irrigation demand of 91 000 dam^3 is expected to rise to 115 000 dam^3 by the year 2000 and 147 000 dam^3 by the year 2020.

5.3.1.2 **Findings.** The existing system can meet the anticipated demands at the year 2020. This finding is based on mean monthly flows and average irrigation demands. Experience in the 1980s showed that shorter period peak demands and extreme dry weather can create periods of shortage which do not show up on mean monthly analysis. These short period shortages can be expected to increase in frequency if additional increases in capacity are not provided.

The level of Blackstrap and Little Manitou lakes would be in their desirable range 57 and 83 percent of the time. These frequencies are down from 76 to 93 percent of the time under current conditions.

5.3.2 Demand Management (SE20C1R1 and R2)

5.3.2.1 Water Demand. Demand management scenarios with 40 percent and 20 percent reductions in consumptive uses were studied.

5.3.2.2 Findings. Since the Base Case scenario had no shortages in consumptive uses, demand management could not improve these supplies. These scenarios did show that water levels in the lakes could be improved. Desirable levels on Blackstrap Lake would be attained 68 and 65 percent of the time, up from 57 percent. Desirable levels on Little Manitou Lake would be attained 94 and 88 percent of the time, up from 83 percent in the Base Case.

5.3.3 Increased Canal Capacity (SE20C2R1)

The section of canal from Lake Diefenbaker to Broderick Reservoir is the component of the SSEWS system that limits its delivery capability. Therefore, a scenario with an increase in capacity from its existing 14 m^3/s to 20 m^3/s was studied.

5.3.3.1 Water Demand. The demands were the same as for the Base Case.

5.3.3.2 Findings. The consumptive demands would continue to be fully met. The frequency of desirable levels on Blackstrap Lake would increase from 57 percent to 62 percent of the time and on Little Manitou Lake from 83 percent to 87 percent of the time.

Although this monthly flow model could not show the difference, this increased capacity would reduce the short periods of irrigation shortage that occur in hot dry weather.

5.4 Swift Current Creek Scenario Development

The existing water users in the Swift Current Creek drainage basin utilize all of the available supply in dry years. Significant shortages can be expected to occur in about 15 percent of the years at the present level of development. The system is operated so that the domestic and municipal water users are always assured of a supply. Irrigation users ration the water in drought years.

Irrigation farming can remain viable if rationing is reasonably infrequent but if the frequency exceeds the current situation in the Swift Current Creek Basin, irrigation would not be feasible. For this reason, SaskWater has not permitted any additional irrigation development since the early 1980s.

The only growth in demand anticipated is the modest growth of the city of Swift Current. The long-term scenarios were therefore considered in two groups.

The first group considered situations with only the existing water storage reservoirs. The operating modifications studied for the short-term were tested to determine how the system can be expected to respond to the anticipated modest growth in urban water demand in the long-term.

The second group of scenarios evaluated the opportunities for additional water storage reservoirs to store water from wet years to overcome droughts. Potential pipelines to improve the delivery of water were also considered. Since the first group of scenarios confirmed the short-term finding that more use could be made of the existing storage at Duncairn Reservoir, it was assumed that the wider operating range would be implemented before major new projects were built. Scenario SC20C2R2 was used as the Base Case for this second group of scenarios.

5.4.1 Operational Scenarios (SC20BASE, SC20C1R1, SC20C2R1, SC20C2R2, SC20C2R3, SC20C3R1, SC20C4R1, SC20C4R2, SC20C4R3, SC20C5R1 and SC20C5R2)

These scenarios were intended to confirm that the operational options studied for the short-term would remain viable in the long-term. The operating rules and water demands were the same as the short-term conditions except for the growth in demand at city of Swift Current and village of Herbert.

5.4.1.1 **Water Demand.** Since no new irrigation was assumed, water demand for irrigation would remain at about 28 250 dam^3/year. The only change in water use pattern would be the growth in urban demand from 3 192 dam^3/year currently to 5 533 dam^3/year in the year 2020.

5.4.1.2 **Findings.** As a result of the higher urban demand, the frequency of shortages to irrigation would be increased by one to two years out of the 75 year study period. That is, the risk of irrigation shortages would rise by 1 to 3 percent.

The increased use of water would result in a slight (less than 1 percent) decrease in the frequency of desirable levels for recreation on Duncairn Reservoir compared to the same scenarios under current conditions.

These scenarios confirmed that the short-term operation assumptions can be applied to the long-term conditions without jeopardizing critical water uses while reserving sufficient water for in-stream uses such as fish survival in Duncairn Reservoir.

Therefore, the short-term finding that more drawdown on Duncairn Reservoir could be permitted to firm-up the irrigation water supply without hazard to the urban water supply is confirmed. For this study, it was assumed that this opportunity to reduce shortages would be implemented before additional expenditures on capital works were undertaken to firm-up the supply. Scenario SC20C2R2 which provides for an additional 2 m of drawdown in critical drought periods was used as the base case for the scenarios with capital developments which follow.

Scenario SC20C2R2 demonstrates that the frequency of irrigation shortages at the current level of irrigation demand could be 17 percent of the years under year 2020 conditions if the potential of Duncairn Reservoir is fully used.

5.4.2 Raising Duncairn Reservoir FSL (SC20C6R1 and SC20C6R2)

The natural variability of the runoff is causing shortages in low flow years. In order to make more use of the water, additional storage would be needed to carry water from periods of excess to periods of drought. One way to increase the storage would be to enlarge the existing reservoir at Duncairn Reservoir by raising the Duncairn Dam. Studies by PFRA have shown that raising the FSL from 807.72 m to 808.90 m might be possible. This would increase the storage capacity by 16 950 dam^3.

This additional storage could be used to reduce the frequency of shortages to existing users or to provide water to new areas which would suffer shortages with the same frequency as the existing projects or in about 17 percent of the years. Two scenarios were studied.

5.4.2.1 **Water Demand.** In the first scenario (SC20C6R1) the demands were not changed. The added storage at Duncairn Reservoir improved the frequency of satisfying these full demands.

In the second scenario (SC20C6R2), the irrigation area was increased to an area that resulted in similar frequency of shortages to that experienced with the existing demand.

In both cases the municipal and domestic water demands were fully met.

5.4.2.2 **Findings.** Adding 16 950 dam^3 of live storage at Duncairn Reservoir would reduce the frequency of shortages from 17 percent of years to 9 percent if the extra storage was used only to overcome shortages.

If used to serve added area, the total irrigated area could be increased by about 1 030 ha requiring about 3 100 dam^3 per year of water.

Since irrigated agricultural production is directly proportional to the water used, the economic value of the additional storage would be proportional to the average annual uses. In the Base Case, irrigation demand is 28 250 dam^3 per year and the average annual shortage was 1 318 dam^3 for an average annual use of about 26 932 dam^3. If the increased storage is used to reduce shortages, the average annual shortage is reduced to 1 032 dam^3 and the average annual use increases to 27 218 dam, an increase of 286 dam^3.

If the extra capacity was used to support the increased area, the average annual demand would rise to 31 350 dam³. The average annual shortage would increase to 1 682 dam³. The average annual water use would be 29 668 dam³, a 2 736 dam³ increase over the base case.

By increasing the irrigated area and accepting the same frequency of shortages, the average supply is enhanced 2 736 dam³ as compared to an enhancement of only 286 dam³ if the added storage is dedicated to reducing shortages to existing irrigated areas.

Raising the FSL and resuming the extra storage for existing users would increase the frequency of high lake levels. The lake would be in the desirable range 51 percent of the time, down from 68 percent in the base case. It would be above the desirable range, above the old FSL, 25 percent of the time.

Raising the FSL and reserving the irrigated area would substantially increase the variability of the lake level. The frequency in the desirable range would drop to 42 percent and above the desirable range would drop to 20 percent.

5.4.3 Additional Upstream Storage (SC20C7R1 to SC20C7R6)

Past studies by PFRA have considered the potential for storage upstream of Duncairn Reservoir at a site designated SC1. Reservoir sizes of 60 000, 100 000 and 150 000 dam³ at this location were considered.

As was the case with raising Duncairn Reservoir FSL, two options for use of the increased storage were considered. The storage could stabilize existing uses or it could serve new areas at the same frequency of shortages.

5.4.3.1 **Water Demand.** In the odd numbered runs (SC20C7R1, R3 and R5) the demands were kept the same as in the Base Case and the frequency and magnitude of water shortages to irrigation were reduced.

In the even numbered runs (SC20C7R2, R4 and R6) the demand area irrigated was assumed to increase so the frequency of shortages remained the same as the Base Case.

5.4.3.2 **Findings.** Table 14 summarizes the findings related to irrigation water supply and Duncairn Reservoir levels.

By retaining the existing demand and adding large volumes of storage, only modest improvements in the average water use can be obtained. This occurs because the added storage would be used infrequently in droughts when the existing storage is inadequate. Between uses, in the 83 percent of the years when shortages are not occurring, the added reservoir would add to evaporation losses but would sit idle in terms of water supply.

Even in the scenarios where irrigation uses were increased, the large volumes of storage add relatively small increments of usable water. The first 60 000 dam³ of storage only adds 2 475 dam³ to the average supply for a ratio of 24 dam³ of storage per one dam³ of use. The 40 000 dam³ increase from 60 000 to 100 000 dam³ is even less efficient with a ratio of 38 dam³ of storage per one dam³ of use. The next 50 000 dam³ increment only adds 869 dam³ of use for a ratio of 58:1. This phenomena of decreasing return on each increment of storage is common to water management in arid climates. The first increments of storage receive runoff the most frequently and their annual value is greatest. Subsequent increments of storage are utilized less frequently and their average annual value diminishes.

The upstream reservoirs could have a significant benefit to recreation interests at Duncairn Reservoir if water is released to maintain Duncairn Reservoir levels.

5.4.4 Downstream Storage (SC20CBR1, R2 and R3)

Several options for additional storage downstream of the city of Swift Current were studied. The first two options involve a small, 1 240 dam³, off-channel reservoir (Reservoir 8B) adjacent to existing irrigation which receive water by releases from Duncairn Reservoir. For this small reservoir, the additional storage could be used to reduce shortages to existing irrigation or to serve new areas. The third option involves a larger reservoir of 14 000 dam³, further downstream (Reservoir 7B) which might serve new areas. Since this larger reservoir would be downstream of all existing irrigated areas, it could not be used to firm-up the supply to these areas and only one option, development of new areas with similar shortages was studied.

TABLE 14 IMPACTS OF RESERVOIR SC1

Scenario	SC1 Volume (dam^3)	Percent of Years With Shortages	Annual Demand (dam^3)	Average Annual Shortage (dam^3)	Average Annual Supply (dam^3)	Improved Annual Supply (dam^3)	Duncairn Desirable Range (Percent)
SC20C2R2	0	17	28 250	1 318	26 932	0	68
SC20C7R1	60 000	9	28 250	950	27 300	368	80
SC20C7R3	100 000	9	28 250	881	27 369	437	81
SC20C7R5	150 000	8	28 250	760	27 490	558	83
SC20C7R2	60 000	16	30 850	1 443	29 407	2 475	71
SC20C7R4	100 000	16	31 950	1 489	30 461	3 529	71
SC20C7R6	150 000	16	32 650	1 320	31 330	4 398	72

5.4.4.1 **Water Demand.** In Scenario SC20C8R1 the demands were kept the same as in the Base Case and the frequency and magnitude of shortages were reduced. In the other two scenarios the irrigated area was increased so the frequency of shortages remained the same.

5.4.4.2 **Findings.** Table 15 summarizes the findings.

These downstream reservoirs are more efficient in terms of storage volume versus average annual usable water than upstream reservoirs. This is because they capture runoff from the uncontrolled area downstream of the city of Swift Current and the excess releases which would otherwise flow to Lake Diefenbaker.

These reservoirs have little impact on Duncairn Reservoir levels because they would utilize water that is not available to Duncairn Reservoir.

5.4.5 Additional Storage on Rushlake Creek (SC20C9R1 and R2)

The existing Rushlake Creek Reservoir takes advantage of most of the local runoff but some potentially usable water is spilled in extreme wet years.

Two scenarios were tested to determine if additional storage on Rushlake Creek would be useful. A relatively large, 40 000 dam^3, reservoir was studied. If additional local water was found to be usable, it would reduce the demand on Duncairn Reservoir and help all users of this system.

5.4.5.1 Water Demand.

As described previously, this reservoir was tested in two ways. First, run SC20C9R1, determined if the reservoir could reduce shortage to existing users. The second test, respresented by run SC20C9R2, added more irrigated areas with similar water shortages to those presently experienced.

5.4.5.2 **Findings.** This reservoir would only marginally improve the supply to existing users. The frequency of shortages would only reduce from 17 to 16 percent and the average annual shortage increased slightly.

The option of increasing demand only identified an additional 400 dam^3 of available water. When compared to the 40 000 dam^3 reservoir studied, this indicates a storage to use ratio of 100:1, much worse than reservoirs on Swift Current Creek.

5.4.6 Pipeline from Duncairn Reservoir to Swift Current (SC20CBR1 and R2)

A pipeline would remove the need to release water from Duncairn Reservoir by the natural channel of Swift Current Creek in the winter. This would eliminate significant channel losses.

5.4.6.1 **Water Demand.** Two options were studied. The first, SC20CBR1, considered the existing demands and reduced irrigation shortages. The second, SC20CBR2, considered the potential for added area with similar shortages.

5.4.6.2 **Findings.** This pipeline option could reduce shortages from 17 percent to 7 percent of the years or free 4 400 dam^3 of added water for irrigation development.

5.4.7 Pipeline from Lake Diefenbaker (SC20CCR1 and R2)

A pipeline from Lake Diefenbaker to Swift Current would remove the City as a demand on the water of Swift Current Creek and would eliminate the channel losses for winter releases from Duncairn Reservoir.

5.4.7.1 **Water Demand.** Similar options to the Duncairn Reservoir pipeline were studied.

TABLE 15 IMPACTS OF RESERVOIRS 7B AND 8B

Scenario	Reservoir Volume (dam^3)	Percent of Years with Shortages	Annual Demand (dam^3)	Average Annual Supply (dam^3)	Average Annual Supply (dam^3)	Improved Annual Supply (dam^3)	Duncairn Desirable Levels (Percent)
SC20C2R2	0	17	28 250	1 318	26 932	0	68
SC20C8R1	1 240	16	28 250	1 104	27 146	214	70
SC20C8R2	1 240	17	29 050	1 300	27 750	818	69
SC20C8R3	14 000	17	40 250	1 245	39 005	12 073	68

5.4.7.2 **Findings.** This pipeline option could reduce shortages from 17 percent to 3 percent of the years or free an additional 10 000 dam^3 of water for irrigation developments.

5.4.8 Increased Water Demands (SC20CDR1 and R2)

No new irrigation areas have been developed in the Swift Current Creek basin in recent years and since additional areas would increase the frequency of shortages to unacceptable levels, no new areas are expected to be permitted by the year 2000. However, there are additional areas that could benefit from irrigation and more farmers would like to irrigate. Therefore, these scenarios evaluate the possibility of letting irrigation development grow at average historical rates after the year 2000.

5.4.8.1 **Water Demand.** If the average long-term growth rate for irrigated area was allowed to occur from the year 2000 to 2020, the area would grow from 7 618 ha to about 8 830 ha and the average annual water use would grow from 28 250 to 34 000 dam^3.

Municipal and domestic demands were assumed to be the same as in all long-term scenarios.

5.4.8.2 **Findings.** If this growth in demand was allowed to occur without any added storage reservoirs, the frequency of shortages would increase to 32 percent from 17 percent and the average annual shortage would rise from 1 318 dam^3 to 3 364 dam^3. The frequency of desirable levels on Duncairn Reservoir would drop from 68 percent to 49 percent of the time.

Although the frequency of water supply shortages would increase, the average annual water use, which reflects the average agricultural output, would rise from 26 932 dam^3 to 30 636 dam^3.

5.4.9 Demand Management (SC20CER1, R2 and R3)

In this set of scenarios, the possibility of reducing the water demand by 40, 20 and 10 percent was tested in Scenario SC20CER1, SC20CER3 and SC20CER2 respectively. For these scenarios, the Base Case was Scenario SC20CDR1 in which irrigation demands were assumed to increase after the year 2000. The reductions could be the result of a combination of improved water use efficiencies, reduced irrigation, etc.

5.4.9.1 **Water Demand.** All consumptive water uses were assumed to be reduced by the specified percentages.

5.4.9.2 **Findings.** The frequency of shortages which rose to 32 percent in Scenario SC20CDR1 would be reduced to 0, 7 and 19 percent respectively by the 40, 20 and 10 percent demand management options.

The frequency of desirable Duncairn Reservoir levels which had dropped to 49 percent in Scenario SC20CDR1 would rise to 93, 74 and 64 percent, respectively, with demand management.

6.0 SYSTEM-LIMIT ANALYSIS

In order to determine how the current and forecast short-term and long-term water uses compare to the ability of the river system to support these types of uses, a series of scenarios were studied which defined the upper limit of potential development. The system-limit scenarios were not intended to represent probable developments. They were intended only to define the limits of water supply in order to determine the sustainability of the actual and projected uses.

Since these scenarios dedicate all water to one type of use they are not considered to be realistic for development purposes. For this reason, the evaluation only considers one factor for each scenario.

6.1 MAINSTEM

The System-Limit Scenarios identify the limits for each type of water use including municipal, industrial, irrigation, recreation and hydro-electric power generation.

Since these system-limits would apply to some point in time far into the future, water uses in Alberta might have advanced beyond the uses forecast in the long-term. The absolute limit of Alberta development would occur when diversions equalled the full allotment under the Master Agreement on Apportionment. At this point Saskatchewan would be receiving about 50 percent of the natural flow annually. However, it would be very difficult for Alberta to develop works or storage to divert all of the apportionment flow in wet years. In the long-term, diversion is expected to reach about 33 percent of annual natural flow on average. In the far-future this might expand to 40 percent.

Two sets of far-future scenarios were studied, one with Alberta diverting an average of 40 percent and the other 50 percent of the natural flow. For most purposes, both alternatives produce similar results because in either case, in the critical dry years, the diversion will be the full 50 percent. The scenario results are labelled MF5 and MF6 for 50 percent and 60 percent delivery to Saskatchewan respectively, in Appendix C.

Minimum water demands in Saskatchewan as projected to the year 2000 were assumed to continue into the far future. That is, in each scenario, all demands at the year 2000 projected level were satisfied before any new system-limit requirements were calculated. The minimum flow of 42.5 m^3/s downstream of Gardiner Dam was included as an existing use which would be protected.

6.1.1 Base Case Scenario (MF5Base and MF6Base)

6.1.1.1 **Water Demand.** In the Base Case Scenarios off-stream water uses were set at the year 2000 projected demand. The Water Resource Management Model simulation was carried out with the same rules and penalty points as the Short-Term Base Case Scenario.

6.1.1.2 **Findings.** Although the total volume from Alberta decreases, as a result of greater flow regulation in Alberta, the frequency of flows in the desirable range upstream of Lake Diefenbaker increases from 34 percent in the short-term to 39 percent for the Far Future Base Case. The frequency of below desirable flows rises 7 percent from 12 to 19 percent and the occurrences of flows below 42.5 m^3/s, which are less than 1 percent in all cases, increase slightly.

Winter flows which are usually between 42.5 m^3/s and 400 m^3/s, could drop below 42.5 m^3/s about 2 to 5 percent of the time in the far future.

The reduced flow volume would result in significantly lower levels on Lake Diefenbaker. Desirable levels which could be expected 27 percent of the time in the short-term Base Case would only occur 18 to 20 percent in the far future Base Cases.

Desirable flows downstream of Gardiner Dam would similarly decrease from 26 percent to 8 or 9 percent. Summer flows would be below 60 m^3/s more than 75 percent of the time.

Average annual power generation at Coteau Creek Generating Station would drop by 24 to 32 percent and at the Nipawin and E.B. Campbell Generating Stations by 10 to 14 percent.

6.1.2 Maximum Irrigation Scenarios (MF5C1 and MF6C1)

6.1.2.1 Water Demand. Although irrigation might be developed at other locations, for these scenarios, it was assumed that it would draw on Lake Diefenbaker. It was further assumed that the rate of use would be 457 mm.

At present irrigators from the South Saskatchewan River in the study area are assured of having water available 100 percent of the time. On most streams in southwest Saskatchewan and southern Alberta, including the South Saskatchewan River Basin in Alberta, irrigators occasionally ration water due to shortages in the supply. Therefore, in addition to identifying the irrigation potential with a firm, 100 percent supply, the irrigation potential with occasional (15 percent of the years) rationing was also identified.

Lake Diefenbaker is presently operated as a multipurpose reservoir and flow regulation is a major criterion in its operation. The lake is regularly drawn down through the winter to provide storage for the following summer's peak flows. This operation was retained in the System-Limit Base Case Scenario and in the initial simulations of maximum irrigation. However, if the system was to be dedicated to irrigation, the winter drawdown would not be the best operation. Therefore scenarios with one, two and four metres less winter drawdown than at present were also studied.

All other uses were assumed to remain constant at the year 2000 projected demand.

6.1.2.2. Findings. Without changing any operating patterns or requiring any rationing, an additional 110 000 ha of irrigation beyond that projected for the year 2000 could be developed even if Alberta used its full 50 percent of the water. The area would increase to 180 000 ha if Alberta uses are assumed to leave an average of 60 percent of the flow. These potential areas would more than double if rationing in 15 percent of the years is permitted. These areas are in addition to the 62 000 ha projected for the year 2000 and represent a 177 percent and 290 percent increase respectively.

If the typical winter drawdown is reduced by one, two or four metres, the potential area increases by 9, 18 and 45 percent respectively.

If the required minimum flow downstream of Gardiner Dam was increased from 42.5 to 60 m^3/s, the system-limit irrigation potential would be reduced by about 80 percent.

6.1.3 Maximum Municipal Development Scenarios (MF5C2 and MF6C2)

6.1.3.1 Water Demand. Although municipal demands will likely increase at other locations as well as Saskatoon, it was assumed for these scenarios that all of the demand would be at Saskatoon. No allowance was made for the potential reuse of treated effluent at downstream locations. These scenarios therefore provided a minimum indication of the supply potential.

6.1.3.2 Findings. Without changing any operating patterns, an additional 560 000 dam^3 of water could be used for municipal purposes beyond the 76 000 dam^3 projected for the year 2000 even if Alberta used its full 50 percent of the water. The population served by the water of the basin could grow by a factor of eight, from 400 000 to 3 200 000. This volume of water would increase to 900 000 dam^3 if Alberta delivers an average to 60 percent of the natural flow.

If the winter drawdown is reduced by one, two or four metres, the potential municipal supply increases by 9, 18 and 45 percent respectively.

If the required minimum flow downstream of Gardiner Dam was increased from 42.5 to 60 m^3/s, the system-limit municipal potential would be reduced by about 80 percent.

6.1.4 Maximum Industrial Development Scenarios (MF5C3 and MF6C3)

6.1.4.1 Water Demand. The largest industrial water uses from the study area at present are the potash mines on the SSEWS system. Additional industrial use occurs at potash mines and the thermal power station near Saskatoon and a portion of the Qu'Appelle River diversion is used by industries. All of these uses are receiving water from Lake Diefenbaker either through gravity releases to the rivers or by pumping. Therefore, the System-Limit Scenarios for industrial water use assumed that the future industrial growth would rely on Lake Diefenbaker as its source of supply. It was further assumed that there would be no return flows.

6.1.4.2 Findings. The quantities of water would be the same as for the municipal scenario above.

The basin could support an industrial base about 100 times larger than at present.

6.1.5 Maximum Hydro-electric Power Scenarios (MF5C4 and MF6C4)

6.1.5.1 Water Demand. Off-stream uses were held at year 2000 levels.

Three additional hydro-electric power stations were assumed to be developed: two on the South Saskatchewan River near Dundurn and near St. Louis and one on the South Saskatchewan River near the Forks.

6.1.5.2 Findings. In the far future, the total average hydro-electric capacity of the South Saskatchewan and Saskatchewan Rivers in the Base Case could be 6 100 000 and 6 500 000 Mwh for the 50 percent and 60 percent Alberta supplies from the three existing and three potential power stations. By comparison, the three existing stations produce about 4 200 000 Mwh under 1986 flow conditions. With no additional power stations, the average annual power output would drop to 3 200 000 or 3 400 000 Mwh for the 50 and 60 percent Alberta water supplies.

Operating variations ranging from a one metre increase to a five metre decrease in the winter drawdown on Lake Diefenbaker and from 42.5 to 100 m^3/s for base flows were tested. The resulting change in total generation was less than 2 percent. Scenarios that improved total generation resulted in reduced winter generation.

6.1.6 Maximum Lake Diefenbaker Recreation Scenarios (MF5C5 and MF6C5)

6.1.6.1 Water Demand. Off-stream uses were held at year 2000 levels.

6.1.6.2 Findings. If the short-term operation proposals were implemented, Lake Diefenbaker could be expected to be in its desirable summer range about 25 percent of the time, above desirable 46 percent, and below desirable 29 percent of the time. If the short-term operation proposals were not adjusted in the future and Alberta delivered an average of 60 or 50 percent of the natural flow, the frequency of desirable levels would drop to 20 or 19 percent respectively and the frequency above the desirable range will drop to 26 or 20 percent of the time, respectively. The frequency of below desirable lake levels would rise to 54 or 61 percent of the time, respectively.

Scenarios with one, two and four metre reductions in the winter drawdown were tested and the four metre reduction provided the best improvements to the lake levels. The frequency of desirable levels rose to 44 and 56 percent of the time for the 50 percent and 60 percent Alberta flows respectively. The excursions from the desirable levels would almost all be above the desirable range, 44 and 56 percent respectively, rather than below desirable.

6.1.7 Maximum Recreation Downstream of Lake Diefenbaker Scenarios (MF5C6 and MF6C6)

6.1.7.1 Water Demand. Off-stream uses were held at year 2000 levels.

6.1.7.2 Findings. If the short-term operation proposals were implemented, the flow below Gardiner Dam could be expected to be in its desirable summer range about 35 percent of the time, above the desirable range 31 percent of the time, and below the range 34 percent. If the short-term operation proposals were not adjusted in the future and Alberta delivered an average of 60 or 50 percent of the natural flow, the frequency of desirable levels would drop to 9 and 8 percent respectively, above desirable flows would drop to 19 and 14 percent and below desirable flows would rise to 72 and 78 percent of the time.

If the operation of Lake Diefenbaker was dedicated to maintaining downstream flows only, the occurrences of flows below 60 m^3/s could be eliminated and the flow could be maintained in the desirable range more than 80 percent of the time.

6.2 SSEWS SYSTEM

The SSEWS system is a manmade water delivery system and, if future demands require expansion, this system could be expanded to meet the needs. For the System-Limit Scenarios, the existing physical system was held constant and additional demands were added until water shortages occurred. Future development would be maximized if it occurs in the upstream end of the system where canal capacities are greatest.

It should be noted that these system-limit water uses on the SSEWS are not in addition to the system-limit uses on the Mainstem. These SSEWS system uses are a part of the Mainstem uses.

6.2.1 Maximum Irrigation Scenario (SEF5C1R1)

6.2.1.1 Water Demand. All water uses except irrigation were held constant at the year 2000 projected level. Irrigation water use was assumed to increase until shortages began.

6.2.1.2 Findings. The area of irrigation along the SSEWS system could increase as shown below:

Broderick Reservoir	3 000 ha	13 700 dam^3
Brightwater Reservoir	100 ha	4 600 dam^3
Blackstrap Lake	1 900 ha	8 700 dam^3
Total	5 000 ha	27 000 dam^3

6.2.2 Maximum Municipal Scenario (SEF5C2R1)

6.2.2.1 Water Demand. If the growth in water demand was to occur in the municipal sector, the SSEWS system could supply a larger quantity of water because the demand would be spread over the year and would compete less for canal capacity with existing peak summer irrigation demands.

6.2.2.2 Findings. The water delivery capacity for municipal uses would increase as follows:

Broderick Reservoir	39 000 dam^3
Brightwater Reservoir	30 000 dam^3
Blackstrap Lake	18 000 dam^3
Total	87 000 dam^3

This is approximately a 100-fold increase over the projected year 2000 municipal demand.

6.2.3 Maximum Industrial Scenario (SEF5C3R1)

6.2.3.1 Water Demand. Industrial uses were assumed to be spread uniformly over the year.

6.2.3.2 Findings. The water delivery capacity for industrial uses would increase as follows:

Broderick Reservoir	31 000 dam^3
Brightwater Reservoir	15 000 dam^3
Blackstrap Reservoir	11 000 dam^3
Bradwell Reservoir	1 000 dam^3
Total	58 000 dam^3

The total is slightly smaller than the municipal demand increase because more water is used in winter when the canals cannot function.

The SSEWS system could support about 16 times as much industry as it presently serves.

6.3 SWIFT CURRENT CREEK

The System-Limit Scenarios for Swift Current Creek identify the limits for municipal, recreation and irrigation development.

The water available for management on Swift Current Creek all arises in Saskatchewan so use patterns in Alberta are not a concern.

6.3.1 Maximum Municipal Development Scenario (SC20CFR1)

6.3.1.1 Water Demand. Existing developments on Swift Current Creek divert a much larger portion of the available flow than is the case on the mainstem. By the early 1980s irrigation developments were using sufficient water that, in drought years, the supply was inadequate and rationing occurred. No new irrigation development has been permitted in recent years and unless some major new storage is developed, no new irrigation is expected in the short-term future. Therefore, in the System-Limit Scenario for municipal development, irrigation use was held constant at the current level. The frequency of shortages to irrigation users was also held constant.

In order to maximize the supply, additional storage would be needed. For this scenario it was assumed that the existing Duncairn Reservoir FSL would be raised 1.12 m to 808.9 m and a new reservoir with a capacity of 150 000 dam^3 would be built upstream of Duncairn Reservoir.

It was assumed that the municipal use would be concentrated at the city of Swift Current and that no return flows would be available.

6.3.1.2 Findings. If these additional storage opportunities were developed and if they were dedicated to providing water for municipal development at the city of Swift Current, a firm additional supply of 19 000 dam^3 of water per year could be made available. The population served could grow by a factor of five from 15 000 to about 80 000 people.

6.3.2 Maximum Recreation Development Scenario (SC20C7R5).

6.3.2.1 Water Demand. In this scenario it was assumed that a large, 150 000 dam^3, storage reservoir would be constructed upstream of Duncairn Reservoir. This new reservoir would be dedicated to meeting the existing irrigation demand and municipal demand and Duncairn Reservoir would be maintained in its desirable range when possible for recreation uses.

6.3.2.2 Findings. By developing additional storage upstream of Duncairn Reservoir and holding irrigation development constant, the frequency of desirable levels on Duncairn Reservoir could be increased from 78 percent to 83 percent of the time.

6.3.3 Maximum Irrigation Development Scenario

These scenarios test the limit of development potential with a 150 000 dam^3 reservoir at SC1; both downstream reservoirs, 7B and 8B; and Duncairn Reservoir FSL raised, all in one scenario. Since the Rushlake Creek reservoir was ineffective, it was not included in these scenarios.

6.3.3.1 **Water Demand.** As in the other scenarios, two options were studied. The first, SC20CAR1, considered the existing irrigated area and reduced shortages. The second, SC20CAR2, considered the potential for added area with similar shortages.

6.3.3.2 **Findings.** Even with all of the potential storage development, there would be occasional shortages to the existing users. The frequency of shortages would drop from 17 percent to 7 percent of the years.

If additional irrigation area was developed, an additional water demand of 15 300 dam^3 per year could be established. This represents an increase of about 50 percent over current irrigation demand.

7.0 PROJECT EVALUATION PROCEDURES

7.1 INTRODUCTION

The Framework Plan for water management developed from the South Saskatchewan River Basin Study is composed of three parts: Basin Management Strategies, the Project Evaluation Procedures, and the Inter-agency Implementation Plan. This chapter describes the Project Evaluation Procedures.

7.2 PROJECT EVALUATION PROCEDURES

The evaluation of specific water resource projects was never considered to be part of the South Saskatchewan River Basin Study. Rather, one of the study objectives was to:

> "develop a framework plan for the conservation and management of the water in the South Saskatchewan River Basin in Saskatchewan which allows for the evaluation of water resource projects".

Thus, the Framework Plan was intended to devise suitable evaluation strategies for future projects as project proponents came forward with detailed plans for consideration. The development of such suitable evaluation strategies fits in well with the fact that both federal and provincial evaluation procedures were under review at the time the South Saskatchewan River Basin Study was underway.

There are two important aspects to the effective evaluation of a project. First, the evaluation should be comprehensive, and include impact assessment from the socio-economic, engineering and environmental perspectives. Second, the evaluation procedures should be consistently applied at a stage of the project planning when real alternatives for decision-making still exist.

Project evaluation is a major undertaking. Impacts on the entire region in which the project is proposed, as well as the specific sites within the affected river basin, must be assessed. Water allocation, system operation alternatives and overall development schemes all have to be considered to ensure that approval is granted for the best proposed project among those alternatives available.

7.2.1 Existing Evaluation Processes

Presently, a complex process for evaluating water resource development proposals exists at both the federal and provincial levels of government. The empowering legislation of many agencies requires them to be involved in specific aspects of new project evaluation.

The South Saskatchewan River Basin Study Water Management Technical Appendix describes historic and existing water management institutions. This document identifies all of the agencies, legal authorities, boards, and committees, as well as the administrative structures of all levels of government, that have some role in the management of water resources in the basin.

There are three main evaluation mechanisms which may apply to water resource development proposals in the study area. These are the water use licensing process as administered by SaskWater, and the provincial and federal environmental assessment processes.

7.2.1.1 SaskWater. The licensing and regulation of water use projects in Saskatchewan is the responsibility of SaskWater. Section 43(1) of the Water Corporation Act, July, 1984, specifies that "Subject to subsection (2), no person shall divert or use any surface water or construct or cause to be constructed any dam or other works for the impounding of surface water unless authorized by the Corporation." Notwithstanding exceptions noted in The Act, persons initiating water use projects are required to submit an application to SaskWater before constructing works. The complete application consists of three components: 1) a completed application form; 2) a fee as prescribed in the regulations; and where not waived, 3) acceptable engineering plans and other additional information necessary to complete the application.

SaskWater reviews the application in relation to other existing and potential uses of the water, and if suitable, SaskWater issues an Approval to Construct Works and construction of the project can begin according to the approved plans, with appropriate conditions. The applicant has one year in which to complete construction; however, extensions are permitted under certain conditions. Upon completion of the works, SaskWater conducts an inspection to ensure the project conforms to plans, and if satisfied issues an Approval to Operate, subject to any terms and conditions considered appropriate.

Under the terms of the Water Corporation Act, project approval from Saskatchewan Environment and Public Safety is required before any SaskWater approval is issued.

7.2.1.2 Saskatchewan Environment and Public Safety. Much of Saskatchewan Environment and Public Safety's interest in proposed water management projects occurs under the auspices of the Environmental Management and Protection Act, and the Water Pollution Control and Water Works Regulations and Environmental Spill Control Regulations associated with it. This Act is the primary legislation regarding pollution control in the Province of Saskatchewan. Although it is intended to address problems related to air, water, and land-based pollution, it is heavily oriented to water quality management, and specifically deals with water pollution control, industrial effluent works, sewage works and water works.

Within the definition section of legislation, two important terms must be noted. First, pollutant is defined as any substance that causes or may cause environmental pollution. Second, pollution includes the alteration of physical, chemical, biological, or aesthetic properties of the environment, including the addition or removal of any substance that will render the environment harmful to the public health, is unsafe or harmful for domestic, municipal, industrial, agricultural, recreational, or other lawful uses of the environment, or is harmful to wild animals, birds or aquatic life.

Regulations require that no one discharge, without a permit, contaminants which might reasonably cause a change in water quality or water pollution. The construction, installation, alteration, extension, or operation of any industrial effluent works requires a valid and subsisting permit.

The Environmental Management and Protection Act is intended to be all-encompassing. It specifies that any licence, permit or other authority for the discharge of waste into the environment is invalid unless issued pursuant to this legislation, or if used prior to the passage of this legislation, unless it has received approval of the Minister.

7.2.1.3 Environment Canada. The federal government's Environmental Assessment and Review Process (EARP) provides much of the framework Environment Canada requires to participate and assist in the evaluation of water resources projects in Canada.

This process applies to any "initiative, undertaking or activity for which the Government of Canada has a decision-making responsibility"; defined as a "proposal". Although interpreted for many years as an informal "guideline", recent decisions by the Federal Court (Rafferty/Alameda Dam, Oldman Dam) have confirmed its status as a non-discretionary regulation. The process essentially consists of two phases, initial assessment and public review. Initial assessment may include screening or further study or "initial environmental evaluation". If potential impacts are insignificant or mitigable with known technology the process is completed. If potential impacts are significant, unknown or public concerns are significant; the proposal may be referred to an Environmental Assessment Review Panel for a public review. At this stage, the proponent is required to prepare a comprehensive Environmental Impact Statement (EIS) for evaluation by government and the public through formal public hearings. The Panel reviews all relevant input and makes recommendations to the Minister of the Environment on whether the proposal should proceed and under what conditions it should proceed. The federal environmental assessment and review process is currently under review. New legislation, the Canadian Environmental Assessment Act (CEAA, Bill C-13), is presently before Parliament.

The Federal Environmental Assessment and Review Office (FEARO) is responsible for administering the federal Environmental Assessment Review Process. The purpose of Environmental Assessment Review Process is to ensure that the environmental consequences of all federal proposals, and proposals affecting areas of federal responsibility, are assessed for potential adverse affects early in the planning process. A project is considered federal if it is undertaken by a federal department, or may have an environmental effect on an area of federal responsibility, or involves a commitment of federal funds, is located on lands administered by the federal government or involves federal Crown Corporations.

The Federal Environmental Assessment and Review Office is independent of Environment Canada, with the Executive Chairman reporting to the federal Minister of the Environment. Federal agencies are responsible for applying Environmental Assessment Review Processes for proposals within their area of decision-making responsibility and must make a screening decision. Records of environmental screening decisions by federal agencies, in terms of allowing projects to proceed with mitigation, or recommendation for a Public Review by an independent Panel, are forwarded to the Federal Environmental Assessment and Review Office for publication. The Federal Environmental Assessment and Review Office provides advice to the Minister on screening decisions as appropriate, and arranges Panel membership and terms of reference when requested by federal agencies.

To date, no project in the basin has been subject to a Public Review by a Panel, although a variety of projects have been screened, and results have been forwarded to the Federal Environmental Assessment and Review Office.

7.2.1.4 Other Agencies. In addition to these main evaluation processes and regulations, there are a variety of other government organizations involved in project evaluation. Some examples of federal legislation and how the affected agencies are involved include:

- Navigable Waters Protection Act - no one may build a work in, upon, over, under, through or across any navigable water without ministerial approval;
- Fisheries Act - no undertaking or work may be carried out which results in harmful alteration, disruption, or destruction of fish habitat unless authorized by the Minister;
- Canada Shipping Act - regulations exist under this Act which govern the discharge from ships of specified pollutants into waters.

Similarly, a number of pieces of provincial legislation may apply to proposed water resources projects, including:

- Provincial Lands Act - outlines regulations regarding the ownership of the bed of all water courses, and rights of public access to water resources;
- Critical Wildlife Habitat Protection Act - prevents any alteration of critical wildlife habitat lands without Ministerial authorization;
- Heritage Property Act - no one can destroy, alter, or change real property fixtures which have been designated under this legislation.

7.3 PROJECT EVALUATION TOOLS AND DATABASES

As discussed in Chapter 2 of this appendix, the South Saskatchewan River Basin Study developed a Framework Plan which included proposals to help resolve issues identified within the study area and to develop information and evaluation tools that will improve the effectiveness of government-administered project evaluation procedures.

Not all of the changes in water resources management involve the construction of new projects. New government policies or programs may have a direct effect on water management. Some of the evaluation tools applicable to project evaluation may also find application in the assessment of proposed changes in established government policies and programs.

Many of the project evaluation procedures developed by the study use as their centrepiece a tool of one sort or another. These tools may consist of computer models, databases, maps, or survey results. The following section describes these project evaluation procedures.

7.3.1 Databases

DATABASE: INSTREAM WATER USE PREFERENCES

Agency: Integrated Resources Branch, SaskWater

Location: SaskWater
111 Fairford Street East
Moose Jaw, Saskatchewan

Computer: not applicable

Description: Instream uses in the South Saskatchewan River Basin require a variety of flows to meet the requirements of each use. It is extremely important that some of these criteria be met by regulating river flows, while other criteria are less important because there are alternate opportunities for that use. The different instream uses must be considered when various water management opportunities are evaluated. These evaluations may involve the modelling of various aspects of the river or river basin, and basic information regarding river flows and how they impact various uses must be available.

This database provides the necessary instream use information. Data was gathered by means of surveys of individuals knowledgeable about the requirements of a particular use. Respondents were asked to identify the preferred, minimum and maximum criteria required for use as well as to provide information on any other criteria required for their particular instream use.

Critical values were defined as follows:

- **MINIMUM CRITERIA** are the lowest water levels, flows, velocities, depths or concentrations of water quality constituents at which a use may occur safely and effectively, although at a impaired state.
- **MAXIMUM CRITERIA** define the highest water levels, flows, velocities, depths or concentrations of water quality constituents at which a use may occur safely and effectively, although at a impaired state. Theoretically, outside of the maximum and minimum critical values, the use cannot occur.
- **PREFERRED CRITERIA** are the water levels, flows, velocities, depths or concentrations of water quality constituents which are ideal for a particular use.

Once the criteria for particular sites on the river were identified, they were compared to the criteria of other uses in the same reach.

Data Requirements: The type, location and scope of the proposed project are the primary data requirements for this database. This information will enable the person evaluating possible impacts on instream users to better appreciate their differing needs, and the variety of trade offs that must be considered when considering alternative water management strategies.

Limitations: As the majority of persons interviewed could not cite a specific flow or water level, criteria were frequently identified in terms of a particular time period. Memory is not always accurate and errors can result. It is important to note that the derived values are based on the experience of user groups or their representatives, water resource managers and operational staff, experts and members of interest groups. The resulting values were usually formulated based on the conversion of time periods to mean monthly flows or water levels. This has subsequently resulted in a significant degree of qualitativeness and variance in the results. The criteria identified by this tool should therefore be considered as estimates rather than absolute values. By contacting more than one user, a range of values has been established for types of uses such as recreation and transportation. When the range is relatively narrow, the accuracy of the value can be expected to be quite high. Wider ranges probably reflect a degree of inaccuracy, especially in terms of extreme high of low values.

Applications: The Instream Water Use Preferences database will assist the water resources planner in the process of water resources project development and review. It will augment this process by providing basic information on the needs of instream users presently existing within the basin, and will help ensure that the impacts on users resulting from any changes in water management strategies are more fully understood right from the initial stages of basin planning and development.

Examples of Output: not applicable

Reference: Beak Associates Consulting Ltd. (1987) South Saskatchewan River Basin Instream Water Use. Prepared for the South Saskatchewan River Basin Study Office as SSRBS Technical Report E.7.

DATABASE: HYDROMETEOROLOGIC BASIC DATA FILE (HBDF)

Agency: Hydrology Branch

Location: SaskWater
111 Fairford Street East
Moose Jaw, Saskatchewan

Computer: VAX mainframe computer

Description: The Hydrometeorologic Basic Data File (HBDF) is a weekly/monthly data base file containing the following information:

a. Hydrometric data (natural/recorded flows);

b. Meterological data (evaporation and precipitation);
c. Water demands

The Hydrometeorologic Basic Data File was a major data source for both the Water Resources Management Model (WRMM), and the Hydro System Simulation (HYDSIM) model used in the South Saskatchewan River Basin Study to examine the impacts of various operating scenarios on different components of the river system.

Natural flow arrays were developed based on historical streamflow data. Data collected at each station operated by Environment Canada (Water Survey of Canada) was not always complete for the full 1912 - 1986 period. As a result, several hydrometric stations were required to complete a monthly flow array for the entire period for any given location.

Precipitation data was developed on a monthly basis for the 1912 - 1986 period for each of the reservoir and lake sites in the study area. While climatological data has been extensively collected in the province during this period, not all of the climatic stations have operated for its duration. In these cases, the extensions of records was done using regressional analysis, and the development of monthly precipitation values for each reservoir or lake site followed accepted data transfer techniques.

Gross evaporation was based on three PFRA gross evaporation stations: Swift Current, Saskatoon and Prince Albert. The PFRA gross evaporation calculation is based on the Meyer equation.

Water demand data was obtained from the database maintained by the Registrar of SaskWater. The Registrar has information on all water use and diversion projects, whether in the application stage, authorized, or licensed. For the purposes of the Hydrometeorologic Basic Data File, authorized and licensed projects were included from the Registrar's database when compiling the water demand data sets.

DATABASE: WATER INTAKE AND OUTFALL SURVEY

Agency: Integrated Resources Branch, SaskWater

Location: SaskWater
111 Fairford Street East
Moose Jaw, Saskatchewan

Computer: not applicable

Description: The Water Intake and Outfall Survey was undertaken to provide an inventory of intakes and outfalls on the South Saskatchewan River. Intakes supply water for municipal, agricultural, industrial and instream uses, and their function is dependent upon the level of the water. Outfalls deliver effluent to the river, and are relatively insensitive to the water level although effluent dilution is very closely associated with the amount of water available in the receiving body. The information provided by this survey is used to help determine use criteria for offstream water users.

SaskWater water rights maps were reviewed to identify all water intakes on the mainstem of the South Saskatchewan River, Swift Current Creek and SSEWS system. This information was combined with that obtained from a review of surface water rights files located at SaskWater regional offices. Permanent outfalls were located through an examination of Saskatchewan Environment and Public Safety's permit files.

The survey identified permanent and temporary intakes and outfalls, and includes such associated data as the name of the user, location, elevations, license number and status, etc. The final section of the report outlines remedial actions that could be undertaken to fill the identified gaps in the data, and suggests options for determining criteria for permanent intakes.

Data Requirements: n/a

Limitations: Data obtained by this survey was found to be generally insufficient and inadequate to determine criteria for all intakes in the South Saskatchewan River Basin. The mapping done by SaskWater to illustrate intake locations is not complete, there being discrepancies between intakes identified in the water rights files and those that were mapped.

It was not possible to determine water allocations for all water rights projects. Water allocations are granted as a final step in the approval process, and there are cases in which water rights plans have waited over 25 years to receive allocations. In addition, it was found on occasion that there were missing "as constructed" drawings as required for final approval. Finally, of the 124 permanent structures in the study area, only 74 were surveyed to geodetic elevation. Other structures reviewed in this report were found to have had no invert elevation provided on the water rights plans. Flow criteria cannot be identified for structures having unknown or assumed datum inverts.

Applications: Information collected during the Water Intake and Outfall Survey will help the water resources planner determine use criteria for offstream users.

Reference: Beak Associates Consulting Ltd. (1987). South Saskatchewan River Basin Water Intake and Outfall Survey. Prepared for the South Saskatchewan River Basin Study Office as SSRBS Technical Report E.6.

DATABASE: RECREATION SURVEY DATABASE

Agency: Integrated Resources Branch, SaskWater

Location: SaskWater
111 Fairford Street East
Moose Jaw, Saskatchewan

Computer: personal computer

Description: This 472 record recreation survey database was developed by the South Saskatchewan River Basin Study Office from a survey undertaken during the summer of 1988. The data base takes the form of nine ASCII text files – one for each site surveyed. The objective of the study for which this database was developed was to establish the economic value, as a measure of the demand, for water-based recreation at selected parks within the basin.

Survey data was collected at 15 parks, which included six provincial parks, six regional parks and three other (private and municipal) facilities. Only those parks in the basin with water-based recreation which are relatively well known and with significant visitations were included in the analysis. The data included responses to a questionnaire which was either self-administered or administered by Study Office staff depending on circumstances at each park. Axle count data was also collected at 13 of the 15 parks. Finally, a daily log was maintained by the surveyors in which information such as wind speed and direction, precipitation, and crowding, was recorded.

The survey questionnaire was divided into four sections. Sections A and D of the questionnaire were designed to provide background information to any type of analysis, particularly those methods dealing with travel cost and contingent valuation (the individual's willingness to pay for the good in question). Section B was designed to provide information relevant to estimating the value of fishing activities at each of the sites, while Section C was intended to provide information regarding the importance of managing water levels and algae.

7.3.2 Evaluation Models

MODEL: WATER RESOURCES MANAGEMENT MODEL (WRMM)

Agency: Hydrology Branch, SaskWater

Location: SaskWater
111 Fairford Street East
Moose Jaw, Saskatchewan

Computer: Micro Vax II computer

Description: The Water Resources Management Model (WRMM) is used as an instrument for water management planning. The Water Resources Management Model was developed by Alberta Environment in 1981 to analyze water management alternatives in the South Saskatchewan River Basin in Alberta. It was used in a similar fashion by Hydrology Branch, SaskWater, to evaluate the implications of future water development and management strategies for the South Saskatchewan River Basin in Saskatchewan.

The Water Resources Management Model was used to assess, over a given time interval, the response of the South Saskatchewan River system to a set of planning alternatives based on natural water supply conditions and existing or some projected water requirements. The model simulates the ability of the natural river system to meet the demands placed on it by users while at the same time maintaining flows for instream uses.

The Water Resources Management Model models the physical river system by the use of standard components. These components are linked together by a simulation control file which describes how each component represents the river system being modelled. Table 16 lists the model components available.

When operating, the model performs water balances for each component. The model is applied in a series of time intervals, each representing a simulation decision period, and optimizes the conditions for that time period (weekly or monthly) with the output being used as the starting value for the next time period. The result is the production of a data set covering the entire simulation period for each component, with the exception of junctions (where the flow between two or more components is either joined or split).

Data Requirements: Two files are generally created in order to run the Water Resources Management Model:

1. Hydrometeorologic Basic Data File (HBDF)
   Weekly/monthly data base file may contain the following data:

   a. Hydrometric data (natural/recorded flows);

   b. Meterological data (evaporation and precipitation); and

   c. Water demands.

   Note: the above data is place in the Hydrometeorologic Basic Data File when a complete array or data set is required for the simulated time period.

2. Simulation Control File (SCF)
   - Basin Model:

   a. Identifies and describes the model control parameters (starting date, time intervals and apportionment periods);

   b. Describes the physical system (depicts physical river system with each physical feature being represented by a model component [Figures 4, 5 and 6] and describes the interrelationship of the model components);

   c. Describes the priority system (determines the operating policy for allocation of water); and

   d. Water supply and demand data (if not in the Hydrometeorologic Basic Data File file).

Limitations: A short-coming of the modelling results is that they are expressed in terms of average monthly flow values and are the product of a water balance procedure with no real-time forecasting and reservoir operating decisions. The Water Resources Management Model will satisfy the ideal conditions when there is an adequate water supply for each time interval in the simulation period. The Water Resources Management Model does not, however, have the capability of foreseeing possible shortages or surpluses in the water supply and so does not modify the operating policies according to these circumstances. The model provides "best estimates" for the normal water supply and water demand conditions in the basin or river system under examination and the results must be analyzed with this in mind. It is reasonable to assume that as hydrologic conditions deviate from normal, so will the model results vary from the actual operations.

Applications: The Water Resources Management Model was used by the South Saskatchewan River Basin Study to help evaluate the implications of future water developments and management strategies for the Saskatchewan portion of the South Saskatchewan River Basin.

TABLE 16	MODEL COMPONENTS
COMPONENT NAME	MODELLED PROCESSES
Reservoir*	- storage - releases (excluding hydropower) - net evaporation
Natural Channel	- channel flow
Hydropower	- power flows - energy generation
Diversion Channel	- gravity or pumped flow in a diversion channel
Minor Withdrawal	- consumptive use
Major Withdrawal	- consumptive use - return flow
Irrigation	- consumptive use - return flow
Apportionment Channel	- channel flow which is governed by an apportionment agreement
Junction*	- joining of flow from two or more components; also splitting of flow to two or more components

*Natural runoff is simulated as inflows at reservoirs and junctions

Two base SCF files were developed by SaskWater during the modelling for the South Saskatchewan River Basin Study. The first SCF file was established for the Swift Current Creek Basin, and the second file for the mainstem and Saskatoon Southeast Water Supply (SSEWS) systems. These two files were modified as required to simulate the various scenarios which SaskWater analyzed during the study. Figure 6 shows a typical schematic configuration of the Swift Current Basin.

SaskWater also developed a number of programs to analyze and display the results of Water Resources Management Model output. Appendix C provides typical outputs generated during the modelling work for the South Saskatchewan River Basin Study.

Reference: Hydrology Service, SaskWater (1988). South Saskatchewan River Basin Water Management Model Study. SaskWater, Moose Jaw. Prepared for the South Saskatchewan River Basin Study Office as SSRBS Technical Report C.1.

MODEL: HYDROLOGY MODEL (HEC-II)

Agency: Hydrology Branch, SaskWater

Location: SaskWater
111 Fairford Street East
Moose Jaw, Saskatchewan

Computer: personal computer

Description: The HEC-II computer program calculates water surface profiles for steady state or gradually varied flow conditions. The program is also capable of modelling the effects of structures such as bridges, culverts and weirs. The program was first developed in 1964 by the United States Army Corps of Engineers at the Hydraulic Engineering Centre in Davis, California. Since it was originally developed, the HEC-II model has incorporated a number of modifications. The version which was used in the South Saskatchewan River Basin Study was produced in 1985 for use with personal computers.

Data Requirements: Input data required for the HEC-II program includes the following:

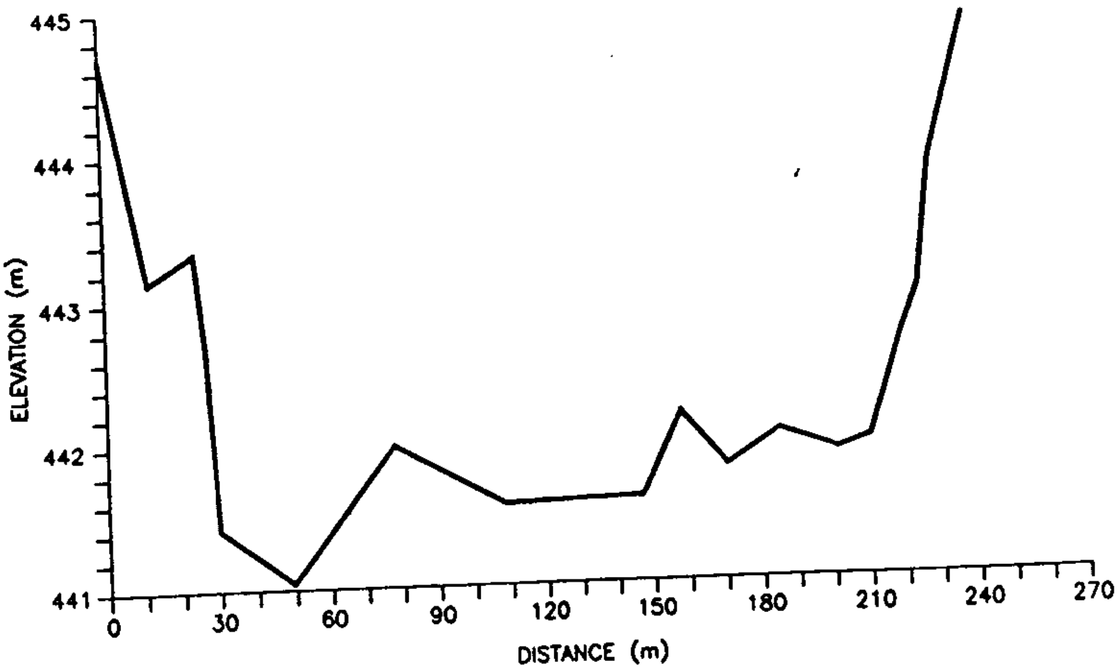
- discharge(s)
- channel cross-sections in coordinate form
- reach lengths
- estimated values for Manning's roughness coefficient "n" for channel and overbank flow areas
- coefficients representing contraction and expansion losses for each reach of the channel
- estimates of head loss coefficients for structural river crossings
- initial flow regime (sub-critical or supercritical)
- starting elevation at first cross-section.

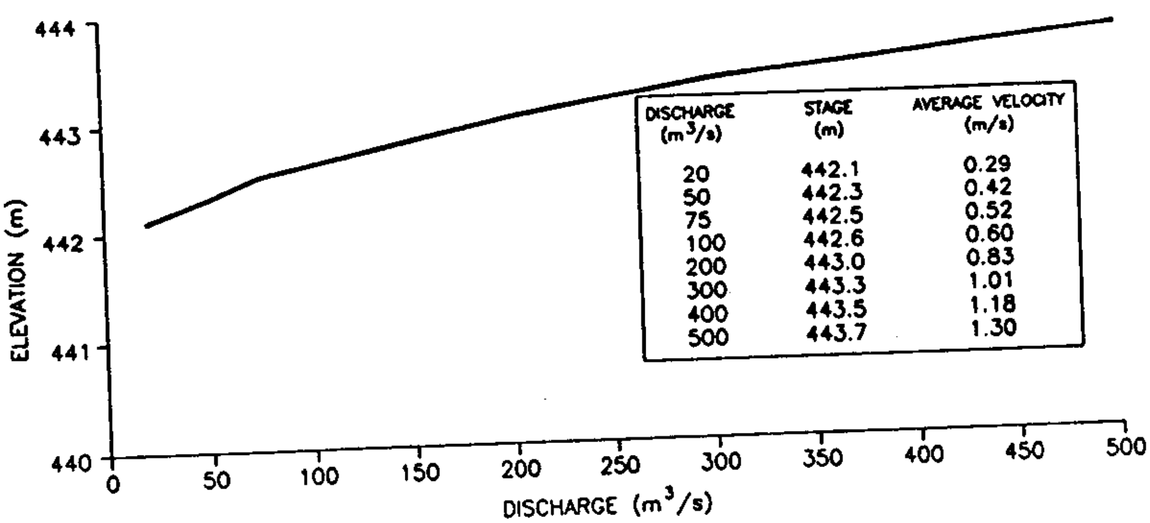
Applications: Two HEC-II computer models, one for the reach upstream of Lake Diefenbaker and one for the reach downstream were created as part of a process to supply specific hydraulic information for the South Saskatchewan River. The model was used as a means of verifying the minimum flow required for such instream uses such as pump intakes and ferry operation as well as to develop rating curves (stage-discharge relationships) for selected locations in the study area. Other uses of the model include the determination of river velocities and the development of water surface profiles.

Hydraulic data generated by this model was also used in the preparation of a fisheries survey of the South Saskatchewan River as well as a water quality model of Lake Diefenbaker.

Examples of Output: Examples of the HEC-II model output are found on Figure 8.

FIGURE 8 SOUTH SASKATCHEWAN RIVER
CROSS-SECTION NO. 143600.000
NEAR BATOCHE





DISCHARGE (m^3/s)	STAGE (m)	AVERAGE VELOCITY (m/s)
20	442.1	0.29
50	442.3	0.42
75	442.5	0.52
100	442.6	0.60
200	443.0	0.83
300	443.3	1.01
400	443.5	1.18
500	443.7	1.30

Limitations: Accurate HEC-II results are dependent on having reliable input data in the form of cross-sections that are representative of the river reach. This implies that a cross-section is required wherever the geometry of the river cross-section changes significantly. The accuracy of the results also depends upon the amount of effort expended in calibrating the Manning's roughness coefficients and head loss coefficients. Observed discharges and water surface profiles greatly enhance the accuracy of model calibration.

References: Beak Associates Consulting Limited (1989). A Hydraulic Study of the South Saskatchewan River. Beak Associates Consulting Limited, Saskatoon. Prepared for the South Saskatchewan River Basin Study Office as SSRBS Technical Report E.12.

Water Quality Branch, Saskatchewan Department of Environment and Public Safety (1988). Lake Diefenbaker Trophic State Model. Saskatchewan Department of Environment and Public Safety, Regina. Prepared for the South Saskatchewan River Basin Study Office as SSRBS Technical Report D.5.

MODEL: HERITAGE RESOURCES MODEL (PREDICTIVE SITE LOCATIONAL MODEL)

Agency: Heritage Branch, Saskatchewan Culture, Multiculturalism and Recreation

Location: Heritage Resources - Archaeology
Heritage Branch
Saskatchewan Culture, Multiculturalism and Recreation
Regina, Saskatchewan

Computer: not applicable

Description: The Heritage Resources Model consists of two components, one which examines archaeological site sensitivity or prediction zones, the other dealing with vertebrate palaeontological resource sensitivity zones. Each component consists of a map on which various sensitivity zones are depicted, thus providing the planner with a tool to help predict the likelihood of encountering heritage sites within the South Saskatchewan River Basin (See Figures 9 and 10).

In the archaeological resources model, four distinct sensitivity zones, each unique in the type, density, visibility and location of sites which may be expected, are defined. Zones 1 and 2 (valley complex and sand hills, respectively) were primary habitation areas for large social groups commonly engaged in communal bison hunting. Zone 1 had a higher human carrying capacity than Zone 2 and was consequently more intensively used. Large sites, such as base camps and communal kills, may be expected in these zones in addition to smaller, transitory camps and ceremonial locations.

Zones 3 and 4 (moderate to strongly rolling and flat to gently rolling terrain, respectively) were mainly occupied in a periodic or transitory manner by small groups. Sites here are typically small, short-term occupations, frequently consisting of tipi rings and containing few artifacts.

In the vertebrate palaeontological resource model, two types of sensitivity zones are defined. The first represents areas of high potential which contains abundant resources. Here, impact assessment, mitigation, or other protective action would be required in advance of water resource development. The second type of zone represents more moderate heritage site potential, containing scattered resources. In most cases, these resources can be sufficiently protected by means of incidental development or construction monitoring.

In the context of future water management and development, the following archaeological impact assessment and management requirements are anticipated. Comprehensive field survey and sub-surface testing will likely be required to assess most development proposals in Zone 1. Deep probing may be required along river terraces and valley or coulee bottoms. As well, many sites in Zone 1 may require salvage excavation or other comprehensive data recovery prior to development. Generally, only projects involving moderate to large-scale impacts will require comprehensive assessment in Zone 2. Sub-surface testing and trench monitoring would be routinely employed. Site survey and assessment (including sub-surface testing) will be necessary for most developments in Zone 3, especially those proposed in undeveloped areas. Impact mitigation (e.g. salvage excavation) will generally be more limited in scope. In Zone 4, site survey and assessment may be necessary for large-scale developments, especially in uncultivated areas.

Data Requirements: The type, location and scope of the proposed project are the primary data requirements for this model. This information will enable the user to locate the area under consideration on the heritage resource sensitivity maps.

FIGURE 9 **ARCHAEOLOGICAL RESOURCE SENSITIVITY ZONES IN THE SASKATCHEWAN PORTION OF THE SOUTH SASKATCHEWAN RIVER BASIN**

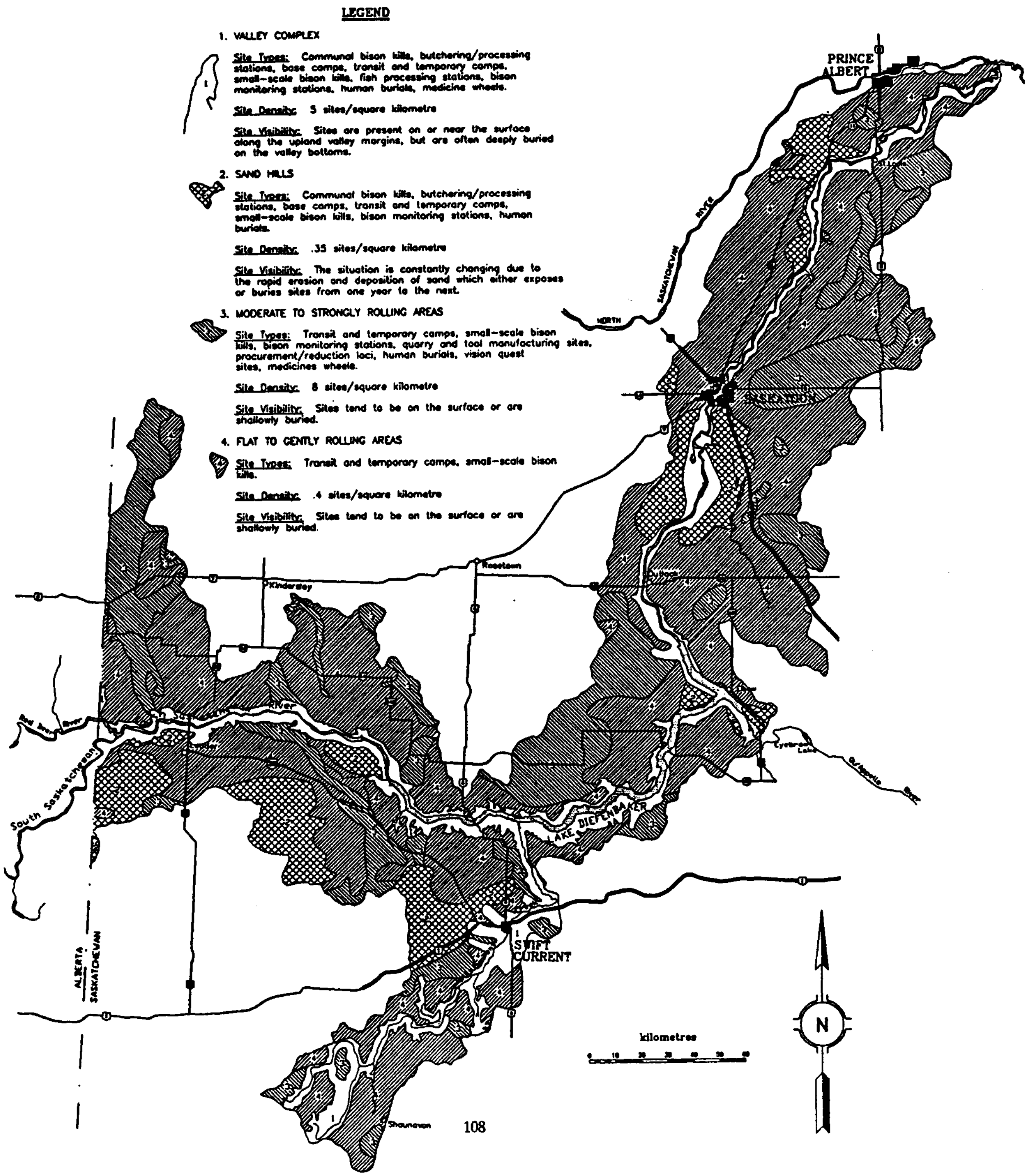
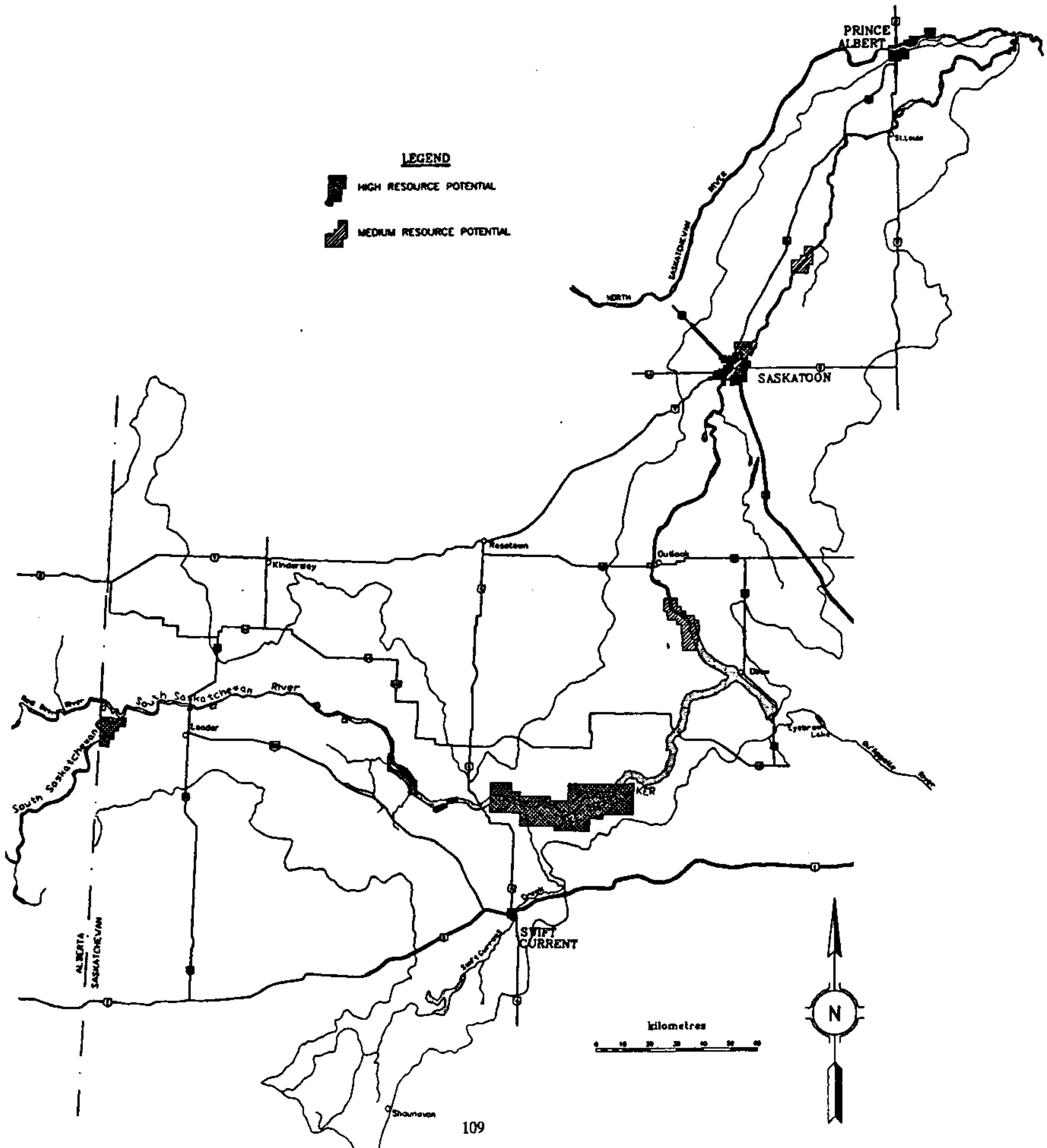


FIGURE 10 PALAEONTOLOGICAL RESOURCE SENSITIVITY ZONES IN THE SASKATCHEWAN PORTION OF THE SOUTH SASKATCHEWAN RIVER BASIN



Limitations: The heritage resource sensitivity maps are not designed to substitute for field work as they do not illustrate actual site locations. Rather, they identify areas, which, based on certain environmental and geological factors and a general understanding of prehistoric settlement patterns, are expected to contain sites. As the available data on actual site distribution and density is patchy and incomplete, the construction of more detailed or refined predictive models is not possible. It is likely that some adjustment or modification of the sensitivity classification, including additional zones or refined predictions, may be required as new data are made available.

Applications: The Heritage Resources Model will assist the water resources planner in the process of water resources project development and review. It is designed to facilitate and augment this process by addressing potential heritage concerns in the initial stages of basin planning and development. Included are recommendations as to the type of action that should be taken to protect different heritage resources identified in the model, based on the type, location and scope of the proposed development.

Examples of Output: not applicable

Reference: Heritage Resources - Archaeology, Heritage Branch, Saskatchewan Parks, Recreation & Culture (1989). South Saskatchewan River Basin Heritage Resources. Heritage Branch, Saskatchewan Parks, Recreation & Culture, Regina. Prepared for the South Saskatchewan River Basin Study Office as SSRBS Technical Report E.16.

MODEL: HYDRO SYSTEM SIMULATION MODEL (HYDSIM)

Agency: Forecasting and Generation Planning, SaskPower

Location: SaskPower
2025 Victoria Avenue
Regina, Saskatchewan

Computer: IBM 4381 mainframe

Description: The Hydro System Simulation Model (HYDSIM) was developed in-house by SaskPower for planning and operation of SaskPower's hydro-thermal power system. The Hydro System Simulation Model model is capable of simulating the operation of multi-purpose multi-reservoir hydro systems on a variable (e.g. weekly, half-monthly or monthly) time period. The model was written in Fortran 77. It employs heuristic techniques for simulating the operation of hydro systems.

The program, for each period, and for each reservoir: allocates water to multiple users (e.g. irrigation, municipal and industrial, diversions) according to a set of preassigned priorities and operating limits, estimates the power production at each plant, the reservoir levels and releases and the spillage, if any.

The program allows detailed modelling of the operating characteristics of the major components of the system e.g. reservoirs, power plants, spillways, etc. by employing nonlinear models and efficient iterative techniques for solving the simulation problem.

Data Requirements: All the inputs required to run the Hydro System Simulation Model program have been divided into three major groups, namely, i) control or run parameters, ii) operational data, and iii) system description or permanent data. A schematic diagram of the layout of the input system is shown in Figure 11.

i) Control Data

This file selects the type of run to make. The user has to enter data such as the length of the planning horizon, the number of years in it, the operating time interval (week or month), etc. The user must specify or select the appropriate method for estimating the power production and net evaporation. Options for selecting the printing of input data and output results are also made.

FIGURE 11 HYDRO SYSTEM SIMULATION MODEL DATA REQUIREMENTS

INPUT DATA

RIVER SYSTEM DATA FILE

- Description of river(s) system(s)
- No. & Names of Rivers, Reservoirs, Hydro Plants, etc.
- Name plate ratings of hydro plants
- Mathematical models of hydro plants, reservoirs, tailrace characteristics, headloss models, etc

OPERATIONAL DATA FILE

- Inflows
- Irrigation demands
- Recreational needs
- Municipal & Industrial Demands
- Hydro unit maintenance schedules
- Operational guide-lines (Reservoir discharge, lake levels, energy schedules)
- Operational Constraints

RUN/CONTROL DATA FILE

- Start & end dates
- Length of the study period
- No. of time
- Options for input/output printing

INPUT: FULL SCREEN MENU DRIVEN INPUT

ii) Operational Data

Those inputs which typically vary from one simulation run to another are grouped and included in this category. The user can specify the reservoir operating rule in one of the four following ways, namely, the desired discharge, the period end volume or elevation, or the energy power production. The environmental concerns and recreational demands can be modelled either in terms of constraints on discharge or reservoir elevations. The program allows the specification of forced spillage if required, on a period-by-period basis.

The operational constraints on lake levels, discharges, power production, etc. can be dynamically (i.e. period-by-period) allocated.

For power production, the program expects maintenance schedules for units and it can also handle any deratings on the units.

The data to be entered thus consists of:

- Inflows;
- Local inflows;
- Irrigation: industrial and municipal demands, water diversion;
- Priorities for different water users;
- Evaporation;
- Seepage;
- Forced spill
- Desired decision;
  (either discharge or volume or period-end elevation or power production i.e. target values);
- Operational constraints on reservoir levels, discharges, etc.;
- Riparian flows;
- Hydro unit maintenance schedules;
- Recreational and/or environmental concerns;
  (model them either in terms of discharge or lake level);
- Reservoir levels at the beginning and end of the planning horizon.

iii) River System Data File

All the data pertaining to the elements that describe the river or multiple river systems under study is included in this data file. In addition, it contains the mathematical models that represent the operating characteristics of reservoirs, hydro units and plants, tailrace characteristics and spillways.

Thus, the following information is to be supplied:

- Name(s) of river(s) system;
- Number of hydro plants and their names;
- Number of reservoirs and their names;
- An interconnection matrix that describes the configuration of the river system;
- Types of hydro plants and reservoirs;
- Mathematical models to compute forebay levels/reservoir volumes;
- Mathematical models to compute tailrace levels;
- Mathematical models to compute plant's head losses;
- Mathematical models to compute power output of plants at different net heads.

Limitations:

- Hydro System Simulation Model is presently limited to simulating a maximum of 15 reservoirs and 60 periods
- it does not model irrigation in detail
- it is a deterministic model. That is, inflows and water demands are assumed to be known in advance. Hydro System Simulation Model optimizes operation for each simulation period. It does not have the capability of forecasting possible future water surpluses or shortages and therefore does not modify operating policy to account for these circumstances.

- all the system characteristics (e.g. reservoir capacity curves, tailrace relations) need to be expressed in the form of polynomials. In order to improve the computational efficiency, the program is designed not to accept any tables for the system characteristics.

Application: The Hydro System Simulation Model was used by the South Saskatchewan River Basin Study to complement the Water Resources Management Model program by providing a more detailed assessment of the impact of future development strategies on hydro-electric production.

The Hydro System Simulation Model was configured to model the South Saskatchewan River and Saskatchewan River mainstems with existing and potential future reservoirs and hydro plants.

Example of Output: Table 17 and Figure 12 show examples of Hydro System Simulation Model output.

Reference: SaskPower, Planning. 1989. South Saskatchewan River Basin Hydro System Simulation (HYDSIM) Model Study Report. SaskPower, Regina. Prepared for the South Saskatchewan River Basin Study Office as SSRBS Technical Report C.7.

MODEL: LAKE DIEFENBAKER TROPHIC STATE MODEL

Agency: Water Quality Assessment Section, Saskatchewan Environment and Public Safety

Location: Saskatchewan Environment and Public Safety
3085 Albert Street
Regina, Saskatchewan

Computer: personal computer

Description: The trophic state model was designed to be used on Lake Diefenbaker for the prediction of in-lake, phosphorus, and chlorophyll concentrations and secchi disk depths. The model was written in spreadsheet form (MS Excel) and takes into account phosphorus loadings to the lake from the South Saskatchewan River, atmospheric deposition and runoff. The model is also sensitive to the volume of inflow to the lake.

Data Requirements:

- Inflows to the lake from the South Saskatchewan River
- Phosphorus loadings from the South Saskatchewan River
- Areas of the drainage basin used for unimproved pasture, dryland farming, irrigated farming, forest and urban purposes.

Application: The model can be used to evaluate the impact of land use changes or changes in phosphorus loadings from the river, on the trophic state of the lake. It was also used to develop water quality objectives for the lake.

New developments either upstream or on the lake can also be evaluated using the model.

Reference: Water Quality Branch, Saskatchewan Environment and Public Safety (1988). Lake Diefenbaker Trophic State Model. Saskatchewan Environment and Public Safety, Regina prepared for the South Saskatchewan River Basin Study Office as SSRBS Technical Report D.5.

MODEL: WATER QUALITY MODELS FOR SOUTH SASKATCHEWAN RIVER

Agency: Water Quality Assessment Section, Saskatchewan Environment and Public Safety

Location: Saskatchewan Environment and Public Safety
3085 Albert Street
Regina, Saskatchewan

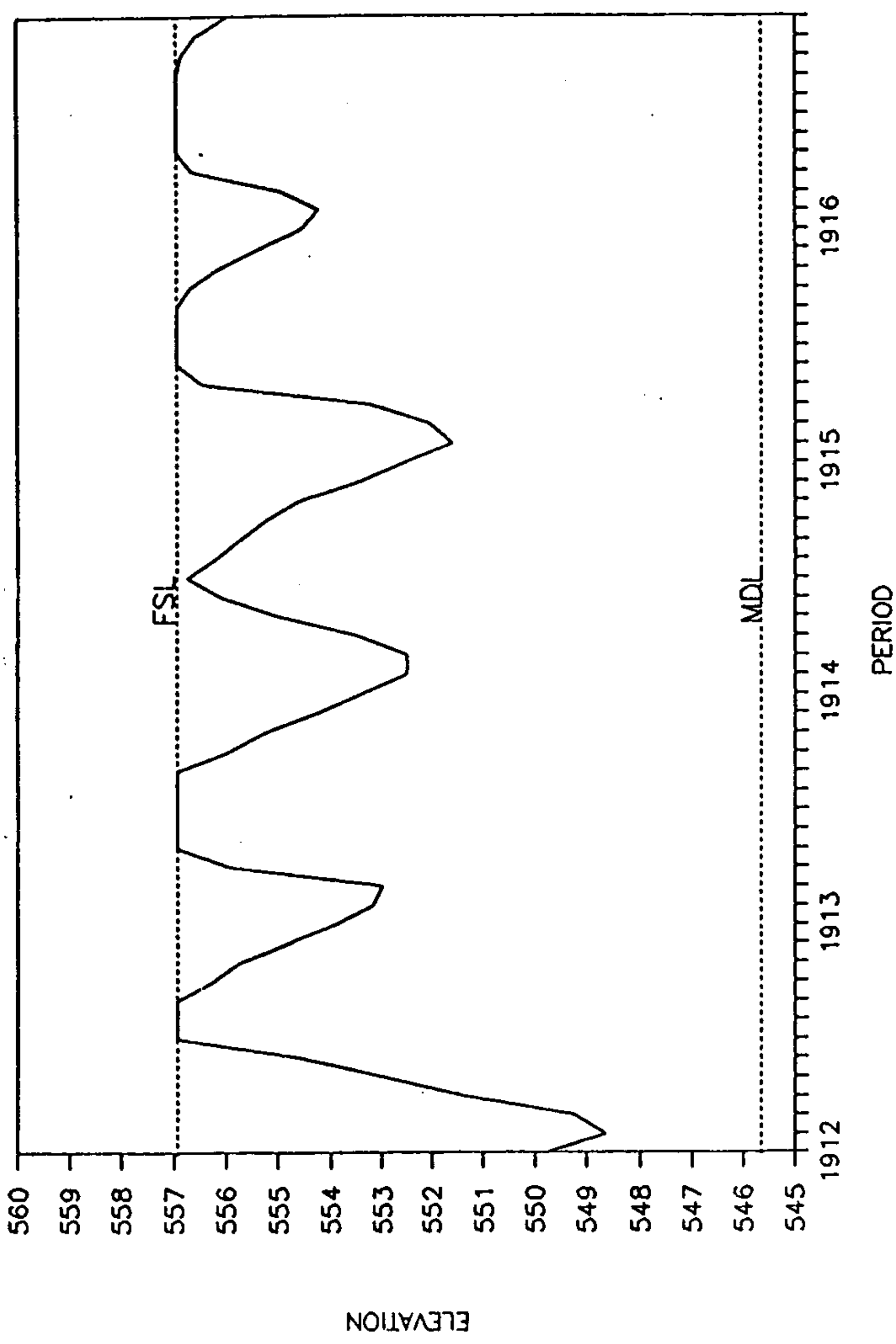
Computer: MSDOS - personal computer with Math Co-Processor

TABLE 17

HYDSIM SIMULATION OUTPUT FOR SASKATCHEWAN RIVER
STUDY PERIOD 1986-1-1 TO 1986-12-1

PERIOD NUMBER	STARTING DATE	ENERGY PRODUCED		TOTAL INFLOW (m^3/s)	PLANT DISCHARGE (m^3/s)	SPILL (m^3/s)	END FOREBAY ELEVATION (METRES)	NET HEAD (METRES)	STORAGE LEFT (DAYS)	EFFICIENCY FACTOR [$MW/(m^3/s)$]	CAPACITY FACTOR
		(MW)	(GWH)								
1	Jan 1	110.19	81.98	111.60	241.25	0.00	551.64	50.35	52.03	0.46	0.59
2	Feb 1	104.80	70.42	90.40	232.69	0.00	550.65	49.54	42.75	0.45	0.56
3	Mar 1	76.39	56.83	308.70	172.68	0.00	551.68	50.63	52.43	0.44	0.41
4	Apr 1	25.79	18.57	173.60	61.66	0.00	552.45	52.40	59.89	0.42	0.14
5	May 1	70.27	52.28	343.20	156.58	0.00	553.66	52.76	72.07	0.45	0.37
6	Jun 1	124.36	89.54	663.00	266.07	0.00	556.03	52..54	97.44	0.47	0.66
7	Jul 1	84.84	63.12	326.50	171.43	0.00	556.78	55.89	105.86	0.49	0.45
8	Aug 1	73.02	54.33	169.40	150.62	0.00	556.62	56.49	104.08	0.48	0.39
9	Sep 1	66.04	47.55	132.70	137.88	0.00	556.50	54.33	102.71	0.48	0.35
10	Oct 1	153.09	113.90	300.30	305.12	0.00	556.39	54.98	101.42	0.50	0.82
11	Nov 1	128.06	92.21	130.70	269.86	0.00	555.50	53.55	91.59	0.47	0.68
12	Dec 1	122.11	90.85	134.30	256.01	0.00	554.68	53.01	82.72	0.48	0.65

FIGURE 12 LAKE DIEFENBAKER, SIMULATED ELEVATION 1912 - 1916



Description: Two stochastic river water quality models (SRWQM) of the South Saskatchewan River in Saskatchewan were developed. The SRWQM were divided into one upstream and one downstream of Lake Diefenbaker. The water quality model upstream of Lake Diefenbaker begins at Highway #41 in Alberta on the South Saskatchewan River and on the Red Deer River near Bindloss, Alberta and extends to Eston Regional Park in Saskatchewan. The water quality model downstream of Lake Diefenbaker begins at Gardiner Dam and extends to the confluence of the North and South Saskatchewan River. The water quality models were used to simulate the South Saskatchewan River, including instream kinetics and processes, so that the factors affecting water quality and the effect of varying headwater flows could be examined.

The computer programs used in the water quality modelling were received from Alberta Environment and documented by its developers, HydroQual Consultants of Calgary, Alberta. The water quality model consists of three modules: DOSTOC, UNSTOC and NUSTOC. DOSTOC was used to examine dissolved oxygen, ultimate carbonaceous biochemical oxygen demand (BOD) and nitrogenous biochemical oxygen demand (NOD). UNSTOC was used to examine four conservative water quality parameters: chloride (Cl), sodium (Na^+), sulphate (SO^{4-}), and total dissolved solids (TDS). UNSTOC was also used to examine one non-conservative water quality parameter: fecal coliform (FC) for the downstream water quality model. NUSTOC was used for the downstream water quality model of the South Saskatchewan River to examine three forms of nutrients: ammonia, nitrate plus nitrite and dissolved phosphorous (DP).

The river hydraulics of the water quality models were defined by the Leopold-Maddox (1953) relationships. The relationships were derived from Water Survey of Canada gauged streamflow data, HEC-II hydraulic simulations (U.S. Army Corps of Engineers, 1981) and WPCD (1987).

The municipal effluent of Leader, Outlook, Saskatoon and St. Louis and the industrial effluent of Armak and Saskatoon Chemicals were considered as point source loads contributing to water quality in the South Saskatchewan River. The location of these discharges were incorporated into the water quality model.

Data Requirements: Input data requirements for the stochastic river models are summarized in HydroQual (1989). The actual inputs are extensive and will not be presented here. The models are driven by:

- Leopold-Maddox hydraulic parameters derived from the HEC II model
- Headwater water quality
- Instream chemical and physical modifications
- Point source inputs and withdrawals
- Non-point sources inputs and withdrawals

Changes in any of these general groups can be taken into account by the model and new predictions made for water quality.

Application: The main application of the stochastic models is the evaluation of the basin management strategies on water quality.

Secondary uses of the model are the evaluation of specific development on water quality within the basin.

Limitations: The model is limited by the accuracy of some of the reaction co-efficients upstream of Saskatoon. It is also limited by its stochastic nature in that it can not represent dynamic changes in Headwater flow or quality or Point Source.

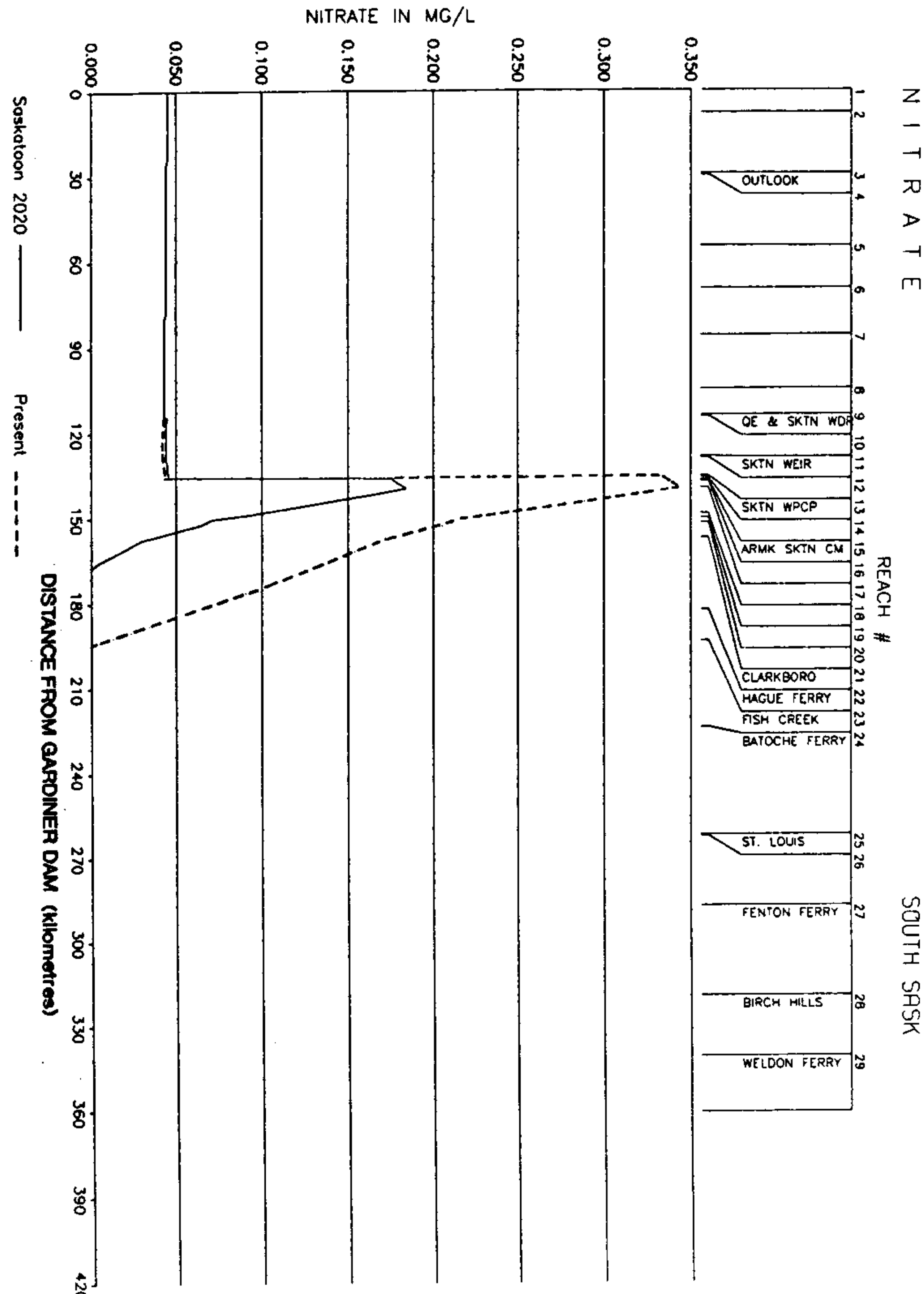
Example of Output: A sample of the model output can be found on Figure 13.

Reference: HydroQual et al. (1989). Stochastic River Quality Model: Manual Version 2. Produced for Planning Division. Alberta Environment, Edmonton.

MODEL: REPORT ON FLOODING, GARDINER DAM TO THE FORKS

Agency: Integrated Resources Branch, SaskWater

FIGURE 13 **COMPARISON OF SOUTH SASKATCHEWAN RIVER NITRATE CONCENTRATIONS: PRESENT (1986) VALUES WITH SASKATOON (YEAR 2020) AT A FLOW OF 60 m^3/s**



Location: SaskWater
111 Fairford Street East
Moose Jaw, Saskatchewan

Computer: not applicable

Description: Lake Diefenbaker substantially reduces flood peaks in the downstream river. Traditionally Lake Diefenbaker has been at a low level in the spring and early summer which is the season of maximum flood potential. In the future, as upstream storage and summer water use increase, the optimum water supply operation at Lake Diefenbaker could use less winter drawdown. The flood storage could be reduced. Therefore a method of quantifying the flood damage potential was required as input to the decisions on how much flood storage is necessary.

Hydrology, hydraulic and damage potential studies for the city of Saskatoon in the early 1980s under the Canada-Saskatchewan Flood Damage Reduction Program were updated and interpreted in a form that best reflects the impact of changes in operation at Lake Diefenbaker on the flood hazard at Saskatoon.

The flood potential for July to September events was also evaluated because the lake tends to be higher later in the year but because the flow potential is smaller than early in the summer, the damage can be controlled without major reserve storage.

A review of agricultural crop losses was also completed but it was found that modest variations in Lake Diefenbaker operation have insignificant impact on crop losses due to flooding.

Data Requirements: Information on the normal spring water levels of Lake Diefenbaker are required.

Applications: The procedures developed allow for a comparison of the flood damage potential that would result from various operations of Lake Diefenbaker.

Example: In order to compare the flood hazard increase that would result from raising the mid-May level of Lake Diefenbaker 1 m the following steps would apply:

1. From the report, the flood peak flow frequency for each starting elevation is listed in Table 18.

TABLE 18 SOUTH SASKATCHEWAN RIVER BELOW GARDINER DAM FLOOD PEAK POTENTIAL

PROBABILITY	STARTING ELEVATION	
	553.05 m	554.05 m
1:10	1 580 m^3/s	1 780 m^3/s
1:25	2 670 m^3/s	2 910 m^3/s
1:50	3 500 m^3/s	3 650 m^3/s
1:100	4 340 m^3/s	4 500 m^3/s
1:500	5 970 m^3/s	6 040 m^3/s

2. These flood flows can be converted to economic damage potential from the report as listed in Table 19.

TABLE 19 FLOOD DAMAGE POTENTIAL AT SASKATOON		
PROBABILITY	STARTING ELEVATION	
	553.05 m	554.05 m
1:10	$	$ 70 000
1:50	1 800 000	1 950 000
1:100	2 650 000	2 750 000
1:500	4 400 000	4 400 000

3. The damage potential can be plotted against probability of occurrence in any one year. The average annual damage can be determined from the area under the damage potential versus probability curve. In this case, the current conditions or 553.05 m starting elevation average annual damage is $125 000 and the 554.05 m starting elevation gives an average annual damage of $140 000.

4. The flood damage potential increase that would result from operating Lake Diefenbaker 1 m higher is the difference, $15 000 per year or a 12 percent increase.

Limitations:

1. The dollar values were derived from studies in the early 1980s and do not include adjustments for inflation.

2. The damage estimates were derived without allowance for emergency actions such as sand bagging and removal of furniture which would reduce the total damage substantially.

3. A four day forecast and no allowance for long range forecasts based on snow survey data were assumed. In an actual flood event, these forecast assumptions are the worst case scenario.

4. Rural damages outside Saskatoon were not included due to a lack of reliable data.

Because of these limitations the actual dollar values are only an order of magnitude estimate but the relative proportions of the damages will be quite accurate. That is, in the example above, the calculated average annual change of $15 000 is a very rough indication of the dollar value of the change but the 12 percent is expected to be a fairly close indication of the relative magnitude of the flood risk.

Reference: Water Resources Consultants Ltd. (1989). South Saskatchewan River Basin Study Report on Flooding, Gardiner Dam to the Forks. Water Resources Consultants Ltd., Regina prepared for the South Saskatchewan River Basin Study Office as SSRBS Technical Report C.8.

MODEL: WATER USE ANALYSIS MODEL (WUAM)

Agency: Water Planning and Management Branch, Environment Canada

Location: Environment Canada
300 Park Plaza
2365 Albert Street
Regina, Saskatchewan

Computer: personal computer

Description: The Water Use Analysis Model (WUAM) was developed by Acres International Limited under the direction of the Inland Waters Directorate for the Canadian Department of Energy, Mines and Resources. The objective was to provide a tool to assess changes in water use and to estimate their impacts on surface water supplies. The Water Use Analysis Model uses economic and demographic forecasts to estimate future water use. Water balance calculations, using historical hydrometeorlogical data, identify the imbalances between water demand and water supply.

The Water Use Analysis Model has been designed to answer the "what if" questions relating multi-sectoral growth to water availability. The Water Use Analysis Model can evaluate the water resource impacts of site-specific projects, on economic and demographic growth, of changing water use coefficients and of various remedial measures such as storage or transfers.

The Water Use Analysis Model requires a set of base or region wide parameters and a set of site specific parameters. The general or base parameters define the economic regions and sectors, the priorities for rationing, crop types and crop growth parameters, and irrigation types. The site specific parameters need demographic and economic numbers and water use coefficients to calculate the arrays of water use data. The Water Use Analysis Model also requires site specific details about irrigation projects and about hydro and thermal power plants. The Water Use Analysis Model uses calculated natural monthly streamflow and evaporation data and reservoir storage-flooded area relationships for the water balance calculations. The general data base was provided by Acres International in its Phase VI report.

A. Water Use (Demand)

1. Municipal/Rural Domestic/Agriculture (non irrigation)
   - population
   - percentage of diversion consumed
   - monthly distribution
   - ground water fraction

2. Irrigation
   - irrigated area
   - system delivery efficiency
   - water salinity/max & min allowable soil salinity
   - fraction of the water from ground water
   - area under each crop type
   - soil types and soil parameters
   - irrigation application efficiency
   - crop water use coefficients
   - monthly evapotranspiration rates

3. Industrial
   - water use coefficient (volume of water per million dollars of output per year)
   - percent dollar contribution to economic region
   - water consumption as a percent

4. Power production
   a. Thermal Power
      - type of flow year
      - plant fuels type
      - cooling type
      - condenser types and number
      - intake and consumption coefficients
   b. Hydro-power
      - installed capacity
      - average hydraulic head
      - turbine efficiency
      - flow factors

B. Water Supply

1. Monthly mean natural flows at each study point (node) with a common record length

2. Monthly mean gross potential evaporation

3. Monthly precipitation totals

4. Flows constraints (i.e. minimum required flows)

5. Reservoir description including elevation - flooded area - storage relationships and reservoir operation rules

6. Water transfers into/out of the basin

C. Special Features

Economic and demographic growth projections are used to forecast demands in each water use category. These scenarios can also include water price/demand interactions, efficiency changes and site-specific projects. Instream water use requirements are met by specifying minimum flows at each study point.

The Water Use Analysis Model is divided into a number of modules which may be called upon to calculate water demands or perform the historical water balance simulation. Of particular interest are the modules which calculate irrigation, thermal power and hydro-power demands.

The irrigation demands are estimated on a monthly basis over the historical period using either one year or historical period records of evapotranspiration rates and historical monthly precipitation totals. Other factors such as delivery efficiency, off stream storage, crop types and irrigation application efficiency are used to estimate irrigation demands. A separate file of gross irrigation diversion and return flows is produced for each irrigation area or district. Irrigation water salinity, soil types and depletion equations are included to point out any water quality or soil productivity problems.

The characteristics, such as installed capacity, average head and efficiency, are used in conjunction with reservoir outflows to estimate electric power production. Water intake values have been related to power plant capacity rather than power production.

Limitations: The Water Use Analysis Model's major limitations are its complexity, user unfriendliness/poor documentation and lack of standard input/output formats.

Any model which combines economic growth, population change, irrigation and power plant use with water balance calculations will be very complex. Water Use Analysis Model needs a multi-disciplinary approach involving people with different areas of expertise. Although the multi-disciplinary approach is appealing, it makes the model difficult to set up, calibrate and run.

A particular problem with applying an input/output model like the Water Use Analysis Model in the South Saskatchewan River Basin is the fact that the economy of the area is a very simple one. This simple economy can result in the model giving incorrect results for some sectors of the economy.

In the prairie provinces, most agencies follow the standard input formats used by the Prairie Provinces Water Board or Water Survey of Canada. These standard formats include internal file documentation (i.e. file names and explanation as part of the file) and standard format and cell size.

Reference: Water Planning and Management Branch, Inland Waters Directorate, Environment Canada. (1990). Water Use Analysis Model Study. Prepared for the South Saskatchewan River Basin Study Office as SSRBS Technical Report D.19.

MODEL: FARM LEVEL DROUGHT ANALYSIS MODEL

Agency: Integrated Resources Branch, SaskWater

Location: SaskWater
111 Fairford Street East
Moose Jaw, Saskatchewan

Computer: IBM-PC or compatible with Lotus Symphony software

Description: The Farm Level Drought Analysis Model is a simple dynamic farm-level economic model, the purpose of which is to measure the impact of short water supplies on crop yields, estimate expected gross revenues, calculate cash and non-cash operating expenses, and judge whether or not cash flows can be covered and adequate allowances have been made for recapitalization of farm assets. If a water shortfall does occur, then allowances can be made by foregoing non-cash allowances and, eventually, by increasing farm indebtedness. If shortfalls become too frequent, then the farm becomes uneconomical and a "non-viability" flag is raised. The ultimate measure or comparisons between various levels of water shortfall is "ending farm net worth" at the end of a ten-year simulation period.

The model consists of a series of "windows" or modules which correspond in general with the seven components illustrated by Figure 14. These components are: water supply, yield, inventory, cost of production, accounting, adjustment, and performance criteria.

Data Requirements: The data contained in the model, as it is presently configured, meets the requirements specified by the South Saskatchewan River Basin Study Office. Modifications to crop mixes and prices, farmer equity, family living allowances, failure criteria, and the intensity and duration of shortages, are all possible.

Limitations: This model measures the long-term financial impact of drought on a farm. It does not take into account the fact that many farms include a non-irrigation component which can be used to subsidize the irrigation component. The model therefore deals only with the economics of the irrigation enterprise.

Applications: The Farm Level Drought Analysis Model is intended to be utilized as a tool to assist in the development of irrigation water allocation policies. As the allocation process is a complex interaction of physical, environmental, social, economic and political considerations, the model permits the modification of the severity and effects of a water shortage, depending on how water is allocated in accordance with these considerations. Water shortage is only one of the many variables that farmers consider when making cropping decisions. Such variables as price, yield and weather all play important roles in farm management decisions. The model is capable of providing information relevant to these considerations.

Example of Output: Table 20 is an example of the Farm Level Drought Analysis Model output. The output of the model shows the impact of a water shortage on an irrigation farm relative to the performance of an identical farm operation without shortages. This reference value is represented by the first row in Table 20. Subsequent rows in the table illustrate that the ending net worth of the farm (a measure of the farm's financial performance over a ten-year period) varies with each combination of water shortage frequency and severity. The net worth value is calculated for different cropping options (represented by the columns).

The financial position of the farmer can be varied by changing the amount of equity in the farm (i.e. the farm's level of indebtedness). In Table 20, the farmer has 80 percent equity in the farm. At this level of equity, the farmer could theororetically afford to weather several poor years of returns on the farming operation. This ability to endure poor returns is reduced as equity in the farm is diminished.

Reference: UMA Engineering Ltd. (1990). Farm-level Drought Analysis Model. UMA Engineering Ltd., Lethbridge, Alta. Prepared for the South Saskatchewan River Basin Study Office as SSRBS Technical Appendix E.15.

MODEL: TRAVEL COST MODEL

Agency: Integrated Resources Branch, SaskWater

Location: SaskWater
111 Fairford Street East
Moose Jaw, Saskatchewan

Computer: personal computer

Description: This evaluation tool is part of a study that was intended to provide analysis of recreation survey data collected by the South Saskatchewan River Basin Study Office during the summer of 1988. The objective of the study was to establish the economic value, as a measure of the demand, for water-based recreation at selected parks within the basin. Consumer surplus or the aggregate dollar amount which recreationists would be willing to pay, over and above their actual (money, time and utility of travel) costs, has been used as an estimate of recreational demand or site value.

Survey data was collected at 15 parks (see Table 21), which included six provincial parks, six regional parks and three other (private and municipal) facilities. Only those parks in the basin with water-based recreation which are relatively well known and with significant visitations were included in the analysis. The data included responses to a questionnaire which was either self-administered or administered by Study Office staff depending on circumstances at each park. In addition, axle count data was collected at 13 of the 15 parks.

FIGURE 14 FARM LEVEL ECONOMIC MODEL

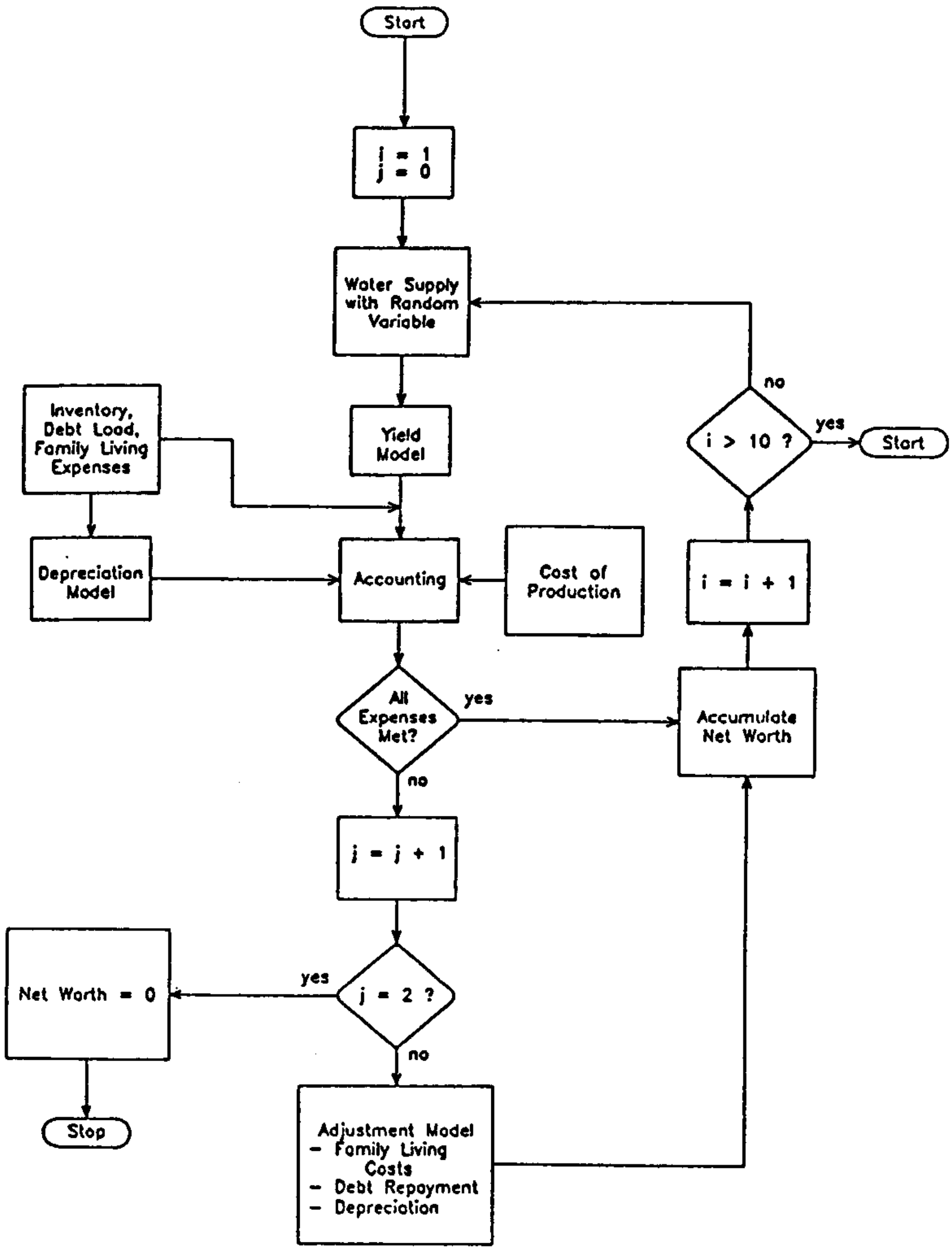


TABLE 20

TYPICAL OUTPUT FARM LEVEL DROUGHT ANALYSIS

Farm Type Price Scenario Equity Percent = 80 Percent		Grain Hi 80 Percent	Forage Hi 80 Percent	Specialty Hi 80 Percent	Grain Exp 80 Percent	Forage Exp 80 Percent	Specialty Exp 80 Percent	Grain Low 80 Percent	Forage Low 80 Percent	Specialty Low 80 Percent
Shortage	Freq Percent	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10.00	10.00	0.99	0.98	0.97	0.98	0.98	0.97	0.99	0.98	0.96
20.00	10.00	0.97	0.97	0.94	0.97	0.96	0.94	0.84	0.96	0.92
30.00	10.00	0.95	0.95	0.91	0.95	0.94	0.90	0.84	0.93	0.85
40.00	10.00	0.93	0.93	0.85	0.91	0.92	0.83	0.85	0.87	0.76
10.00	20.00	0.97	0.97	0.94	0.97	0.97	0.94	0.98	0.96	0.92
20.00	20.00	0.94	0.93	0.88	0.93	0.93	0.87		0.91	0.84
30.00	20.00	0.91	0.90	0.82	0.90	0.89			0.88	
40.00	20.00	0.86	0.85			0.85				
10.00	30.00	0.95	0.95	0.91	0.95	0.95	0.90	0.95	0.94	0.88
20.00	30.00	0.90	0.90	0.82	0.89	0.89	0.81		0.87	0.76
30.00	30.00	0.84	0.84	0.73	0.83	0.83			0.81	
40.00	30.00	0.77	0.78			0.77				
10.00	40.00	0.94	0.94	0.88	0.93	0.93	0.87	0.92	0.92	0.84
20.00	40.00	0.87	0.87	0.76	0.86	0.86	0.74		0.83	0.68
30.00	40.00	0.80	0.79	0.64	0.78	0.78			0.74	

TABLE 20

TYPICAL OUTPUT FARM LEVEL DROUGHT ANALYSIS

Farm Type Price Scenario Equity Percent = 80 Percent		Grain Hi 80 Percent	Forage Hi 80 Percent	Specialty Hi 80 Percent	Grain Exp 80 Percent	Forage Exp 80 Percent	Specialty Exp 80 Percent	Grain Low 80 Percent	Forage Low 80 Percent	Specialty Low 80 Percent
Shortage	Freq Percent	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
40.00	40.00	0.70	0.71			0.69				
10.00	50.00	0.92	0.92	0.85	0.92	0.92	0.84	0.91	0.90	0.80
20.00	50.00	0.84	0.84	0.70	0.82	0.82	0.68		0.79	0.60
30.00	50.00	0.75	0.74	0.55	0.72	0.72			0.67	
40.00	50.00	0.65	0.64			0.61				

NOTE: Blanks indicate failure. Failure for this analysis has been defined as a farm's inability to meet basic cash and operating costs, interest payments and a reduced family living allowance in any 2 out of the 10 year simulation period.

TABLE 21	TRAVEL COST STUDY SITES
PROVINCIAL PARKS	REMARKS
Blackstrap	
Danielson	This site consists of two physically separate sections, a day-use facility with beaches and interpretive centre, and a camping facility. for the purposes of this study, the sections were treated as two sites: Danielson B (beach) and Danielson C (camping).
Douglas	
Pike Lake	
Saskatchewan Landing	
REGIONAL PARKS	
Cabri	
Eston Riverside	
Lac Pelletier	
Lemsford Ferry	
Outlook and District	
Palliser	
OTHER	
Cranberry Flats	A recreation site on the South Saskatchewan River, just south of Saskatoon and operated by the Meewasin Valley Authority
Elbow Harbour	A provincial recreation site leased to private operators
Rotary Park	An urban park within the city of Saskatoon on the shore of the South Saskatchewan River

The Study Office formatted its data for use in a travel cost model and ultimately selected the zonal travel cost model as being the most practical approach given data and budget limitations. A semi-log equation was specified in defining the site demand schedule and total visitation estimates were calculated for 13 parks. The remaining two parks lacked an estimate of total visitation as provided by the axle counter data and therefore no visitation model estimate was possible.

Visitor origins were categorized into seven distance zones for each recreation site. Two models were also specified for each site; the first being visits of one-day or less in duration and the second being multiple-day visits.

The relative demand for recreation estimated by the travel cost model can be used in determining investment trade-offs between parks, and in determining some base value to society of these parks. In addition, the model estimates total visitation to the parks, as well as visitation from four urban centres, which can be used in forecasting visitation to additional similar parks in similar locations.

The travel cost method (TCM) was developed specifically for the valuation of public recreation sites. The general procedure of the travel cost method is to estimate the demand for a public recreation site indirectly, by observing the manner in which visitation to a park is affected by the cost of travelling to that park from the visitor's home.

The fundamental assumptions underlying the travel cost method are twofold: first, that the value of a park to a recreationist is reflected in the cost which he/she is willing to incur to reach the park; and second, that the recreationist responds to an increase in travel cost in exactly the same manner as he/she would if park entry fees (prices) increased by the same amount. Given these assumptions, it is possible to estimate a demand function for the park, which, in turn, provides an estimate of the consumer benefit associated with that park.

The travel cost method proceeds in two stages. In the first stage, a so-called "trip demand function" is estimated for the park. This demand function assumes the general form:

$$V = f(TC)$$

where V = number of visits to a park
TC = travel cost associated with visiting the park

The estimation of a trip demand function yields a "travel cost coefficient" for that park. This coefficient measures the relationship between travel cost and visitation or, in other words, the way in which changes in travel cost affect park visitation.

The second stage of the travel cost method involves using the travel cost coefficient, estimated above, to predict how total visitation to the park would change in response to increased entry fees. A "site demand schedule" is constructed by plotting predicted park visitation against hypothetical increases in travel cost which are, by the assumptions of the model, predicted to be identical in effect to increases in site entry fees. In this manner, the demand function for a site is estimated.

The Study Office selected the zonal travel cost model for use in this analysis because of its modest data requirements and its relative simplicity.

The zonal travel cost method was developed several years prior to the introduction of the individual observations method. The zonal travel cost model assigns individual park visitors to a particular "zone of origin." These zones are defined according to the distance from the site to the visitor's home. Typically, the zones are organized as a series of concentric rings around a site.

Once all visitors are assigned to their respective zones, the zonal travel cost method proceeds as follows: for each zone, a single travel cost value is calculated. This value is typically the average (return trip) travel cost from the midpoint of each zone to the site. Then, estimates of the total populations for each zone are derived. Once the sample visitation estimates are converted into estimates of total visitation for each zone, a trip demand function of the following general form is estimated:

$$VP_{ij} = f(TC_{ij})$$

where VP_{ij} = visits per capita from zone i to site j

TC_{ij} = average travel cost (return trip) for a visitor from zone i to reach site j

In estimating this trip demand function, the number of observations is identical to the number of zones in the model; each VP_{ij} - TC_{ij} combination (there is one for each zone) represents a single data point. The estimated trip demand function yields a travel cost coefficient which, as described earlier, is used to construct a site demand schedule (Stage 2 of the travel cost method). Stage 2 of the zonal travel cost method involves the construction of a site demand schedule for each zone, then aggregation across zones to yield the complete site demand schedule.

Data Requirements: Data was obtained from the questionnaires completed during the course of the water-based recreation study.

Limitations: This evaluation model is a useful tool for helping to better understand recreationalists' decision-making. It must, however, be used with the knowledge that the model results do have limitations. There are four basic problems with zonal travel cost models. First, the use of aggregated data results in a loss of statistical efficiency, thereby reducing the precision of both the estimated travel cost coefficient and the benefit estimates derived from it. Meaningful confidence intervals or ranges are not easily derived and hence the results hinge on a single mean value estimate.

Second, the zonal model is unable to separate the effects of travel time from those of travel cost. However, there is a common perception on the Canadian Prairies that travel is expected and necessary and thus the time taken in travel becomes a part of the recreation experience.

The third problem with the zonal model is that it cannot account for the effect of substitute prices (i.e., the cost of travel to alternate sites). Initially, an attempt was made to systematically grade the recreation sites according to facilities and features, but lack of data frustrated the effort. It can be argued that the available resources at all of the sites are relatively homogeneous and that if demand exists, they could all be developed to a comparable state. Furthermore, the effects of other "demand shifters" (e.g. income) are often lost due to aggregation. Even if zonal income could be calculated, its estimated effects would almost certainly be insignificant because of the aggregation problem. Further, for most people, visits to South Saskatchewan River Basin parks represent a low cost form of participatory recreation relative to total household budget. This would tend to reduce the effect of income as a factor in measuring demand for recreation.

Finally, in cases where the populations of the origin zones differ substantially from one another, the statistical problem of heteroscedasticity may significantly reduce the precision of the estimates.

Regardless of the type of travel cost model used, there are several conditions under which the travel cost method is inappropriate. Two conditions of particular relevance to this study are: first, when there is too little variation in observed travel cost to adequately estimate a trip demand function; and second, when a park visit is not the sole purpose of the visitor's trip. This is the so-called "multiple destination problem". Both of these conditions are especially prominent in the case of urban parks; the latter condition is also a potentially significant problem for sites which are close to major transportation routes.

Yet another consideration in the use of the travel cost model is its underlying assumption that each visitor to a site receives the same amount of "recreational services". In cases where the length of stay varies among site visitors, this assumption is violated. The solution to this problem is to estimate separate demand functions for each length of visit (e.g. 1 day, 2 days, etc.).

The estimates of consumer surplus must be used with discretion since they are based on the period of May through September only and no off-season benefits are captured. Multiple-destination visits were reduced but could not be totally deleted from the data set, and still present the possibility of over-estimation of benefits. Further, the benefits for Rotary Park, an urban park with significant but unmonitored foot traffic, may have been underestimated. Option and existence values were not estimated in this study, which also suggests that the benefits are underestimated.

Applications: The potential applications of the model are twofold. In the first case, the model provides estimates of relative demand for recreation in selected South Saskatchewan River Basin parks. This can have use in determining investment trade-offs between these parks, and it can have use in determining relative values of these parks should difficult decisions of restraint or curtailment be necessary.

In the second case, the model provides estimates of visitation to 13 selected sites. This can have use in estimating visitation to similar parks in similar locations should there be the need to consider additional parks in the Basin.

Examples of Output: Table 22 provides an example of the statistical summary prepared from the database used in the model.

TABLE 22 **TRAVEL COST ESTIMATES OF PARK VALUE**

SITE	Estimation Method I **					Estimation Method II ***			
	Combined Visits (People)	Total Consumer Surplus ($)			Consumer Surplus Combined Visits ($ Per Visitor)	Total Consumer Surplus ($)			Consumer Surplus Combined Visits ($ Per Visitor)
		1 Day Visit	> 1 Day Visit	Combined Visits		1 Day Visits	> 1 Day Visits	Combined Visits	
Blackstrap	66 013	148 820	25 917	174 737	2.65	158 683	42 178	200 861	3.04
Danielson Beach	39 500	87 000	73 842	160 842	4.07	100 589	97 815	198 404	5.02
Danielson Camp	10 254	6 278	109 060	11 533 883	11.25	13 962	151 063	165 025	16.09
Douglas	13 093	11 204	72 660	83 864	6.41	27 271	95 322	122 593	9.36
Pike Lake	115 419	133 791	323 891	457 682	3.97	142 196	349 937	492 133	4.26
Sask. Landing	56 529	63 049	274 794	337 843	5.98	74 499	298 386	372 885	6.60
Eston	21 577	13 800	7 906	21 706	1.01	17 429	12 032	29 461	1.37
Lac Pelletier	24 153	9 508	54 682	64 190	2.65	13 786	64 077	77 863	3.22
Outlook	38 241	85 470	15 115	100 585	2.63	92 329	30 043	122 372	3.20
Palliser	32 392	19 776	63 322	83 098	2.57	24 956	75 482	100 438	3.10
Cranberry Flats	13 231	20 127		20 127	1.52	23 285		23 285	1.76
Elbow Harbour	48 490	180 084	161 408	341 492	7.04	192 955	206 952	399 907	8.25
Rotary	33 731	76994		76 994	2.28	81 699		81 699	2.42

** Estimation Method I measures the area under the site demand schedule up to the point where projected visitation in each model equals 250 vehicles per year.

*** Estimation Method II measures the area under the site demand schedule up to the point where projected visitation in each model equals 50 vehicles per year.

Reference: UMA Engineering Ltd. (1990). The Demand for Water-Based Recreation in the South Saskatchewan River Basin in Saskatchewan. UMA Engineering, Ltd., Lethbridge, Alta. Prepared for the South Saskatchewan River Basin Study Office as SSRBS Technical Appendix E.17.

MODEL: RESIDENTIAL WATER USE MODEL

Agency: Integrated Resources Branch, SaskWater

Location: SaskWater
111 Fairford Street East
Moose Jaw, Saskatchewan

Computer: personal computer

Description: This evaluation tool was developed as part of a study that documents past and present levels of municipal water use in the South Saskatchewan River Basin. Data were collected by means of two surveys of municipalities. The first survey was conducted at the municipal water supply level. The second was conducted at the household level. Details on 61 municipal water systems were obtained, covering such areas as annual pumpage, major uses of water, water treatment, water supply problems and the water rate structure in use, in addition to information regarding household characteristics and water use. Once this data base was assembled, a demand function for residential water use in the basin was estimated. Parameters for the water demand function were determined using standard regression analysis.

The report provides a series of equations for the best- fit linear and logarithmic relationships and concludes that the logarithmic relationships provide the best results in estimating the aggregate price elasticity of water. Since the data was collected from households where the billing periods range from monthly to semi-annual, and since it was determined that water use responses varied with the billing periods, separate relationships for each billing period were generated. A total of ten separate regression relationships were developed.

The major factors that determine residential water demands were: price; household income; number of occupants; net evapotranspiration; season; and, water charge policies. Price elasticity of water demand ranged from -0.81 to -0.35. Income elasticity was found to be low, and consistently near 0.08. The households billed on a quarterly basis and on an increasing block structure showed the strongest sensitivity to price.

Data Requirements: Residential water use can be estimated based on price, household income; number of occupants; net evapotranspiration; season; and, water charge policies.

Limitations: Data collection was limited to those communities physically located within the drainage basin of the South Saskatchewan River.

Applications: The Residential Water Use Model provides basic information on the residential water user in the study area. The effects on water use resulting from price and other factors can be estimated.

References: Kulshreshtha, S., T. McIntosh, and J. Engel. (1987). South Saskatchewan River Basin Municipal and Residential Water Use Study. Prepared for the South Saskatchewan River Basin Study Office as SSRBS Technical Report E.5.

7.3.3 Maintenance of Evaluation Tools

Hand-in-hand with the preparation of new tools and databases comes the necessity of developing a suitable method of maintaining them so that they remain up to date and efficient, and a useful part of government evaluation procedures. It is to this end that the Inter-agency Implementation Plan identifies those agencies which will find a particular tool most applicable, and thus, should undertake responsibility for its maintenance. In most cases, these are the same agencies that were directly involved in the original development of the model or tool.

The maintenance and review of the project evaluation procedures is discussed in detail in Chapter 5.0 of this technical appendix.

7.4 DATABASE INTEGRATION

As a result of the South Saskatchewan River Basin Study, the number of databases, computer models and other tools for the evaluation of possible water management projects in the South Saskatchewan River Basin was increased. While this meant such evaluations could be more detailed and so more effective, the entire project evaluation process became more complicated. Not all regulatory agencies or project proponents are aware of all the evaluation tools now available, or what agency is responsible for employing them.

A further complicating factor lay in the fact that the data in the different databases is not always compatible, either between databases or as it might be applied to discrete geographic areas. This meant that consistency in the way projects might be evaluated became very difficult to attain.

These factors were all recognized over the course of the study, and a finding was developed in the study that noted: "The databases and tools used to evaluate projects would be more useful if they were more compatible". This finding in turn led to a study recommendation that set this goal: "Work toward more compatible databases and tools to help ensure a more consistent approach to project evaluation.".

One of the most effective ways of accommodating this South Saskatchewan River Basin Study recommendation lies with some relatively new technology -- the GIS or Geographic Information System. Geographic information systems are powerful computer-based tools for integrating and analyzing data derived from widely differing sources such as satellite imagery, topographic maps, aerial photographs, census data and water quality and quantity monitoring stations. Data stored in a GIS can be rapidly and easily analyzed, manipulated, and mapped in a format and at a scale specified by the user.

Geographic information systems have become well established in a variety of resource management applications including land use monitoring, surface water management and planning, (hydrometric networks, irrigation-related issues, shoreline planning and flooding potential), groundwater management, forest inventory, and environmental assessment. Because of the great flexibility offered by geographic information systems in data management, they should be a leading option when decision-makers consider suitable means of integrating the databases developed over the course of the South Saskatchewan River Basin Study.

8.0 INTER-AGENCY IMPLEMENTATION PLAN

8.1 INTRODUCTION

The Framework Plan for water management developed from the Canada-Saskatchewan South Saskatchewan River Basin Study is composed of three parts: Basin Management Strategies, Project Evaluation Procedures, and the Inter-Agency Implementation Plan. The Framework Plan forms a separate technical appendix to the South Saskatchewan River Basin Study.

The inclusion of an inter-agency implementation program in the Framework Plan was necessary because no agency acting alone has the necessary breadth of legislative authority to implement a comprehensive water resource management plan. The implementation of the Framework Plan must therefore be approached as a co-operative, multi-agency program.

Some twenty-five agencies at the federal, provincial and municipal levels of government have been involved in the process of building the Framework Plan. However, five agencies have been identified as having crucial roles to play in the Framework Plan implementation. These are SaskWater, Saskatchewan Environment and Public Safety, Environment Canada, the Prairie Farm Rehabilitation Administration, and SaskPower.

The Inter-agency Implementation Plan focuses on the roles of these lead agencies. It identifies where action by one or more of the supporting agencies is required for effective implementation, and does so by means of the existing legal and administrative infrastructure.

The Inter-agency Implementation Plan itself is comprised of three parts. The first deals with the implementation of the recommendations identified as Basin Management Strategies, while the second part considers the maintenance of the Project Evaluation Procedures that have been developed over the course of the South Saskatchewan River Basin Study. The final component of the Inter-agency Implementation Plan examines the question of when the present study should be updated; or, in other words, when another study of the South Saskatchewan River Basin should be undertaken. Details of each of these components are discussed in the following pages.

8.2 LEGAL AND ADMINISTRATIVE FRAMEWORK

Since no one agency can execute the Framework Plan, it was decided that a multi-agency approach was necessary to implement the plan. This required an understanding of the capabilities of the various water management authorities in the basin.

The South Saskatchewan River Basin Study Water Management Technical Appendix, describes the historic and existing water management institutions. This document identifies all of the agencies, legal authorities, boards, and committees, as well as the administrative structures of all levels of government, that have some role in the management of water resources in the basin. The information was used during the development of the Inter-Agency Implementation Plan to identify which agencies should be made responsible for the implementation of the various study recommendations. Appendix C lists both the agencies and the principle water management legislation associated with each. Table 23 presents similar information, but arranged in a simpler matrix format, with more general groupings of agencies and resource management activities.

In order to expand upon the information contained in the legal and administrative framework outline presented in Appendix C and Table 23, the following provides a brief overview of the various agencies and departments involved in water management in the study area.

8.2.1 Federal Agencies

Federal legislation pertaining to water resource management acknowledges that the provinces own the water. However, it also recognizes that the federal government has certain responsibilities and rights with respect to water, and that the provinces share responsibilities on interjurisdictional streams. In addition there are national implications to water development and management in general, and there are federal interests in areas such as droughts, floods, planning, environmental protection, data collection, navigation and shipping, federal lands, and national standards relating to food and water contaminants.

From the perspective of federal legislation, two government departments and the legislation they administer are particularly important in water management in the South Saskatchewan River Basin. These are Environment Canada and Agriculture Canada (the latter through the auspices of the Prairie Farm Rehabilitation Administration or PFRA).

TABLE 23 AGENCIES/RESOURCE MANAGEMENT ACTIVITIES MATRIX

	AGENCIES														
	FEDERAL				PROVINCIAL							OTHER			
RESOURCE MANAGEMENT ACTIVITIES	ENVIRONMENT CANADA	PRAIRIE FARM REHABILITATION ADMINISTRATION	AGRICULTURE CANADA	DEPARTMENT OF FISHERIES AND OCEANS	SASK WATER	SASKATCHEWAN ENVIRONMENT AND PUBLIC SAFETY	SASKATCHEWAN AGRICULTURE AND FOOD	SASKATCHEWAN COMMUNITY SERVICES	SASKATCHEWAN RURAL DEVELOPMENT	SASKATCHEWAN PARKS AND RENEWABLE RESOURCES	SASKATCHEWAN WETLAND CONSERVATION CORPORATION	PRAIRIE PROVINCES WATER BOARD	MUNICIPALITIES	MEEWASIN VALLEY AUTHORITY	DUCKS UNLIMITED
WATER ALLOCATION					●										
SYSTEM OPERATION					●										
WATER QUANTITY MONITORING	●				●										
WATER QUALITY MONITORING	●					●									
POLLUTION CONTROL	●					●									
LAND USE CONTROL					●			●	●				●		
FISHERIES				●						●					
WILDLIFE	●									●					●
FERRIES									●						
PARKS/RECREATION	●									●				●	
AGRICULTURE			●				●								
WETLANDS	●	●			●	●	●			●	●				●
INTERJURISDICTIONAL WATERS	●				●	●						●			
PUBLIC INFORMATION	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
RESEARCH	●	●	●		●		●								

8.2.1.1 Environment Canada. This department has responsibility over federal interests in the preservation and enhancement of the quality of the natural environment, including water, air, and soil quality. Environment Canada is comprised of three services. The Conservation and Protection Service has the most significant interest in water management in the basin. This service is in turn divided into three branches: Inland Waters Directorate, Environmental Protection, and the Canadian Wildlife Service.

INLAND WATERS DIRECTORATE (IWD)

Inland Waters Directorate manages interprovincial waters through the continuing co-operation of a wide range of provincial and federal departments. Part of Environment Canada's mandate is to provide national leadership for freshwater management, and to this end the Inland Waters Directorate plans and conducts a variety of federal, federal-provincial, interprovincial and international water management programs and policies. Inland Waters Directorate has three branches involved in basin management. These are the Water Resources Branch, Water Quality Branch, and Water Planning and Management Branch.

Water Resources Branch: This branch is responsible for federal water quantity and sediment monitoring programs, and for maintenance of the federal hydrometric network. Other duties of the branch include the interpretation and analysis of collected data, assessment of the hydrometric network, and the determination of natural flows for purposes of interprovincial apportionment of water.

Water Quality Branch: The purpose of the Water Quality Branch is to provide authoritative scientific and technical information on water quality in Canada to water resource managers, the scientific community and the general public. The branch works to establish baseline information, identify water quality trends on a national and regional scale, establish water quality objectives and monitors to ensure the compliance of water quality objectives. Water Quality Branch monitors water quality on federal lands such as Indian Reserves, national parks and PFRA pastures as well as interprovincial and international locations. The branch also provides analysis, reporting and advisory functions to other government agencies.

Water Planning and Management Branch: This branch is responsible for providing information and technical assistance in the management of international and interprovincial waters, as well as any waters of national concern. The branch assists in the federal environmental assessment and review process, being involved in the review of major water projects funded wholly or in part by the federal government. The Water Planning and Management Branch helps establish federal-provincial water resource management planning programs, and also provides a funding and supervisory role in any such joint planning studies.

ENVIRONMENTAL PROTECTION (EP)

The mandate of Environmental Protection is to protect the quality of the environment as it relates to the national interest, or as it is controlled by federal legislation. Under an agreement between Fisheries and Oceans Canada and Environment Canada, Environmental Protection is responsible for administering that portion of the Fisheries Act dealing with the setting and enforcement of regulations to protect fish habitat. The service also provides technical advice to other departments on environmental concerns.

CANADIAN WILDLIFE SERVICE (CWS)

The main activities of the Canadian Wildlife Service relate to monitoring and protection of migratory birds, and threatened and endangered wildlife. The service has some involvement in the establishment and administration of bird sanctuaries associated with water management projects.

8.2.1.2 Federal Environmental Assessment and Review Office (FEARO). FEARO is independent of Environment Canada, and is responsible for administering the federal Environmental Assessment Review Process (EARP). The purpose of the Environmental Assessment Review Process is to ensure that the environmental consequences of all federal proposals, and proposals affecting areas of federal responsibility, are assessed for potential adverse effects early in the planning process.

8.2.1.3 Prairie Farm Rehabilitation Administration (PFRA). PFRA is a branch of Agriculture Canada and its mandate requires it to help strengthen and diversify the prairie economy by providing technical, financial and material assistance to farmers, local governments and other federal and provincial agencies for soil and water conservation and development activities. PFRA programs that work towards these goals include the development of water sources such as wells, dugouts, dams and water pipelines for farms and small communities, as well as the implementation of federal-provincial water development agreements.

8.2.1.4 Other Federal Agencies. A number of other federal agencies are, or can be, involved in specific water resource management concerns. One example is Health and Welfare Canada, which monitors water quality, water supply, and waste treatment processes on federal lands, including Indian Reserves.

A second example is the Food Production and Inspection Branch of Agriculture Canada, which is leading a co-operative federal-provincial effort in monitoring pesticide residues in surface and ground water supplies.

8.2.2 Provincial Agencies

The Province of Saskatchewan acquired the authority to manage the water resources within the province with the passage of the Resources Transfer Agreement in 1930. Accordingly, Saskatchewan became responsible for all aspects relating to data collection, interpretation, analysis, policy and program planning, and management of both the quantity and quality of surface water and ground water supplies.

8.2.2.1 SaskWater. A provincial crown corporation, SaskWater's mandate requires it to manage, administer, develop, control and protect the water and related land resources of Saskatchewan. Since water management is a provincial responsibility, SaskWater allocates all water in the province, and is further charged with the operation of all water management structures including Gardiner Dam. The Corporation also represents Saskatchewan in the area of interjurisdictional water management. These sweeping areas of responsibility make SaskWater the lead agency in any discussion of provincial water management strategies.

SaskWater is further required by its legislation to be involved in the collection, analysis and dissemination of water resource data, the undertaking of water resource planning programs, and the maintenance of communications with other agencies and organizations that have a bearing on water management in Saskatchewan. Examples of two of these water resource planning programs are the Reservoir Development Areas (RDA) and the Flood Damage Reduction Program (FDRP).

8.2.2.2 Saskatchewan Environment and Public Safety. This department is responsible for the protection and enhancement of the quality of Saskatchewan's environment, including the water. To this end, Saskatchewan Environment and Public Safety is involved in water quality monitoring, the development and enforcement of licensing standards and regulations, and the undertaking of Environmental Impact Statement reviews where required. These water management activities are pursued by the two main branches of the department, the Water Quality Branch and the Environmental Assessment Branch.

WATER QUALITY BRANCH

The Water Quality Branch of Saskatchewan Environment and Public Safety is responsible for the general supervision, control and regulation of all matters concerning water quality and its impairment by pollution. Branch responsibilities are exercised through participation in Saskatchewan's environmental assessment review process and the Branch's role as a licensing agent for any project involving drinking water works, sewage, and industrial effluents.

ENVIRONMENTAL ASSESSMENT BRANCH (EAB)

The Environmental Assessment Branch was created as a means of administering Saskatchewan's Environmental Assessment Act (1979). By terms of the Act, any developer or proponent of a project which may be expected to have impacts on the environment is responsible for the preparation and submission of a Project Proposal to the Environmental Assessment Branch for screening. If the Branch determines that the project is unlikely to have significant residual impacts on the environment and meet the regulations and requirements of the appropriate legislation, the Environmental Assessment Branch may excuse the proponent from further impact assessment research.

In the event that screening raises significant environmental concerns, the Environmental Assessment Branch will demand that the proponent prepare an impact statement. The impact statement will in due course be submitted to the Environmental Assessment Branch, and after following a legislated review process, the Minister of Saskatchewan Environment and Public Safety may give approval to the proponent to proceed with development, give conditional approval, or deny approval to proceed with the project.

8.2.2.3 SaskPower. SaskPower is a user of water at Lake Diefenbaker through the Coteau Creek Generating Station. Like all users, except SaskWater, SaskPower has limited capability for independent action relating to water use or management decisions. It has a mandate to provide adequate electrical energy at the lowest possible cost. Hydro-electric power from Gardiner Dam is an inexpensive form of energy, and SaskPower therefore strives to maximize use of this source, particularly at times of peak load. It carries out the scheduled release of water from Lake Diefenbaker under the direction of the SaskWater.

8.2.2.4 Saskatchewan Parks and Renewable Resources. Saskatchewan Parks and Renewable Resources (SPRR) has the authority to deal with park, wildlife and fish related issues pertaining to the study area. Its concerns relate primarily to non-consumptive in-stream recreation, waterfowl and fishery uses and are addressed by the Parks Branch, Wildlife Branch and Fisheries Branch. Three provincial parks (Danielson, Douglas and Saskatchewan Landing) are directly adjacent to the South Saskatchewan River, and another two (Blackstrap and Pike Lake) use water from the river. Under agreement between SaskWater and Saskatchewan Parks and Renewables Resources, water is also provided from the reservoir for Ducks Unlimited's wildlife marsh projects along the Saskatoon Southeast Wate Supply (SSEWS) system.

Saskatchewan Parks and Renewable Resources deals with other provincial agencies on water management issues through two committees. These committees are the Wetlands Technical Advisory Committee and the Qu'Appelle Operations Committee. Other input relating to water management issues is provided on an informal basis as required.

8.2.2.5 Saskatchewan Agriculture. With the 1987 transfer of the Irrigation Branch to SaskWater, Saskatchewan Agriculture has become much less involved in water management activities. The Department's major involvement now is through the administration of long term agricultural leases of provincial Crown Land.

8.2.2.6 Saskatchewan Rural Development. Saskatchewan Rural Development has a direct involvement with water management through its control over ferries and bridges. River flows, and in particular, flood levels, are all of concern to the planning and management of ferries and bridges. Rural Development also has an indirect, but important, involvement in water management through land use controls and policies, pursuant to the Planning and Development Act.

8.2.3 Federal-Provincial Joint Agencies

Involved in water management in the South Saskatchewan River Basin are two joint federal-provincial Boards: the Prairie Provinces Water Board and the South Saskatchewan Reservoir Board.

Established under Federal-Provincial Agreements, these Boards are comprised of federal and provincial members, with both levels of government being considered equal.

8.2.3.1 Prairie Provinces Water Board (PPWB). The Prairie Provinces Water Board manages interprovincial waters through the co-operation of a wide range of provincial and federal departments. It was reconstituted under the terms of Schedule C of the Master Agreement on Apportionment signed in 1969 by Canada, Alberta, Saskatchewan and Manitoba. This Agreement laid out the terms by which the prairie provinces share the flow and consider the quality of eastward flowing interprovincial streams.

By the terms of the Agreement, the Prairie Provinces Water Board seeks to ensure that interprovincial apportionments of water are adhered to by the members. Canada is responsible for monitoring quantity and quality of waters as specified in Schedule A and B of the Agreement and the collection and publication of data, river discharge analyses, and natural flow calculations on the South Saskatchewan and Qu'Appelle rivers. Natural flow reports are forwarded to the Executive Director of the Prairie Provinces Water Board and to each of the Board members. If there are any indications that certain aspects of the Agreement may not be met, members discuss the situation and arrange for the necessary steps to be taken to ensure that the terms of the Agreement are met.

In addition to this apportionment monitoring function, the Prairie Provinces Water Board considers other water resource management issues as requested. These matters include water quality management and other issues pertaining to water resource management.

Separate committees have been established to assist the Board in specific undertakings. There are currently three standing committees that are responsible for doing much of the work for the Prairie Provinces Water Board. These are: the Committee on Hydrology, the Committee on Water Quality, and the Committee on Groundwater.

THE COMMITTEE ON HYDROLOGY

The Committee on Hydrology, at the request of and under the direction of the Prairie Provinces Water Board, investigates, oversees, reviews, reports, and makes recommendations on matters relating to the hydrology of inter-provincial basins. The Committee may consider natural flows, streamflow forecasting, data collection and processing, natural design and any other item of a hydrological character which the Board may wish to investigate.

THE COMMITTEE ON WATER QUALITY

The Committee on Water Quality investigates, reviews, oversees, reports, and recommends on matters relating to the quality of water at interprovincial boundaries. The Committee may, for example, assess water quality, evaluate the impact of projects on water quality at the interprovincial boundary, establish emergency responses to spills on interprovincial streams, and carry out other activities at the request of Board. The Committee is currently developing site specific Water Quality indicators which the Board can use to evaluate water quality at inter-provincial boundaries and identify potential interprovincial water quality concerns.

THE COMMITTEE ON GROUNDWATER

The Terms of Reference for the Committee on Groundwater specify that the Committee investigate, oversee, review, report, and make recommendations on matters pertaining to the quantity and quality of groundwater at or near provincial boundaries, as directed by the Board. The responsibilities of the Committee include exchange of information and data, data interpretation, recommendations on groundwater information and monitoring, and determination of the implications of proposed projects on groundwater at interprovincial boundaries.

8.2.3.2 South Saskatchewan Reservoir Board. The South Saskatchewan Reservoir Board was established in accordance with section 10 of the 1958 Federal-Provincial Agreement which provided for construction of the Gardiner and Qu'Appelle dams. Under terms of the Agreement, the South Saskatchewan Reservoir Board "shall . . . maintain effective liaison and co-ordination of maintenance and operation of the reservoir". This mandate includes the determination and implementation of policies pertaining to the operation of the dam to the extent that such policies affect the maintenance and safety of the project.

The South Saskatchewan Reservoir Board is comprised of four members: two federal members represented by PFRA and two provincial members. Saskatchewan's Board members currently represent SaskWater and SaskPower. PFRA members provide technical input related to the dam, SaskPower participation on the Board reflects its major investment in the Coteau Creek Generating Station and its role as a major user of water, and SaskWater participation takes into account its overall responsibility for management of the province's water resources.

Because the Board co-ordinates the safety and maintenance aspects of the operations of the Gardiner Dam, the Qu'Appelle River Dam, and Lake Diefenbaker, it is involved as a decision-maker in resolving matters relating to the operation of the dam and reservoir, such as maintenance of target elevations, response to rapid runoff, maintenance of downstream flows and similar operating concerns.

8.2.4 Local Agencies

In addition to the numerous federal and provincial agencies already discussed, there are a number of other agencies with direct input into the use or management of the water resources of the study area. These agencies are involved in smaller scale projects relating to water use, but are a significant part of the overall administrative and legal structure of the basin.

8.2.4.1 **Meewasin Valley Authority (MVA).** The Meewasin Valley Authority was established in 1979, and given broad rights over the river and surrounding land along the South Saskatchewan River centred on Saskatoon. It has the ability to pass bylaws, encourage certain forms of development, control development, and adopt protection or development policies. The Meewasin Valley Authority is also a developer in its own right, annually spending at least one-third of its total budget on capital works projects.

In general, Meewasin Valley Authority is a conservation agency established to protect and develop the natural, recreational and heritage resources of the area under its jurisdiction, and promote a better understanding of these resources through interpretive centres and special events. As a management, decision-making, and approval agency, involved in the management of water resources of the South Saskatchewan River in and near Saskatoon, Meewasin Valley Authority has a significant interest in water quantity and quality downstream of Gardiner Dam.

8.2.4.2 **Ducks Unlimited Canada.** Ducks Unlimited Canada is a private non-profit organization with the objective to increase the numbers of waterfowl by improving wetland habitat. They operate over 500 wetland projects in Saskatchewan, all of which enhance existing or provide new wetland nesting habitat.

8.2.4.3 **Conservation and Development Authorities.** Conservation and Development Authorities can be established under the Conservation and Development Act when a group of farmers get together on primarily soil conservation or drainage oriented projects. In some cases, the Authorities may also deal with some irrigation or other water use concerns, such as a backflood irrigation project.

Once established, Authorities become a form of local government. They have the power to control project operations, as well as tax landowners within the authority boundary for costs associated with the project.

8.2.4.4 **Water Users Associations.** Under the Water Users Act, the Minister responsible for SaskWater can approve the establishment of Water Users Associations. These Associations are local bodies which can assist a group of farmers sharing a common irrigation or water use project. They provide administrative and operational assistance to their members.

8.2.4.5 **Irrigation Districts.** The only existing irrigation district is the South Saskatchewan River Irrigation District #1, based at Outlook. The general mandate of the District is to supply water for irrigation to farmers within its boundary. This is accomplished by managing the administration, operation, and maintenance associated with the major Outlook area irrigation project owned by SaskWater.

8.2.4.6 **Watershed Associations.** A group of organizations with common watershed interests can establish a Watershed Association under the Watershed Associations Act. These Associations are normally groups of Conservation and Development Authorities, Water Users Associations, urban municipalities and rural municipalities. Watershed Associations provide means of dealing with conflicts and common interests experienced by different organizations in a given watershed. They also develop overall operation plans for water use and control systems.

8.2.4.7 **Chinook Parkway.** The Chinook Parkway is an area of public reserve land on either side of Swift Current Creek in the city of Swift Current. It was established by city council, with a mandate to provide some measure of environmental control and public recreation opportunities along the river.

8.2.4.8 **Urban Municipalities.** Urban Municipalities are empowered to make by-laws in support of providing safe water supplies, water treatment, and waste treatment, based on standards set by Saskatchewan Environment and Public Safety. The powers of urban municipalities in such water management programs are subject to the Water Corporation Act and to the provincial Environmental Management and Protection Act.

8.2.4.9 **Rural Municipalities.** Rural Municipalities adjacent to water bodies can exert land use policies and controls which limit the types of water use activities that can occur. They can prepare and adopt planning statements, development plans, and zoning bylaws.

With the proper development plans and zoning bylaws in place, a rural municipality is an important approval agent in developing water projects. Without municipal approval, a water development project cannot proceed.

8.2.4.10 <u>Buffalo Pound Water Administration Board</u>. The Buffalo Pound Water Administration Board administers water supply and treatment systems at Buffalo Pound Lake for the cities of Regina and Moose Jaw. As part of its role in providing water, the Board is concerned with outflows from Lake Diefenbaker into the Qu'Appelle River.

SUMMARY

In summary, the lead agency in most instances at the federal level is Environment Canada, whose mandate includes water quantity and quality monitoring, parks, waterfowl, wetlands and wildlife, and interjurisdictional waters. Provincially, water management is the responsibility of SaskWater, the agency which allocates water, administers land use controls on areas adjacent to reservoirs, and represents Saskatchewan with respect to interjurisdictional water management. The other lead agency in the province is Saskatchewan Environment and Public Safety, whose water management involvement primarily pertains to water quality monitoring and standards enforcement. The other organizations identified and discussed generally play supporting roles to the agencies with the primary responsibilities.

8.3 STUDY RECOMMENDATIONS

The recommendations of the Canada-Saskatchewan South Saskatchewan River Basin Study are summarized below. They are based on the short-term, long-term and system-limit planning exercises, and are organized into three groups: public involvement, water management, and research.

The responsibility for implementing these recommendations has been assigned to the appropriate agencies according to their respective mandates. In most cases, a single agency has the primary responsibility for implementation with one or two other agencies acting in support.

<u>PUBLIC INVOLVEMENT</u>

o Develop and implement a public information program to assist the public in understanding the water resource management issues of the study area and a process to facilitate their input.

Lead: SaskWater
Supporting: all agencies

o Continue to inform users about extreme variations in water quantity and quality that may affect their use of the water.

Lead: SaskWater, Saskatchewan Environment and Public Safety

o Make new water users aware of the extreme variations in water levels that can occur to ensure that water use activity and associated structures can cope with the extremes.

Lead: SaskWater
Supporting: Meewasin Valley Authority

o Encourage water conservation by all users, particularly those on SSEWS system and Swift Current Creek, where water shortages already occur.

Lead: SaskWater, municipalities
Supporting: Saskatchewan Environment and Public Safety, Saskatchewan Community Services, Environment Canada, PFRA

WATER MANAGEMENT

o Implement the basin-specific water quality objectives developed through the study and the monitoring program designed to ensure that the objectives are met.

Lead: Saskatchewan Environment and Public Safety, Environment Canada
Supporting: Prairie Provinces Water Board

o Encourage appropriate development, including the provision of sufficient public access, in shoreline areas.

Lead: municipalities
Supporting: SaskWater, Environment Canada, Saskatchewan Community Services, Saskatchewan Rural Development, Meewasin Valley Authority

o Continue to develop reservoir operating plans based on the seasonal forecasts for water supply and the needs of users on the reservoir and downstream.

Lead: SaskWater
Supporting: PFRA, SaskPower, Saskatchewan Parks and Renewable Resources

o Establish a summer target daily average flow of 60 to 150 cubic metres per second for the South Saskatchewan River downstream of Gardiner Dam.

Lead: SaskWater

o Continue the practise of maintaining a minimum daily average flow of 42.5 cubic metres per second downstream of Gardiner Dam.

Lead: SaskWater

o Apply the target and minimum flow criteria for the South Saskatchewan River from Gardiner Dam to confluence with the North Saskatchewan River.

Lead: SaskWater

o Do not exceed the current levels of irrigation development in the Swift Current Creek system unless more water is made available through conservation, changes in reservoir operation, or the development of new storage.

Lead: SaskWater, PFRA

o Consider modifying the operating plans for Duncairn and Highfield reservoirs to make more water available in the Swift Current Creek system.

Lead: SaskWater
Supporting: PFRA

o Investigate the feasibility of developing regional water supply systems for municipalities and other users that currently experience water quantity or water quality problems.

Lead: SaskWater
Supporting: PFRA, Saskatchewan Community Services, Saskatchewan Rural Development, municipalities

RESEARCH

o Encourage research aimed at quantifying the benefits of instream water uses.

Lead: SaskWater
Supporting: Saskatchewan Parks and Renewable Resources, Environment Canada

o Encourage research aimed at developing a monitoring system capable of detecting subtle long-term changes in the health of the natural ecosystem.

Lead: Environment Canada
Supporting: all agencies

o Work toward more compatible databases and tools to help ensure a more consistent approach to project evaluation.

Lead: SaskWater, Environment Canada
Supporting: all agencies

8.4 PROJECT EVALUATION PROCEDURES

There are three main evaluation processes which may apply to water resources development proposals. They include SaskWater's water use permitting process and the provincial and federal environmental assessment processes.

The South Saskatchewan River Basin Study compiled baseline information and developed computer models which can be used to help ensure that projects are evaluated in a consistent and thorough manner. These tools assist in the evaluation of projects from three different perspectives: environmental, social, and economic, and are intended to be used within the context of the existing evaluation processes.

Hand-in-hand with the preparation of new tools comes the necessity of developing a suitable method of maintaining them so that they remain up to date and efficient, and a useful part of government evaluation procedures. The following section lists some of the evaluation tools developed over the course of the South Saskatchewan River Basin Study, the name of an agency identified as the most suitable organization to take on its maintenance responsibilities, and a suggestion as to how often the tool needs to be revised. In most cases, the agency identified for maintenance was responsible for the original development of the tool.

It should be noted that the revision frequency is intended as a general guideline only. Revisions are based on the speed at which the South Saskatchewan River Basin as a system is changing. The need for a tool's update is, for the most part, dependent on its importance to the planning process.

Water Resources Management Model (WRMM)
Maintenance: SaskWater
Revision Frequency: annually

Report on Flooding, Gardiner Dam to the Forks
Maintenance: SaskWater
Revision Frequency: ten years

Lake Diefenbaker Trophic State Model
Maintenance: Saskatchewan Environment and Public Safety
Revision Frequency: five years

Water Quality Models for South Saskatchewan River
Maintenance: Saskatchewan Environment and Public Safety
Revision Frequency: one to two years

Water Use Analysis Model (WUAM)
Maintenance: Environment Canada
Revision Frequency: five years

Heritage Resource Maps
Maintenance: Saskatchewan Culture, Multiculturalism and Recreation
Revision Frequency: ten years

Instream Flow Requirements
Maintenance: SaskWater
Revision Frequency: five years

Hydraulic Model
Maintenance: SaskWater
Revision Frequency: five years

Wildlife Habitat Maps
Maintenance: Saskatchewan Parks and Renewable Resources
Revision Frequency: ten years

Travel Cost Model
Maintenance: Saskatchewan Parks and Renewable Resources
Revision Frequency: ten years

Residential Water Use Model
Maintenance: SaskWater
Revision Frequency: ten years

Hydro System Simulation Model (HYDSIM)
Maintenance: SaskPower
Revision Frequency: annually

Water Intake and Outfall Survey
Maintenance: SaskWater
Revision Frequency: ongoing

In summary, it is apparent that most of the maintenance responsibilities for the evaluation tools will lie with provincial agencies. This is consistent with the mandate of these agencies, each of whom is charged with the responsibility of overseeing different aspects of provincial resources.

8.5 IMPLEMENTATION RECOMMENDATIONS

The implementation plan considers the recommendations developed from the management strategies produced from the study. Three of the recommendations apply directly to the implementation plan. They deal with the issues of database compatibility, a procedure to effect the study's recommendations, and consider the necessity of updating the entire South Saskatchewan River Basin Study in the future.

8.5.1 Database Compatibility

As a result of the South Saskatchewan River Basin Study, the number of databases, computer models and other tools for the evaluation of possible water management projects in the South Saskatchewan River Basin has been increased. While this increased detail has meant that such evaluations are more effective, the entire project evaluation process has become more complex.

A further complicating factor lies in the fact that the data in the different databases is not always compatible, either between databases or as it might be applied to discrete geographic areas. This increases the difficulty in maintaining consistency in project evaluation. Clearly, the databases and tools used to evaluate projects would be more useful if they were more compatible.

This finding was identified over the course of the South Saskatchewan River Basin Study, and a recommendation to alleviate the difficulty was formulated. It is recommended that the study's Implementation Plan:

- o Work toward more compatible databases and tools to help ensure a more consistent approach to project evaluation.

8.5.2 Implementation Plan Agreement

In order to assist in the effective implementation of the various study recommendations and the maintenance of the project evaluation tools, it is recommended that SaskWater and Environment Canada:

- o Establish a procedure to ensure the implementation and to monitor the results of the study's recommendations.

This could be accomplished by the two agencies sponsoring a South Saskatchewan River Basin Study Inter-agency Implementation Plan. Such a commitment would take the form of a joint Canada-Saskatchewan Implementation Agreement.

8.5.3 Study Update

Experience with other river basin planning studies has demonstrated that there is little, if any, consistency in the span of their usefulness. Comprehensive river basin planning studies assess a wide variety of factors, including water quality, quantity, use, environmental aspects, and current and proposed management policies. It is important to the ongoing planning process that this information be kept updated.

The various planning horizons investigated by the South Saskatchewan River Basin Study have identified the period around the year 2010 to be of special importance for the study area. Alberta will be reaching the policy limits it established regarding water resources development in its portion of the South Saskatchewan River Basin. Since this policy limit was a fundamental assumption in the present study, it will be necessary to review Alberta's water demands in the future in order to verify forecasts made in 1991. For this reason, it is recommended in the study to:

- o Consider carrying out a follow-up study of the Saskatchewan portion of the South Saskatchewan River Basin in the year 2010.

The water resources situation in the Alberta portion of the South Saskatchewan River Basin is of critical importance to Saskatchewan, since water use developments in that province have a greater impact on Saskatchewan than do Saskatchewan's own developments.

9.0 REFERENCES

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IBI-ECOS. 1981. Flood Plain Management Program Data Collection Project. Ecos Engineering Services Ltd. Calgary. Prepared for Saskatchewan Environment for the Saskatchewan Flood Plain Management Program.

Prairie Farm Rehabilitation Administration. Design Division. 1988. Condition Assessment Report Duncairn Dam project.

Prairie Farm Rehabilitation Administration. Hydrology Division. 1981. City of Swift Current Flood Damage Reduction Study Hydrologic and Hydraulic Report.

APPENDIX A
SOUTH SASKATCHEWAN RIVER BASIN STUDY
LIST OF TECHNCIAL REPORTS

SOUTH SASKATCHEWAN RIVER BASIN STUDY TECHNICAL REPORTS		
TITLE	SSRB TECHNICAL REPORT	DATE
Annual Report to December 31, 1986	A.3	11.87
Annual Report to December 31, 1987	A.4	07.88
Annual Report to December 31, 1988	A.5	05.89
Annual Report to December 31, 1989	A.6	03.90
Compendium of Water Quality Objectives Development Methodologies	D.9	06.88
Contaminant Organic Compounds in the Surface Waters of the South Saskatchewan River Basin	D.4	12.87
Crop Damage and Associated Economic Impact of Flooding, South Saskatchewan River Downstream of Lake Diefenbaker	E.13	12.89
Data Collection and Date Base Development: South Saskatchewan River Basin Recreation Survey	E.1	11.86
The Delphi Report	B.3	08.90
Demand for Water-Based Recreation in the South Saskatchewan River Basin	E.17	08.90
Economic Profile and Trends 1951-1986	E.9	06.88
Erosion and Sedimentation in the South Saskatchewan River Basin	C.9	12.89
Farm-Level Drought Analysis Model	E.15	08.90
Fishery Survey of the South Saskatchewan River and Its Tributaries in Saskatchewan	D.8	11.88
Flood Frequencies in the South Saskatchewan River Basin	C.5	08.88
Flooding Gardiner Dam to the Forks	C.8	10.89
Framework Plan Working Definition	B.1	09.87
Frequency Analysis of Meterological Drought in the Saskatchewan Portion of the South Saskatchewan River Basin	C.4	07.88
Ground Water and the South Saskatchewan River Basin: Recommendations to the Study Board	C.2	03.88
Ground Water Study: South Saskatchewan River Basin	C.2	03.88
Heritage Resources	E.16	08.90
A Hydraulic Study of the South Saskatchewan River	E.12	05.89
Hydro System Simulation (HYDSIM) Model Study Report	C.7	05.89
Hydrologic Drought Analysis of Simulated Flows - South Saskatchewan River Basin	C.6	02.89
Information Base: Surface Water Hydrology and Water Use	E.2	03.87
Instream Water Use: South Saskatchewan River Basin	E.7	12.87
Irrigation Water Use Pilot Study	E.8	04.88
Irrigation Water Use Survey (South Saskatchewan River Basin Study)	E.11	12.88
Lake Diefenbaker Trophic State Model	D.5	01.88
Land Use in the Effective Drainage Area of the South Saskatchewan River Basin	D.2	10.87

SOUTH SASKATCHEWAN RIVER BASIN STUDY TECHNICAL REPORTS		
TITLE	SSRB TECHNICAL REPORT	DATE
Legal and Administrative Analysis Interim Report	B.2	03.88
Legal and Administrative Summary	B.4	02.91
Low Flow Frequency Analysis for the South Saskatchewan River	C.10	05.91
Major Industrial Water Users in the South Saskatchewan River Basin	E.10	10.88
Mass Loading of Phosphorus to Lake Diefenbaker	D.13	09.89
Municipal and Residential Water Use Study	E.5	08.87
Municipal Water Use Survey	E.3	07.87
Nutrient Quality Review and Objectives Development for the South Saskatchewan River Basin	D.14	01.90
Phosphorus Loading from Non-Point Sources Relevant to the Lake Diefenbaker Basin	D.1	09.87
Proposed Water Quality Objectives for the South Saskatchewan River Basin	D.12	08.89
Public Involvement Program Position Paper	F.1	10.86
Public Opinion Survey, 1988 Survey Design	F.2	03.88
Recreational Data Analysis Report South Saskatchewan River Basin	E.4	07.87
Reservoir Salinity Model: Application to the Saskatoon Southeast Water Supply System	D.16	05.90
Reservoir Salinity Study Phase 1	D.7	10.88
Short-term Water Use Forecast South Saskatchewan River Basin Study	E.14	12.89
Study Plan and Annual Work Plans - 1987	A.2	02.87
Study Proposal for the South Saskatchewan River Basin	A.1	04.86
Style Guides for Reports	A.7	03.90
Summary and Evaluation of the Public Information and Awareness Strategy	F.3	09.89
Summary and Evaluation of the Public Information and Awareness Strategy, April 1990	F.4	04.90
Summary and Evaluation of the Public Information and Awareness Strategy, November 1990	F.5	12.90
Water Demand Management: An Application to the South Saskatchewan River Basin	E.18	08.90
Water Intake and Outfall Survey South Saskatchewan River Basin	E.6	12.87
Water Management Model Study South Saskatchewan River Basin	C.1	01.88
Water Quality Data Review	D.6	03.88
Water Quality Modelling South Saskatchewan River	D.10	04.89
Water Quality Monitoring Plan for the South Saskatchewan River Basin	D.15	04.90
Water Quality Monitoring Review South Saskatchewan River Basin	D.11	06.89
Water Quality Trend Analysis and Data Base Summary	D.3	11.87
Water Use Analysis Model Study: South Saskatchewan River Basin Study	D.19	05.91

APPENDIX B
MASTER AGREEMENT ON APPORTIONMENT

MASTER AGREEMENT ON APPORTIONMENT

THIS AGREEMENT is made in quadruplicate this THIRTIETH day of OCTOBER, 1969, A.D.

BETWEEN:

HER Majesty, the Queen, in right of Canada, represented herein by the Minister of Energy, Mines and Resources

(Hereinafter called "Canada")

- and -

HER Majesty, the Queen, in right of Alberta, represented herein by the Minister in charge of Water Resources for Alberta

(Hereinafter called "Alberta")

- and -

HER Majesty, the Queen, in right of Saskatchewan, represented herein by the Minister in charge of The Water Resources Commission Act of the said Province

(Hereinafter called "Saskatchewan")

- and -

HER Majesty, the Queen, in right of Manitoba, represented herein by the Minister in charge of The Water Control and Conservation Branch Act of the said Province

(Hereinafter called "Manitoba")

WHEREAS under natural conditions the waters of the watercourses hereinafter referred to arising in or flowing through the Province of Alberta would flow into the Province of Saskatchewan and under the said conditions the waters of some of the said watercourses arising in or flowing through the Province of Saskatchewan would flow into the Province of Manitoba;

AND WHEREAS the Governor-in-Council has authorized Canada to enter into this agreement by Order-in-Council P.C. 1969-8/2051 dated October 29, 1969, and the Lieutenant Governors-in-Council for Alberta, Manitoba and Saskatchewan, respectively, have authorized them to enter into this agreement by the following Orders-in-Council:

Alberta	- O.C. 2053-69
Manitoba	- O.C. 1359/69
Saskatchewan	- O.C. 1612/69

AND WHEREAS the parties hereto deem it to be in their mutual interest that an agreement be reached among the four parties as to the apportionment as described in the schedules attached hereto of such interprovincial waters among the three Provinces;

AND WHEREAS Alberta and Saskatchewan have entered into an agreement, which agreement is attached to this agreement as Schedule A, that permits the Province of Alberta to make a net depletion of one-half the natural flow of water arising in or flowing through the Province of Alberta and that permits the remaining one-half of the natural flow of each such watercourse to flow into the Province of Saskatchewan, subject to certain exceptions as are set forth in the said agreement;

AND WHEREAS Saskatchewan and Manitoba have entered into an agreement which agreement is attached to this agreement as Schedule B, that permits the Province of Saskatchewan to make a net depletion of one-half the natural flow of water arising in, and one-half of the water flowing into the Province of Saskatchewan, and that permits the remaining one-half of the flow of each such watercourse to flow into the Province of Manitoba, subject to such conditions and agreements as therein contained;

AND WHEREAS the parties are desirous that the Prairie Provinces Water Board (referred to herein as the Board), reconstituted by this agreement will be responsible for the administration of this agreement;

AND WHEREAS the parties hereto recognize the continuing need for consultation and co-operation as between themselves with respect to the matters herein referred to so that the interests of all the parties are best served;

NOW THEREFORE, THIS AGREEMENT (hereinafter known as the Master Agreement) witnesseth that each party agrees as follows:

Interprovincial Agreements

1. Alberta and Saskatchewan agree that the agreement between them (hereinafter called the First Agreement), a copy of which is set out in Schedule A to the Master Agreement, will become binding upon them upon the date that the Master Agreement is executed.

2. Saskatchewan and Manitoba agree that the agreement between them (Hereinafter called the Second Agreement), a copy of which is set out in Schedule B to the Master Agreement, will become binding upon them upon the data that the Master Agreement is executed.

3. The parties agree to the apportionment of water between Alberta and Saskatchewan and Manitoba as provided in the First and Second Agreements and each party agrees to be bound by the said agreements as they relate to apportionment as if it were a party thereto.

4. The parties agree that the First or Second Agreement, or both, may be altered by an agreement in writing among the four parties to the Master Agreement, but not otherwise.

5. The parties agree that the First and Second Agreements will continue in force and effect until cancelled by an agreement in writing among the four parties to the Master Agreement.

Water Quality

6. The parties mutually agree to consider water quality problems; to refer such problems to the Board; and to consider recommendations of the Board thereon.

Monitoring

7. The parties agree that the monitoring of the quantity and quality of waters as specified in the First and Second Agreements, the collection, compilation and publication of water quantity and quality data required for the implementation and maintenance of the provisions of this agreement shall be conducted by Canada, subject to provision of funds being voted by the Parliament of Canada.

Administration

8. The parties agree, subject to Clause 9 of this agreement that it at any time, any dispute, difference or question arises between the parties with respect to this agreement or the construction, meaning and effect thereof, or anything therein, or the rights and liabilities of the parties thereunder or otherwise in respect thereto, then every such dispute, difference or question will be referred for determination to the Exchequer Court under the provisions of the Exchequer Court Act of Canada and each of the parties hereto agrees to maintain or enact the necessary legislation to provide the Exchequer Court with jurisdiction to determine any such dispute, difference, or question in the manner provided under the Exchequer Court Act.

9. The parties also agree that the Board, with the consent of the parties in dispute, may cause to be prepared, a factual report of the dispute for consideration by the parties hereto prior to the referral of the dispute to the Exchequer Court.

10. The parties agree that the Prairie Provinces Water Board shall monitor and report on the apportionment of waters as set out in the provisions of the First and Second Agreements and ratified by this Master Agreement.

11. The parties agree to revoke the agreement data July 28, 1948, establishing the Prairie Provinces Water Board and to reconstitute the Prairie Provinces Water Board in the form of Schedule C hereto and the said Schedule shall form and become part of this Master Agreement.

12. Because the Orders-in-Council referred to in Schedule D hereto will become redundant upon the execution of this Master Agreement, the parties agree to take steps to have them revoked.

13. The parties agree for the future application of the provisions of the Master Agreement (and the First and Second Agreements thereunder), to work together and to cooperate to the fullest extent each with the other for the integrated development and use of water and related resources to support economic growth according to selected social goals and priorities and to participate in the formulation and implementation of comprehensive planning and development programs according to their national, regional and provincial interest and importance.

14. No Member of the Parliament of Canada or Member of the Legislative Assemblies of the Provinces party to this agreement shall hold, enjoy, or be admitted to any share or part of any contract, agreement, commission or benefit arising out of this agreement.

IN WITNESS HEREOF Canada has caused its presents to be executed by its Minister of Energy, Mines and Resources, and Alberta has caused its presents to be executed by its Minister in charge of Water Resources, and Saskatchewan has caused its presents to be executed by its Minister in charge of The Water Resources Commission Act, and Manitoba has caused its presents to be executed by its Minister in charge of The Water Control and Conservation Branch Act of the day and year first mentioned above.

"A. Davidson"
Witness to the signature of the Minister
(Energy, Mines and Resources) for Canada

"J.J. Greene"
Minister (Energy, Mines and Resources) for Canada

October 30, 1969
Date

"R.E. Bailey"
Witness to the signature of the Minister in
charge of Water Resources for Alberta

"Henry A. Ruste"
Minister in charge of Water Resources for
Alberta

October 30, 1969
Date

"Harold W. Pope"
Witness to the signature of the Minister
in charge of The Water Resources Commission
Act for Saskatchewan

"Allan R. Guy"
Minister in charge of The Water Resources
Commission Act for Saskatchewan

October 30, 1969
Date

"Thomas E. Weber"
Witness to the signature of the Minister in
charge of The Water Control and Conservation Branch Act
for Manitoba

"Leonard S. Evans"
Minister in charge of The Water Control
and Conservation Branch Act for Manitoba

October 30, 1969
Date

4th Recital Clause amended on July 5, 1984

SCHEDULE A

THIS AGREEMENT is made in quadruplicate this THIRTIETH day of OCTOBER, 1969, A.D.

BETWEEN:

HER Majesty, the Queen, in right of Alberta, represented herein by the Minister in charge of Water Resources for Alberta

(Hereinafter called "Alberta")

- and -

HER Majesty, the Queen, in right of Saskatchewan, represented herein by the Minister in charge of The Water Resources Commission Act of the said Province

(Hereinafter called "Saskatchewan")

WHEREAS under natural conditions the waters of the watercourses hereinafter referred to arising in or flowing through the Province of Alberta would flow into the Province of Saskatchewan and under the said conditions the waters of some of the said watercourses arising in or flowing through the Province of Saskatchewan would flow into the Province of Manitoba;

AND WHEREAS the parties hereto deem it to be in their mutual interest and in the interest of Manitoba that an agreement in principle be reached among the said three Provinces as to the apportionment of such interprovincial waters among them;

AND WHEREAS the parties hereto are of the opinion that an equitable apportionment of such waters as between the adjoining Provinces of Alberta and Saskatchewan would be to permit the Province of Alberta to make a net depletion of one-half the natural flow of water arising in or flowing through the Province of Alberta and to permit the remaining one-half of the natural flow of water of each such watercourse to flow into the Province of Saskatchewan, subject to certain prior rights as are hereinafter set forth or may hereafter be mutually agreed upon in writing;

AND WHEREAS on the basis of the foregoing apportionment as between the Provinces of Alberta and Saskatchewan the parties hereto are of the opinion that in a similar manner, an equitable apportionment of the remainder of the natural flow of the said watercourses that flow into the Province of Manitoba after permitting the Province of Alberta to make its depletion of one-half thereof would be to permit the Province of Saskatchewan to make a net depletion of one-half of the said remainder and to permit the other one-half thereof to flow into the Province of Manitoba; and that the natural flow of any tributaries to the said watercourses which tributaries join the said watercourses in the Province of Saskatchewan without arising in or first flowing through the Province of Alberta could be apportioned one-half to the Province of Saskatchewan and one-half to the Province of Manitoba in a manner similar to the apportionment of waters as between the Provinces of Alberta and Saskatchewan, in all cases subject to such prior rights as may be mutually acknowledged by the said Provinces of Manitoba and Saskatchewan;

AND WHEREAS the parties hereto recognize the continuing need for consultation and cooperation as between themselves and with Manitoba with respect to the matters herein referred to so that the best and most beneficial use of the said waters may be made and the interests of all said provinces best served:

NOW THIS AGREEMENT witnesseth as follows:

1. IN THIS AGREEMENT:

   (a) "Natural flow" means the quantity of water which would naturally flow in any watercourse had the flow not been affected by human interference or human intervention, excluding any water which is part of the natural flow in Alberta but is not available for the use of Alberta because of the provisions of any international treaty which is binding on Alberta.

   (b) "Watercourse" means any river, stream, creek, or other natural channel which from time to time carries a flowing body of water from the Province of Alberta to the Province of Saskatchewan and includes all tributaries of each such river, stream, creek or natural channel which do not themselves cross the common boundary between the Provinces of Alberta and Saskatchewan. Such tributaries as do themselves cross the said common boundary between the Provinces of Alberta and Saskatchewan shall be deemed to be "watercourses" for the purpose of this agreement.

2. (a) The parties hereto shall mutually establish a method by which to determine the natural flow of each watercourse flowing across their said common boundary.

(b) For the purpose of this agreement, the said natural flow shall be determined at a point as near as reasonably may be to their said common boundary.

(c) Notwithstanding sub-paragraph (b) the point of which the natural flow of the watercourses known as the South Saskatchewan and Red Deer Rivers is to be determined may be, at the option of Alberta, a point at or as near as reasonably may be below the confluence of the said two rivers.

3. Alberta shall permit a quantity of water equal to one-half the natural flow of each watercourse to flow into the Province of Saskatchewan, and the actual flow shall be adjusted from time to time on an equitable basis during each calendar year, but this shall not restrict or prohibit Albert from diverting or consuming any quantity of water from any watercourse provided that Alberta diverts water to which it is entitled of comparable quality from other streams or rivers into such watercourse to meet its commitments to Saskatchewan with respect to each watercourse.

4. Notwithstanding paragraph 3 hereof, the following special provisions shall apply as between the parties hereto with respect to the watercourse known as the South Saskatchewan River.

(a) Alberta shall be entitled in each year to consume, or to divert or store for its consumptive use a minimum of 2 100 000 acre-feet net depletion out of the flow of the watercourse known as the South Saskatchewan River even though its share for the said year, as calculated under paragraph 3 hereof, would be less than 2 100 000 acre-feet net depletion, provided however Alberta shall not be entitled to so consume or divert, or store for its consumptive use, more than one-half the natural flow of the said South Saskatchewan watercourse if the effect thereof at any time would be to reduce the actual flow of the said watercourse at the common boundary of the said Provinces of Saskatchewan and Alberta to less than 1,500 cubic feet per second.

(b) The consumption or diversion by Alberta provided for under the preceding sub-paragraph shall be made equitably during each year, depending on the actual flow of water in the said watercourse and the requirements of each Province, from time to time.

5. The parties hereto shall work together and co-operate to the fullest extent, each with the other, for the most effective, economical and beneficial use of waters flowing from the Province of Alberta into the Province of Saskatchewan, including the construction and operation of approved projects of mutual advantage to our Provinces on a cost-share basis proportionate to the benefits derived therefrom by each Province, (the approval of which projects shall not be unreasonably withheld by either of the parties hereto) and shall enter into such other arrangements, agreements or accords with each other, and with the Governments of Canada and other Provinces to best achieve the principles herein agreed upon.

6. Notwithstanding paragraph 3 hereof, with respect to each of the three watercourses known as Battle Creek, Lodge Creek, and Middle Creek, the annual flow shall be apportioned such that, in each of the said watercourses, Alberta permits a quantity of water equal to 75 percent of the natural flow to pass the interprovincial boundary from Alberta to Saskatchewan.

7. If at any time any dispute, difference or question shall arise between the parties or their representatives touching this agreement or the construction, meaning and effect thereof, or anything therein, or the rights or liabilities, of the parties or their representatives thereunder or otherwise in respect thereto then every such dispute, difference or question shall be referred for determination to the Exchequer Court under the provisions of The Exchequer Court Act of Canada, and each of the parties hereto agrees to enact the necessary legislation to provide the Exchequer Court with jurisdiction to determine any such dispute, difference or question in the manner provided under Section 30 of The Exchequer Court Act.

8. This agreement shall become effective upon the execution of an agreement by Canada, Alberta, Manitoba and Saskatchewan relative to the apportionment of waters referred to in this agreement.

IN WITNESS WHEREOF Alberta has caused these presents to be executed on its behalf by its Minister in charge of Water Resources, and Saskatchewan has caused these presents to be executed by its Minister in charge of The Water Resources Commission Act, both on the day and year first above mentioned.

"R.E. Bailey"

Witness to the signature of the Minister
in charge of Water Resources for Alberta

"Henry A. Ruste"

Minister in charge of Water Resources for Alberta

"Harold W. Pope"

Witness to the signature of the Minister
in charge of The Water Resources Commission Act

"Allan R. Guy"

Minister in charge of The Water Resources Commission Act

Section 6 amended on July 5, 1984.

SCHEDULE B

THIS AGREEMENT is made in quadruplicate this THIRTIETH day of October, 1969, A.D.

BETWEEN:

HER Majesty, the Queen, in right of Saskatchewan, represented herein by the Minister in charge of The Water Resources Commission Act of the said Province

(Hereinafter called "Saskatchewan)

- and -

HER Majesty, the Queen, in right of Manitoba, represented herein by the Minister in charge of The Water Control and Conservation Branch Act of the said Province

(Hereinafter called "Manitoba")

WHEREAS under natural conditions the waters of the watercourses hereinafter referred to arising in or flowing through the Province of Saskatchewan would flow into the Province of Manitoba;

AND WHEREAS the parties hereto deem it to be in their mutual interest and in the interest of Alberta that an agreement in principle be reached among the said three Provinces as to the apportionment of interprovincial waters among them;

AND WHEREAS the parties hereto are of the opinion that an equitable apportionment of such waters as between the adjoining Provinces of Saskatchewan and Manitoba would be to permit the Province of Saskatchewan to make a net depletion of one-half the natural flow of water arising in, and one-half the flow of water flowing into, the Province of Saskatchewan, and to permit the remaining one-half of the flow of water of each such watercourse to flow into the Province of Manitoba, subject to certain rights as may hereafter be mutually agreed upon in writing;

AND WHEREAS on the basis of the forgoing apportionment as between the Provinces of Saskatchewan and Manitoba, the parties hereto are of the opinion that in a similar manner, an equitable apportionment of the natural flow of the said watercourses arising in or flowing through the Province of Alberta would be to permit the Province of Alberta to make a net depletion of one-half thereof, subject to such prior rights as may be mutually acknowledged by the said Provinces of Alberta, Saskatchewan and Manitoba;

AND WHEREAS the parties hereto recognize the continuing need for consultation and co-operation as between themselves and with Alberta with respect to the matters herein referred to so that the interests of all said Provinces are best served;

NOW THIS AGREEMENT witnesseth as follows:

1. IN THIS AGREEMENT:

   (a) "Natural flow' means the quantity of water which would naturally flow in any watercourse had the flow not been affected by human interference or human intervention.

   (b) "Watercourse" means any river, stream, creek, o r other natural channel which from time to time carries a flowing body of water from the Province of Saskatchewan to the Province of Manitoba and includes all tributaries of each such river, stream, creek or natural channel which do not themselves cross the common boundary between the Provinces of Saskatchewan and Manitoba. Such tributaries as do themselves cross the said common boundary between the Provinces of Saskatchewan and Manitoba shall be deemed to be "watercourses" for the purpose of this agreement.

2. (a) The parties hereto shall mutually establish a method by which to determine the natural flow of each watercourse flowing across their said common boundary.

   (b) For the purpose of this agreement, the said natural flow shall be determined at a point as near as reasonably may be to their said common boundary.

3. Saskatchewan shall permit in each watercourse the following quantity of water to flow into Manitoba during the period from April 1 of each year to march 31 of the year following: A quantity of water equal to the natural flow for that period determined at the point referred to in paragraph 2(b) hereof, less

(a) one-half the water flowing into Saskatchewan in that watercourse from Alberta, and

(b) any water which would form part of the natural flow in that watercourse but does not flow into Saskatchewan because of the implementation of any provision of any subsisting water apportionment agreement made between Alberta and Saskatchewan and approved by Manitoba, and

(c) one-half the natural flow arising in Saskatchewan.

The actual flow shall be adjusted from time to time by mutual agreement on an equitable basis during such period but this shall not restrict or prohibit Saskatchewan from diverting, storing or consuming any quantity of water from any watercourse provided that Saskatchewan diverts water to which it is entitled of comparable quality from other streams or rivers into such watercourse to meet its commitments to Manitoba with respect to each watercourse.

4. Saskatchewan shall be entitled during such period to consume or to divert or store for its consumptive use the water it is not required to permit to flow into Manitoba in each watercourse under paragraph 3 hereof, but such consumption or diversion shall be made equitably depending on the actual flow of water in each watercourse and the requirements of each Province from time to time, but Saskatchewan shall permit sufficient water to flow into Manitoba to meet its commitments during such period under paragraph 3 hereof.

5. The parties hereto shall work together and co-operate to the fullest extent, each with the other, for the use of waters flowing from the Province of Saskatchewan into the Province of Manitoba, including the construction and operation of approved projects of mutual advantage to the said Provinces on a cost-share basis proportionate to the benefits derived therefrom by each Province (the approval of which projects shall not be unreasonably withheld by either of the parties hereto) and shall enter into such other arrangements, agreements or accords with each other, and with the Governments of Canada and other Provinces to best achieve the principles herein agreed upon.

6. If at any time any dispute, difference or question shall arise between the parties or their representatives touching this agreement or the construction, meaning and effect thereof, or anything therein, or the rights or liabilities of the parties or their representatives thereunder or otherwise in respect thereto then every such dispute, difference or question shall be referred for determination to the Exchequer Court under the provisions of The Exchequer Court Act of Canada, and each of the parties hereto agrees to maintain or enact the necessary legislation to provide the Exchequer Court with jurisdiction to determine any such dispute, difference or question in the manner provided under The Exchequer Court Act.

7. This agreement shall become effective upon the execution of an agreement by Canada, Alberta, Manitoba and Saskatchewan relative to the apportionment of waters referred to in this agreement.

IN WITNESS WHEREOF Saskatchewan has caused these presents to be executed by its Minister in charge of The Water Resources Commission Act, and Manitoba has caused these presents to be executed by its Minister in charge of The Water Control and Conservation Branch Act on the day and year first above mentioned.

"Harold W. Pope"
Witness to the signature of the Minister
in charge of The Water Resources Commission Act

"Allan R. Guy"
Minister in charge of The Water Resources Commission Act

"Thomas E. Weber"
Witness to the signature of the Minister
in charge of The Water Control and Conservation Branch Act

"Leonard S. Evans"
Minister in charge of The Water Control and Conservation Branch Act.

SCHEDULE C

PRAIRIE PROVINCES WATER BOARD AGREEMENT

THIS AGREEMENT made this THIRTIETH day of OCTOBER, 1969, A.D.

BETWEEN:

THE GOVERNMENT OF CANADA, hereinafter called "Canada"

- and -

THE GOVERNMENT OF MANITOBA, hereinafter called "Manitoba"

- and -

THE GOVERNMENT OF SASKATCHEWAN, hereinafter called "Saskatchewan"

- and -

THE GOVERNMENT OF ALBERTA, hereinafter called "Alberta"

1. Manitoba, Saskatchewan, Alberta and Canada agree to establish and there is hereby established a Board to be known as the Prairie Provinces Water Board to consist of five members to be appointed as follows:

   (a) two members to be appointed by the Governor General in Council, one of whom shall be Chairman of the Board, on the recommendation of the Minister of Energy, Mines and Resources,

   (b) one member to be appointed by the Lieutenant Governor in Council of each of the Provinces of Manitoba, Saskatchewan and Alberta.

2. Functions

   The Board shall oversee and report on the Master Agreement (including the First and Second Agreements thereunder) executed by Canada, Alberta, Manitoba and Saskatchewan for the apportionment of waters flowing from one Province into another province; shall take under consideration, comprehensive planning, water quality management and other questions pertaining to water resource management referred to it by the parties hereto; shall recommend appropriate action to investigate such matters and shall submit recommendations for their resolution to the parties hereto.

3. Composition of Board

   The members of the Board shall be chosen from those engaged in the administration of water resources or related duties for Manitoba, Saskatchewan, Alberta or Canada, as the case may be, and shall serve as members of the Board in addition to their other duties.

4. Duties of the Board

   In accordance with its functions, the duties of the Board shall be as follows:

   (a) to review, collate, and analyze streamflow data and prepare reports and recommendations on the apportionment of water,

   (b) to review water quality problems, particularly such problems located at the interprovincial boundaries, and to recommend to the parties hereto, appropriate management approaches for their resolution including the establishment of new institutional arrangements,

   (c) to develop recommendations on other water matters, in addition to problems on water quality, referred to the Board by any party hereto including the review and analysis of existing information and the requesting of additional studies and assistance by appropriate governmental agencies to provide information for formulating its recommendations,

(d) to promote through consultation and the exchange of information the integrated development of water resources of interprovincial streams,

(e) to cause to be prepared with the consent of the parties involved factual reports on disputes arising out of the water apportionment for consideration by the parties hereto,

(f) to ensure the co-ordination of such technical programs as water quantity and quality monitoring and streamflow forecasting required for the effective apportionment of water.

5. Confirmation of the Board's Recommendations

A recommendation of the Board with respect to any matters referred to it under Section 2 shall, subject to the Master Agreement for the apportionment of water, become effective when adopted by Orders-in-Council passed by Canada and each of the Provinces.

6. Authority of Board

The Board shall have authority to correspond with all Governmental organizations and other sources of information in Canada or abroad concerned with the administration of water resources, and such other authority as may be conferred on the Board rom time to time by agreement between the parties hereto; all agencies of the four governments having to do with the water and associated resources in the area covered by the Agreement shall be required to supply the Board with all data in their possession requested by the Board.

7. Records

The records relating to the water resources of the three provinces collected and compiled by the P.F.R.A. organization at Regina shall be made available to the Board.

8. Meetings of the Board

The Board shall meet at the call of the Chairman and meetings shall be called at least twice annually; the expenses of the members shall be borne by their respective governments.

9. Reports

The Board shall submit an annual progress report outlining work done and work contemplated in the agreed program to each of the responsible Ministers of the parties hereto and such other reports as may be requested by any one of such Ministers.

10. Operation of the Board

The Secretary for the Board and such other technical and clerical staff as may be required, with a headquarters at Regina, shall be Federal or Provincial public servants. The cost of administration, excluding the cost of monitoring as described in Section 7 of the Master Agreement, but including staff, accommodation, supplies and incidental expenses of the Board, shall be borne by the parties hereto on the basis of one-half by Canada and one-sixth by each of the Provinces. The Board shall prepare for approval of the parties hereto, work program, staff requirements, annual budgets and five-year forecasts and such other reports as may be required in the operation of the Board.

11. Any water development project already constructed or to be constructed by any one of the parties shall be so operated as to maintain the apportionment of water as set out in the Master Agreement (and the First and Second Agreements thereunder) for the apportionment of waters of interprovincial streams.

SCHEDULE D

PREVIOUS ALLOCATIONS OF INTERPROVINCIAL WATERS APPROVED BY ORDERS-IN-COUNCIL BY THE GOVERNMENTS OF CANADA, ALBERTA, MANITOBA, AND SASKATCHEWAN

	Order-in-Council			
Item	Canada	Alberta	Saskatchewan	Manitoba
Allocation of water for specific projects in Alberta	4030/49	857/49	1307/51	1121/49
Allocation of water for specific projects in Saskatchewan	1874/51	1091/51	1310/51	1264/51
Allocation of water for South Saskatchewan River Project in Saskatchewan	973/53	991/53	1271/53	924/53

APPENDIX C
WATER RESOURCE MANAGEMENT MODEL (WRMM) RESULTS SUMMARY

1.0 INTRODUCTION

The Hydrology Branch of Sask Water completed water supply modelling of the South Saskatchewan River Basin using the Water Resource Management Model (WRMM). This model was developed by the Alberta Department of the Environment and was used for the Alberta study of the upper portion of the basin. For the Saskatchewan study, the model was configured to simulate the portion of the basin downstream of the Saskatchewan - Alberta border.

The Water Resource Management Model, as used for this study, is a computer based water balance model which simulates the operation of a river system with natural flows, storage reservoirs and a variety of water uses. Through a system of penalty points, the model optimizes the monthly operation of the river system. By running data for a long series of years, in this study, the 75 years from 1912 to 1986 were used, the success or failure of any operating strategy to meet desirable objectives can be tested.

For details of the theory of this model, the reader is referred to the model documentation developed by Alberta Environment. For details of the calibration to the Saskatchewan portion of the study area, the South Saskatchewan River Basin Water Management Model Study, 1988, provides the details.

For this study, the area was divided into three segments for modelling purposes. The mainstem of the South Saskatchewan River, the SSEWS system and Swift Current Creek were each considered separately.

Details of the water uses are contained in the South Saskatchewan River Basin Study Report on Water Use.

1.1 SCENARIO NUMBERING SYSTEM

The large number of scenarios tested required that a simple numbering system be derived to differentiate among results. In the attached results tables, the scenario numbers contain an alphanumeric designation. The first one or two letters indicate which component of the study area:

M	-	Mainstem,
SE	-	SSEWS; and
SC	-	Swift Current Creek.

The second two digits indicate the development level. Four development levels were studied:

86	-	1986 or current conditions;
00	-	2000 or short-term future;
20	-	2020 or long-term future;
F5	-	Far Future or system limit development with Saskatchewan receiving 50 percent of the natural flow from Alberta on average.
F6	-	Far Future or system limit development with Saskatchewan receiving 60 percent of the natural flow from Alberta on average.

The last four or five digits indicate the Case and Run number. The first scenario in each group is a BASE Case which is provided for comparison to the scenarios that follow. The scenarios are grouped into cases which have similar features by the Case numbers which identify the individual scenarios.

1.2 OUTPUT SUMMARIES

When it is simulating a complex river system for 12 months each year for 75 years, the Water Resource Management Model produces 900 monthly flows or water levels for every point on the system being modelled. If all of this data were printed on paper output, the volume of output would be too large for effective decision making. Therefore the Management Strategies Committee identified key evaluation criteria as described in the South Saskatchewan River Basin Study Report on The Framework Plan. The detailed simulation results from each scenario were stored in electronic media. Subroutines were developed to extract only the numbers required for these evaluation criteria.

2.0 MAINSTEM RESULTS

Since the mainstem carries the bulk of the water of the study area and has the greatest diversity of potential developments, a large number of scenarios were studied. The first set of results show the current conditions, short-term and long-term future scenarios. The second group show the system limit scenarios.

The mainstem modelling included the South Saskatchewan River in Saskatchewan and the reach of the Saskatchewan River to the Manitoba border. The flows of the North Saskatchewan River and the local inflow to the Saskatchewan River were modelled to include developments as they existed in the mid 1980s. These flows from downstream of the study area were not adjusted for future developments.

2.1 CURRENT CONDITIONS, SHORT-TERM AND LONG-TERM SCENARIOS

2.1.1 Current Conditions (1986)

M86BASE - This 1986 Base Case scenario demonstrates the response of the river and lake system if it was operated for the 75 year study period with uses and the operating pattern as they were in the mid 1980s.

The inflow from Alberta was based on results of Alberta Environment studies of the upper basin. On average Saskatchewan receives about 78 percent of the natural flow from Alberta. The operation of Lake Diefenbaker was set to provide similar winter drawdown to recent experience and, when summer flows were adequate, the lake was filled through the summer. Downstream of Lake Diefenbaker, the desirable flow range of 60 to 150 m^3/s was met when supplies were adequate. In drought periods flows as low as 42.5 m^3/s were permitted and in floods, releases were as required to avoid surcharging Lake Diefenbaker.

2.1.2 Short-Term Scenarios (Year 2000)

M00BASE - The year 2000 Base Case Scenario maintained the same operating rules as the 1986 Base Case but, with year 2000 uses in Alberta and Saskatchewan, the river flows were modestly lower and as a result water levels were reduced. On average Saskatchewan is expected to be receiving 72 percent of the natural flow from Alberta by the year 2000. All consumptive users would receive sufficient water, the reduced supply was assumed to reduce the frequency of desirable water levels and flows and the quantity of hydroelectric energy produced.

M00C1R1 - The normal winter drawdown on Lake Diefenbaker was reduced one metre from the Base Case. The full one metre increase in lake levels was applied to the March 1 to May 1 period with a uniform transition to the Base Case levels October 1.

M00C2R1 - This scenario tested the effects of reducing the minimum downstream flow from Lake Diefenbaker from 42.5 m^3/s to 30 m^3/s.

M00C2R2 - This scenario tested the effects of increasing the minimum downstream flow from Lake Diefenbaker from 42.5 m^3/s to 60 m^3/s.

M00C2R3 - The minimum downstream flow was increased from 42.5 m^3/s to 120 m^3/s.

M00C3R1 - This scenario combined a one metre reduction in winter drawdown of M00C1R1 with the increased minimum flow of 60 m^3/s from M00C2R2.

M00C4R1 - The reduction in the winter drawdown of M00C1R1 was increased from one metre to two metres.

M00C4R2 - The two metre reduction in winter drawdown of M00C4R1 was combined with the 60 m^3/s minimum flow of M00C2R2.

2.1.3 **Long-Term Scenarios (Year 2020)**

M20BASE - The year 2020 Base Case Scenario maintained similar operating rules to the 1986 and 2000 Base Cases but with water uses at the projected year 2020 level. As a result of anticipated growth in water use in Alberta, the average water supply was assumed to be reduced to 67 percent of the natural flow. The Alberta flows were defined by Alberta Environment's Water Resource Management Model run OD05.

It was assumed that all intakes in Lake Diefenbaker would be at a sufficient depth to obtain water even if the lake level is low. All irrigation areas were assumed to use 457 mm of depth of water per year.

The winter drawdown on Lake Diefenbaker was assumed to be one metre less than in the 1986 and 2000 Base Cases, similar to M00C3R1.

M20C1R1 - This was a demand management scenario in which the consumptive uses were assumed to be reduced by 40 percent. The uses which were reduced were irrigation, municipal and industrial.

M20C1R2 - This demand management scenario provided for a 20 percent reduction in consumptive uses.

M20C2R1 - In this scenario a higher level of irrigation development was assumed.

M20C2R2 - A lower level of irrigation development was assumed.

M20C3R1 - This scenario emphasized maintenance of desirable water flows downstream of Lake Diefenbaker by raising the minimum flow from 42.5 m^3/s to 60 m^3/s.

M20C4R1 - This scenario included three additional reservoirs downstream of Lake Diefenbaker. These reservoirs would be operated at stable levels for hydroelectric generation.

M20C5R1 - The winter drawdown was reduced one metre from the Base Case.

M20C6R1 - The reduced drawdown of M20C5R1 was combined with the 40 percent demand management of M20C1R1.

M20C7R1 - The higher irrigation area of M20C2R1 was combined with the reduced drawdown of M20C5R1.

M20C7R2 - The lower irrigation area of M20C2R2 was combined with the reduced drawdown of M20C5R1.

M20C8R1 - The higher minimum flow, 60 m^3/s, of M20C3R1 was combined with the reduced drawdown of M20C5R1.

M20C9R1 - The additional reservoirs of M20C4R1 were combined with the reduced drawdown of M20C5R1.

M20C10R1 - The winter drawdown was reduced three metres from the Base Case.

SOUTH SASKATCHEWAN RIVER BELOW RED DEER RIVER

APRIL - OCTOBER
PERCENT OF TIME IN EACH FLOW ZONE (m^3/s)

	GREATER 1000.0	1000.0 400.0	400.0 150.0	150.0 60.0	60.0 42.5	LESS THAN 42.5
M86BASE.	2.67	26.10	35.81	25.52	9.33	0.57
M00BASE.	1.90	22.67	34.48	33.52	7.05	0.38
M20BASE.	2.29	17.90	33.52	37.52	8.76	0.00

NOVEMBER - MARCH
PERCENT OF TIME IN EACH FLOW ZONE (m^3/s)

	GREATER 400.0	400.0 42.5	LESS THAN 42.5
M86BASE.	0.00	100.00	0.00
M00BASE.	0.00	100.00	0.00
M20BASE.	0.00	99.73	0.27

LAKE DIEFENBAKER (MAY-OCTOBER)

PERCENT OF TIME IN EACH ELEVATION ZONE (m)

	GREATER FSL	556.86 556.00	556.00 554.00	554.00 551.00	551.00 545.59	LESS THAN 545.59
M86BASE.	0.00	44.67	25.33	26.22	3.78	0.00
M00BASE.	0.00	37.56	26.89	29.33	6.22	0.00
M00C1R1.	0.00	46.00	24.89	27.78	1.33	0.00
M00C2R1.	0.00	39.78	27.11	28.89	4.22	0.00
M00C2R2.	0.00	37.11	23.33	30.89	8.67	0.00
M00C2R3.	0.00	23.56	15.56	32.89	28.00	0.00
M00C3R1.	0.00	45.33	23.11	28.00	3.56	0.00
M00C4R1.	0.00	50.67	26.00	23.33	0.00	0.00
M00C4R2.	0.00	49.56	24.67	25.11	0.67	0.00
M20BASE.	0.00	32.89	27.78	34.44	4.89	0.00
M20C1R1.	0.00	36.44	26.22	34.44	2.89	0.00
M20C1R2.	0.00	34.44	27.33	34.44	3.78	0.00
M20C2R1.	0.00	29.78	28.89	34.00	7.33	0.00
M20C2R2.	0.00	34.00	27.56	34.44	4.00	0.00
M20C3R1.	0.00	30.89	24.00	34.67	10.44	0.00
M20C4R1.	0.00	31.56	28.44	34.00	6.00	0.00
M20C5R1.	0.00	39.78	27.78	32.44	0.00	0.00
M20C6R1.	0.00	42.67	28.44	28.89	0.00	0.00
M20C7R1.	0.00	36.67	29.78	32.89	0.67	0.00
M20C7R2.	0.00	41.33	27.56	31.11	0.00	0.00
M20C8R1.	0.00	36.67	28.44	33.33	1.56	0.00
M20C9R1.	0.00	38.44	28.89	32.00	0.67	0.00
M20C10R1	0.00	52.67	41.33	6.00	0.00	0.00

SOUTH SASKATCHEWAN RIVER BELOW SASKATOON

APRIL - OCTOBER
PERCENT OF TIME IN EACH FLOW ZONE (m^3/s)

	GREATER 1000.0	1000.0 400.0	400.0 150.0	150.0 60.0	60.0 42.5	LESS THAN 42.5
M86BASE	0.38	6.48	31.81	34.48	26.86	0.00
M00BASE	0.57	5.71	24.38	30.86	38.48	0.00
M00C1R1.	0.76	5.90	26.86	35.43	31.05	0.00
M00C2R1.	0.57	5.71	24.57	31.81	2.86	34.48
M00C2R2.	0.57	5.71	23.43	70.29	0.00	0.00
M00C2R3.	0.57	5.52	19.81	73.14	0.57	0.38
M00C3R1.	0.76	5.90	6.10	67.24	0.00	0.00
M00C4R1.	0.76	7.62	28.57	37.90	25.14	0.00
M00C4R2.	0.76	7.62	28.38	63.24	0.00	0.00
M20BASE	0.76	5.33	19.81	25.90	48.19	0.00
M20C1R1.	0.76	5.71	21.90	28.19	43.43	0.00
M20C1R2.	0.76	5.52	0.38	27.24	46.10	0.00
M20C2R1.	0.76	5.33	18.48	24.00	51.43	0.00
M20C2R2.	0.76	5.52	19.62	27.62	46.48	0.00
M20C3R1.	0.76	5.33	18.86	75.05	0.00	0.00
M20C4R1.	0.76	5.33	20.00	24.95	48.95	0.00
M20C5R1.	0.95	5.90	20.76	31.81	40.57	0.00
M20C6R1.	0.95	6.48	23.05	33.52	36.00	0.00
M20C7R1.	0.76	5.90	20.38	30.48	42.48	0.00
M20C7R2.	0.95	6.29	21.52	32.38	38.86	0.00
M20C8R1.	0.95	5.90	20.38	72.76	0.00	0.00
M20C9R1.	0.76	6.10	20.95	31.05	41.14	0.00
M20C10R1	1.14	7.62	26.67	39.62	24.95	0.00

NOVEMBER - MARCH
PERCENT OF TIME IN EACH FLOW ZONE (m3/s)

	GREATER 400.0	400.0 42.5	LESS THAN 42.5
M86BASE.	0.00	100.00	0.00
M00BASE.	0.27	99.73	0.00
M00C1R1.	0.27	99.73	0.00
M00C2R1.	0.27	99.73	0.00
M00C2R2.	0.27	99.73	0.00
M00C2R3.	0.27	99.73	0.00
M00C3R1.	0.27	99.73	0.00
M00C4R1.	0.27	99.73	0.00
M00C4R2.	0.27	99.73	0.00
M20BASE.	0.27	99.73	0.00
M20C1R1.	0.27	99.73	0.00
M20C1R2.	0.27	99.73	0.00
M20C2R1.	0.27	99.73	0.00
M20C2R2.	0.27	99.73	0.00
M20C3R1.	0.27	99.73	0.00

NOVEMBER - MARCH
PERCENT OF TIME IN EACH FLOW ZONE (m3/s)

	GREATER 400.0	400.0 42.5	LESS THAN 42.5
M20C4R1.	0.27	99.73	0.00
M20C5R1.	0.53	99.47	0.00
M20C6R1.	0.53	99.47	0.00
M20C7R1.	0.53	99.47	0.00
M20C7R2.	0.53	99.47	0.00
M20C8R1.	0.53	99.47	0.00
M20C9R1.	0.53	99.47	0.00
M20C10R1	0.27	99.73	0.00

SOUTH SASKATCHEWAN RIVER BELOW ST. LOUIS

PERCENTAGE OF ALBERTA INFLOW

	HIGHEST	UPPER QUARTILE	MEDIAN	LOWER QUARTILE	LOWEST
M86BASE.	120	96	94	91	72
M00BASE.	121	96	92	88	68
M00C1R1.	121	96	92	87	67
M00C2R1.	119	96	91	87	66
M00C2R2.	127	96	92	88	63
M00C2R3.	156	97	95	90	58
M00C3R1.	123	96	92	88	65
M00C4R1.	116	95	91	87	66
M00C4R2.	122	96	91	87	69
M20BASE.	110	93	87	82	61
M20C1R1.	116	95	91	86	67
M20C1R2.	113	94	89	84	64
M20C2R1.	106	91	85	80	57
M20C2R2.	113	94	89	84	63
M20C3R1.	116	93	89	83	57
M20C4R1.	106	91	85	80	57
M20C5R1.	110	92	87	81	60
M20C6R1.	109	94	90	86	67
M20C7R1.	106	91	85	79	57
M20C7R2.	110	92	88	83	63
M20C8R1.	112	93	87	82	61
M20C9R1.	106	90	85	80	57
M20C10R1	102	91	86	80	63

COTEAU CREEK POWER STATION

POWER PRODUCTION (MW.HR)

	FIRM POWER PRODUCTION			MEAN POWER PRODUCTION		
	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL
M86BASE.	183063	79773	262836	691207	396399	1087606
M00BASE.	158822	77033	235855	635962	347265	983227
M00C1R1.	161939	86809	248748	618687	376915	995602
M00C2R1.	175684	55308	230992	660404	318346	978750
M00C2R2.	166897	104295	271192	632132	385651	1017783
M00C2R3.	125331	106802	232133	518963	451315	970278
M00C3R1.	170321	109178	279499	618105	407534	1025639
M00C4R1.	164999	90682	255681	593876	406582	1000458
M00C4R2.	173606	110492	284098	596602	431989	1028591
M20BASE.	100013	78881	178894	507280	329022	836302
M20C1R1.	129358	77009	206367	555006	329313	884319
M20C1R2.	114662	75533	190195	531560	326610	858170
M20C2R1.	93973	78679	172652	493095	324334	817429
M20C2R2.	110066	79050	189116	523805	332981	856786
M20C3R1.	122218	112227	234445	513806	376912	890718
M20C4R1.	100023	80193	180216	504074	334100	838174
M20C5R1.	101546	81254	182800	489610	350208	839818
M20C6R1.	131580	78306	209886	536049	351151	887200
M20C7R1.	95555	81051	176606	476138	345113	821251
M20C7R2.	111941	82586	194527	505581	356052	861633
M20C8R1.	124693	109922	234615	500116	390736	890852
M20C9R1.	101517	84185	185702	486972	355977	842949
M20C10R1	103371	95187	198558	431529	417101	848630

DUNDURN POWER STATION

POWER PRODUCTION (MW.HR)

	FIRM POWER PRODUCTION			MEAN POWER PRODUCTION		
	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL
M20C4R1.	35931	31357	67288	167495	109093	276588
M20C9R1.	35800	32428	68228	160355	114404	274759

ST. LOUIS POWER STATION

POWER PRODUCTION (MW.HR)

	FIRM POWER PRODUCTION			MEAN POWER PRODUCTION		
	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL
M20C4R1.	75547	58093	133640	367583	241068	608651
M20C9R1.	75259	59646	134905	351373	255536	606909

FORKS POWER STATION

POWER PRODUCTION (MW.HR)

	FIRM POWER PRODUCTION			MEAN POWER PRODUCTION		
	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL
M20BASE.	330187	365299	695486	1033788	1324765	2358553
M20C1R1.	368915	361002	729917	1092858	1325814	2418672
M20C1R2.	346701	363142	709843	1060914	1325128	2386042
M20C2R1.	325890	365346	691236	1021476	1320788	2342264
M20C2R2.	340658	365261	705919	1050611	1328143	2378754
M20C3R1.	351873	392761	744634	1040233	1367995	2408228
M20C4R1.	329926	359645	689571	1029905	1314939	2344844
M20C5R1.	329776	365137	694913	1009972	1339287	2349259
M20C6R1.	368745	363926	732671	1067290	1345394	2412684
M20C7R1.	325648	365160	690808	998537	1334656	2333193
M20C7R2.	343609	368120	711729	1029252	1346568	2375820
M20C8R1.	352713	392556	745269	1020708	1379331	2400039
M20C9R1.	329517	359476	688993	1006888	1328937	2335825
M20C10R1	331377	371239	702616	945127	1394528	2339655

NIPAWIN POWER STATION

POWER PRODUCTION (MW.HR)

	FIRM POWER PRODUCTION			MEAN POWER PRODUCTION		
	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL
M86BASE.	273513	236414	509927	793126	880238	1673364
M00BASE.	255396	236660	492056	754683	852001	1606684
M00C1R1.	256691	238020	494711	739302	861903	1601205
M00C2R1.	267360	222272	489632	771419	832611	1604030
M00C2R2.	258649	254522	513171	750512	877654	1628166
M00C2R3.	259524	283083	542607	708846	952433	1661279
M00C3R1.	260101	254525	514626	737169	884429	1621598
M00C4R1.	256691	238012	494703	718498	874293	1592791
M00C4R2.	260101	254386	514487	718310	894950	1613260
M20BASE.	211063	236506	447569	661870	836622	1498492
M20C1R1.	235268	233800	469068	699163	837007	1536170
M20C1R2.	221599	235153	456752	679235	836714	1515949
M20C2R1.	208468	236506	444974	654121	834233	1488354
M20C2R2.	217742	236506	454248	672634	838646	1511280
M20C3R1.	224139	254367	478506	665143	864672	1529815
M20C4R1.	210878	233296	444174	659348	831549	1490897
M20C5R1.	210801	236508	447309	646449	845197	1491646
M20C6R1.	235137	235847	470984	682580	848807	1531387
M20C7R1.	208314	236508	444822	639267	842471	1481738
M20C7R2.	219258	237964	457222	658403	849185	1507588
M20C8R1.	225283	254229	479512	653098	871005	1524103
M20C9R1.	210617	233297	443914	644448	839809	1484257
M20C10R1	211223	237959	449182	604022	874961	1478983

E.B. CAMPBELL POWER STATION

POWER PRODUCTION (MW.HR)

	FIRM POWER PRODUCTION			MEAN POWER PRODUCTION		
	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL
M86BASE.	237352	197798	435150	675512	748954	1424466
M00BASE.	223242	199493	422735	644916	725066	1369982
M00C1R1.	224106	200861	424967	632332	736800	1369132
M00C2R1.	232702	191124	423826	658264	712671	1370935
M00C2R2.	224949	212005	436954	640578	743908	1384486
M00C2R3.	226682	227825	454507	607746	796253	1403999
M00C3R1.	226533	211950	438483	630234	752681	1382915
M00C4R1.	224106	200830	424936	615621	750301	1365922
M00C4R2.	226533	211836	438369	615087	764504	1379591
M20BASE.	185530	200459	385989	567775	712897	1280672
M20C1R1.	205557	198180	403737	598483	714143	1312626
M20C1R2.	194332	199319	393651	582146	713445	1295591
M20C2R1.	184126	200459	384585	562152	710338	1272490
M20C2R2.	191112	200459	391571	576695	715073	1291768
M20C3R1.	195992	213064	409056	570224	733662	1303886
M20C4R1.	185416	197274	382690	565770	706697	1272467
M20C5R1.	185312	200462	385774	555407	723053	1278460
M20C6R1.	205500	199705	405205	585249	726728	1311977
M20C7R1.	183997	200462	384459	550245	720235	1270480
M20C7R2.	192188	201905	394093	565154	727074	1292228
M20C8R1.	197173	212831	410004	560842	742050	1302892
M20C9R1.	185200	197278	382478	553810	716650	1270460
M20C10R1	185267	201927	387194	520557	751941	1272498

2.2 SYSTEM LIMIT SCENARIO

Two sets of System Limit Scenarios were studied. The first assumed that Alberta might someday fully utilize its 50 percent of the natural flow as defined by the Master Agreement on Apportionment. The second assumed that Alberta uses might never reach the full 50 percent every year and Saskatchewan might receive an average of 60 percent of the natural flow. For each of the 50 percent scenarios (MF5) described below, there is a similar 60 percent scenario (MF6).

MF5BASE - The far future Base Case used the existing and committed off-stream water uses which will be in place by the year 2000. The minimum flow downstream of Lake Diefenbaker was set at 42.5 m^3/s.

2.2.1 Irrigation System Limits

In order to identify the absolute limit on potential future irrigation development a trial and adjustment process was used. While holding all other uses constant, the area under irrigation was increased by increments until shortages began to occur in the dry years. The irrigation potential will vary with the operating assumptions, therefore several operating assumptions were tested. The area of irrigation in the scenario descriptions is in addition to the projected year 2000 area.

Although this irrigation could be developed anywhere along the mainstem or on the SSEWS system, for modelling simplicity, all of the added area was assumed to be at Lake Diefenbaker.

In the past, and the foreseeable future, irrigation along the South Saskatchewan has received its full requirements in every year. However, this is not the case in other areas of the prairie region. On other streams in Southwest Saskatchewan and Southern Alberta, irrigation projects receive less than full irrigation water in dry years. Some areas operate with a reduced supply more frequently than 15 percent of the years. For this study, a series of scenarios were studied which included sufficient development to precipitate shortages in 15 percent of the years. These shortages were exclusively to irrigation, the base flow downstream of Lake Diefenbaker at 42.5 m^3/s and other uses as projected for the year 2000 were not permitted to go short of water.

MF5C1R1A - This scenario assumed the operation was unchanged from MF5BASE. The irrigated area was increased by 110 000 ha before any shortages occurred.

MF5C1R2A - This scenario assumed that winter drawdown was reduced by one metre which permitted the added irrigated area to expand to 120 000 ha before any shortages occurred.

MF5C1R3A - With the winter drawdown reduced by two metres, the area could grow by 130 000 ha.

MF5C1R4A - With the winter drawdown reduced by two metres and the minimum flow downstream of Lake Diefenbaker increased from 42.5 to 60 m^3/s, the irrigated area could only expand by 24 000 ha over the year 2000 level of development.

MF5C1R5A - By reducing the winter drawdown four metres, and returning to the 42.5 m^3/s flow, the expanded area could be 160 000 ha.

MF5C1R1B to MF5C1R3B and MF5C1R5B - These scenarios are the same as MF5C1R1A to MF5C1R3A and MF5C1R5B except that the area under irrigation was expanded until shortages occurred in 15 percent of the years studied. The areas of expansion were found to be 260 000 ha; 300 000 ha; 320 000 ha; and 370 000 ha respectively.

2.2.2 Municipal System Limits

To define the limit of future municipal development, all other uses were held constant and the municipal withdrawal was increased by increments until shortages began to occur. This potential will vary with operating assumptions. The quantity of water was calculated as the volume of water that could be used assuming a seasonal distribution similar to historic uses at Saskatoon.

Although the municipal growth could occur anywhere, for this study it was placed at Saskatoon. It was also assumed that the water would only be used once, no allowance for reuse of treated effluent was calculated.

MF5C2R1 - This scenario assumed that the operation was unchanged from MF5BASE. An added municipal demand of 560 000 dam^3/s was found to be possible.

MF5C2R2 - This scenario was similar to MF5C2R1 with one metre less winter drawdown at Lake Diefenbaker and an added municipal demand of 610 000 dam^3 over the Base Case.

MF5C2R2 - By decreasing the winter drawdown two metres from the Base Case, the municipal supply could increase to 660 000 dam^3.

MF5C2R2 - By decreasing the winter drawdown two metres from the Base Case and increasing the base flow from 42.5 m^3/s to $60^3/s$, the increased municipal supply was knocked down to 110 000 dam^3.

MF5C2R6 - By decreasing the winter drawdown by four metres, the increased municipal supply rose to 810 000 dam^3.

2.2.3 Industrial System Limits

A similar series of scenarios were calculated for industrial demands. Since lake Diefenbaker can supply industrial demands around the lake or downstream, it was assumed for this study that the demands would originate at the lake. Industrial use was assumed to be uniform throughout the year.

MF5C3R1 - Without changing any operation, the industrial use could increase by 570 000 dam^3.

MF5C3R2 - By reducing the winter drawdown on Lake Diefenbaker one metre, the industrial use could increase 630 000 dam^3.

MF5C3R3 - By reducing the winter drawdown two metres, the industrial use could increase 670 000 dam^3.

MF5C3R4 - By reducing the winter drawdown two metres and increasing the downstream flow from 42.5 to 60 m^3/s, the industrial water supply would increase 110 000 dam^3.

MF5C3R5 - By reducing the winter drawdown four metres, the industrial water supply would increase 820 000 dam^3.

2.2.4 Hydro System Limits

The Hydro System Limit Scenarios assumed the development of three new reservoirs to function as head ponds for hydro stations: Dundurn, St. Louis, and the Forks. Although the total power produced is mainly a function of the flow, the timing in the annual cycle and the reliability from year to year can be affected by the operating patterns.

MF5C4R1A - Provides for a one metre increase in the winter drawdown.

MF5C4R2A - Provides for a one metre decrease in the winter drawdown.

MF5C4R2B - Provides for a one metre decrease in the winter drawdown and a minimum flow of 60 m^3/s.

MF5C4R2C - Provides for a one metre decrease in the winter drawdown and a minimum flow of 100 m^3/s.

MF5C4R3A to MF5C4R3C - Provide for a two metre decrease in the winter drawdown and minimum flows of 42.5, 60 and 100 m^3/s.

MF5C4R4A to MF5C4R4C - Provide for a four metre decrease in the winter drawdown and minimum flows of 42.5, 60 and 100 $^3/s$.

MF5C4R5A to MF5C4R5C - Provide for a five metre decrease in the winter drawdown and minimum flows of 42.5, 60 and 100 m^3/s.

2.2.5 Lake Diefenbaker Levels System Limits

These scenarios identify opportunities to provide more stable water levels on Lake Diefenbaker by reducing the winter drawdown.

MF5C5R2 - Provides for a one metre reduction in the winter drawdown.

MF5C5R3 - Provides for a two metre reduction in the winter drawdown.

MF5C5R4 - Provides for a four metre reduction in the winter drawdown.

2.2.6 Downstream Flow System Limits

These scenarios identify the potential to provide fewer occurrences of flows below the desirable minimum of 60 m^3/s. In all of these scenarios the penalty points were adjusted to maintain the flow downstream of Lake Diefenbaker above 60 m^3/s from April to October.

MF5C6R1 - Minimum flow was increased to 60 m^3/s.

MF5C6R2 - Minimum flow was increased to 60 m^3/s and the winter drawdown on Lake Diefenbaker was reduced by one metre.

MF5C6R3 - Minimum flow was increased to 60 m^3/s and the winter drawdown on Lake Diefenbaker was reduced by two metres.

MAXIMUM IRRIGATION PRODUCTION

ADDITIONAL IRRIGATION IN HECTARES

MF5C1R1A	110 000
MF5C1R1B	260 000
MF5C1R2A	120 000
MF5C1R2B	300 000
MF5C1R3A	130 000
MF5C1R3B	320 000
MF5C1R4A	24 000
MF5C1R5A	160 000
MF5C1R5B	370 000
MF6C1R1A	180 000
MF6C1R1B	380 000
MF6C1R2A	190 000
MF6C1R2B	410 000
MF6C1R3A	200 000
MF6C1R3B	440 000
MF6C1R5A	230 000
MF6C1R5B	460 000

MAXIMUM MUNICIPAL DEVELOPMENT

ADDITIONAL MUNICIPAL DEMAND IN DAM^3

MF5C2R1	560 000
MF5C2R2	610 000
MF5C2R3	660 000
MF5C2R5	110 000
MF5C2R6	810 000
MF6C2R1	900 000
MF6C2R2	950 000
MF6C2R3	1 010 000
MF6C2R6	1 140 000

MAXIMUM INDUSTRIAL DEVELOPMENT

ADDITIONAL INDUSTRIAL DEMAND IN DAM^3

MF5C3R1	570 000
MF5C3R2	630 000
MF5C3R3	670 000
MF5C3R4	110 000
MF5C3R5	820 000
MF6C3R1	910 000
MF6C3R2	960 000
MF6C3R3	1 020 000
MF6C3R5	1 160 000

SOUTH SASKATCHEWAN RIVER BELOW RED DEER RIVER
APRIL - OCTOBER

NUMBER OF MONTHS IN EACH FLOW ZONE (m^3/s)

	GREATER 1000.0	1000.0 400.0	400.0 150.0	150.0 60.0	60.0 42.5	LESS THAN 42.5
M86BASE.	2.67	26.10	35.81	25.52	9.33	0.57
M70BASE.	1.90	22.67	34.48	33.52	7.05	0.38
M67BASE.	2.29	17.90	33.52	37.52	8.76	0.00
MF5BASE.	1.33	9.90	32.19	38.48	17.52	0.57
MF6BASE.	2.10	13.52	32.38	39.43	12.00	0.57

NOVEMBER - MARCH

NUMBER OF MONTHS IN EACH FLOW ZONE (m^3/s)

	GREATER 400.0	400.0 42.5	LESS THAN 42.5
M86BASE.	0.00	100.00	0.00
M70BASE.	0.00	100.00	0.00
M67BASE.	0.00	99.73	0.27
MF5BASE.	0.00	94.93	5.07
MF6BASE.	0.00	97.60	2.40

LAKE DIEFENBAKER (MAY-OCTOBER)

PERCENT OF TIME IN EACH ELEVATION ZONE (m)

	GREATER FSL	556.86 556.00	556.00 554.00	554.00 551.00	551.00 545.59	LESS THAN 545.59
M86BASE.	0.00	44.67	25.33	26.22	3.78	0.00
M70BASE.	0.00	37.56	26.89	29.33	6.22	0.00
M67BASE.	0.00	32.89	27.78	34.44	4.89	0.00
MF5BASE.	0.00	19.56	18.44	37.11	24.89	0.00
MF6BASE.	0.00	25.78	19.56	37.33	17.33	0.00
MF5C1R1A	0.00	15.11	16.22	30.22	38.44	0.00
MF5C1R1B	0.00	9.33	8.22	25.11	57.33	0.00
MF5C1R2A	0.00	16.89	19.78	35.11	28.22	0.00
MF5C1R2B	0.00	10.00	10.22	28.22	51.56	0.00
MF5C1R3A	0.00	23.11	19.78	38.44	18.67	0.00
MF5C1R3B	0.00	11.11	14.67	30.67	43.56	0.00
MF5C1R4A	0.00	28.89	18.89	38.22	14.00	0.00
MF5C1R5A	0.00	33.33	41.78	15.78	9.11	0.00
MF5C1R5B	0.00	14.22	29.78	19.11	36.89	0.00
MF6C1R1A	0.00	16.44	12.44	34.44	36.67	0.00
MF6C1R1B	0.00	10.22	8.44	17.56	63.78	0.00
MF6C1R2A	0.00	20.44	11.56	43.56	24.44	0.00
MF6C1R2B	0.00	11.33	10.00	20.67	58.00	0.00
MF6C1R3A	0.00	23.78	18.00	41.78	16.44	0.00
MF6C1R3B	0.00	12.00	13.11	21.11	53.78	0.00
MF6C1R5A	0.00	28.00	50.00	13.78	8.22	0.00
MF6C1R5B	0.00	13.78	22.89	22.00	41.33	0.00
MF5C2R1.	0.00	16.44	16.67	31.11	35.78	0.00
MF5C2R2.	0.00	20.67	18.44	36.22	24.67	0.00
MF5C2R3.	0.00	28.89	18.89	38.22	14.00	0.00
MF5C2R4.	0.00	18.00	17.78	36.22	28.00	0.00
MF5C2R5.	0.00	29.56	19.33	38.22	12.89	0.00
MF5C2R6.	0.00	38.00	41.56	11.78	8.67	0.00
MF6C2R1.	0.00	20.67	10.22	41.56	27.56	0.00
MF6C2R2.	0.00	28.89	25.33	37.78	8.00	0.00
MF6C2R3.	0.00	36.00	29.33	33.33	1.33	0.00
MF6C2R4.	0.00	24.44	17.56	36.44	21.56	0.00
MF6C2R6.	0.00	40.22	42.44	9.11	8.22	0.00
MF5C3R1.	0.00	16.44	16.89	31.78	34.89	0.00
MF5C3R2.	0.00	20.89	18.89	35.56	24.67	0.00
MF5C3R3.	0.00	29.78	18.89	38.44	12.89	0.00
MF5C3R4.	0.00	29.33	19.56	38.22	12.89	0.00
MF5C3R5.	0.00	38.44	41.11	11.78	8.67	0.00
MF6C3R1.	0.00	21.11	11.33	41.11	26.44	0.00
MF6C3R2.	0.00	24.00	17.33	37.56	21.11	0.00
MF6C3R3.	0.00	26.00	25.78	35.56	12.67	0.00
MF6C3R5.	0.00	41.11	41.33	10.00	7.56	0.00

LAKE DIEFENBAKER (MAY-OCTOBER)

PERCENT OF TIME IN EACH ELEVATION ZONE (m)

	GREATER FSL	556.86 556.00	556.00 554.00	554.00 551.00	551.00 545.59	LESS THAN 545.59
MF5C4R1A	0.00	14.22	18.44	31.11	36.22	0.00
MF5C4R2A	0.00	28.22	19.11	40.89	11.78	0.00
MF5C4R2B	0.00	22.89	18.44	38.22	20.44	0.00
MF5C4R2C	0.00	14.44	18.22	29.11	38.22	0.00
MF5C4R3A	0.00	33.11	24.00	40.67	2.22	0.00
MF5C4R3B	0.00	30.89	20.89	41.78	6.44	0.00
MF5C4R3C	0.00	18.00	19.11	32.44	30.44	0.00
MF5C4R4A	0.00	44.44	43.56	12.00	0.00	0.00
MF5C4R4B	0.00	38.89	40.44	20.67	0.00	0.00
MF5C4R4C	0.00	26.44	33.33	25.78	14.44	0.00
MF5C4R5A	0.00	49.33	47.33	3.33	0.00	0.00
MF5C4R5B	0.00	43.78	47.33	8.89	0.00	0.00
MF5C4R5C	0.00	28.22	40.00	20.44	11.33	0.00
MF6C4R1A	0.00	19.33	18.22	35.56	26.89	0.00
MF6C4R2A	0.00	29.56	26.89	36.00	7.56	0.00
MF6C4R2B	0.00	26.89	22.67	38.00	12.44	0.00
MF6C4R2C	0.00	20.67	14.22	38.67	26.44	0.00
MF6C4R3A	0.00	36.89	29.33	32.67	1.11	0.00
MF6C4R3B	0.00	32.44	28.89	36.22	2.44	0.00
MF6C4R3C	0.00	22.44	19.11	39.33	19.11	0.00
MF6C4R4A	0.00	55.78	36.22	8.00	0.00	0.00
MF6C4R4B	0.00	48.44	39.11	12.44	0.00	0.00
MF6C4R4C	0.00	29.78	42.89	18.00	9.33	0.00
MF6C4R5A	0.00	59.33	39.56	1.11	0.00	0.00
MF6C4R5B	0.00	53.56	42.22	4.22	0.00	0.00
MF6C4R5C	0.00	33.78	47.56	11.56	7.11	0.00
MF5C5R2.	0.00	28.22	19.11	40.89	11.78	0.00
MF5C5R3.	0.00	33.11	24.00	40.67	2.22	0.00
MF5C5R4.	0.00	44.44	43.56	12.00	0.00	0.00
MF6C5R2.	0.00	29.56	26.89	36.00	7.56	0.00
MF6C5R3.	0.00	36.89	29.33	32.67	1.11	0.00
MF6C5R4.	0.00	55.78	36.22	8.00	0.00	0.00
MF5C6R1.	0.00	17.78	16.67	33.33	32.22	0.00
MF5C6R2.	0.00	22.89	18.44	38.22	20.44	0.00
MF5C6R3.	0.00	30.89	20.89	41.78	6.44	0.00
MF6C6R1.	0.00	24.00	16.00	37.33	22.67	0.00
MF6C6R2.	0.00	26.89	22.67	38.00	12.44	0.00
MF6C6R3.	0.00	32.44	28.89	36.22	2.44	0.00

SOUTH SASKATCHEWAN RIVER BELOW SASKATOON

APRIL - OCTOBER
PERCENT OF TIME IN EACH FLOW ZONE (m^3/s)

	GREATER 1000.0	1000.0 400.0	400.0 150.0	150.0 60.0	60.0 42.5	LESS THAN 42.5
M86BASE.	0.38	6.48	31.81	34.48	26.86	0.00
M70BASE.	0.57	5.71	24.38	30.86	38.48	0.00
M67BASE.	0.76	5.33	19.81	25.90	48.19	0.00
MF5BASE.	0.00	2.29	11.05	8.19	78.48	0.00
MF6BASE.	0.57	3.43	14.86	9.33	71.81	0.00
MF5C1R1A	0.00	1.71	9.14	6.48	82.67	0.00
MF5C1R1B	0.00	1.71	6.48	5.14	84.57	2.10
MF5C1R2A	0.19	1.90	9.90	7.05	80.95	0.00
MF5C1R2B	0.00	1.90	6.86	4.00	84.95	2.29
MF5C1R3A	0.19	2.48	10.48	8.76	78.10	0.00
MF5C1R3B	0.00	2.29	6.67	4.57	84.00	2.48
MF5C1R4A	0.19	2.86	12.95	84.00	0.00	0.00
MF5C1R5A	0.38	2.67	20.19	13.90	62.86	0.00
MF5C1R5B	0.00	2.48	10.48	5.90	78.29	2.86
MF6C1R1A	0.19	3.05	11.05	6.10	79.62	0.00
MF6C1R1B	0.00	2.48	8.38	4.57	83.05	1.52
MF6C1R2A	0.19	3.43	11.62	6.86	77.90	0.00
MF6C1R2B	0.00	2.67	7.62	4.38	83.81	1.52
MF6C1R3A	0.19	3.81	12.76	8.00	75.24	0.00
MF6C1R3B	0.19	3.24	6.67	5.33	82.86	1.71
MF6C1R5A	0.76	4.38	19.43	12.00	63.43	0.00
MF6C1R5B	0.38	3.62	11.62	5.33	77.33	1.71
MF5C2R1.	0.00	1.71	9.33	6.48	82.48	0.00
MF5C2R2.	0.19	2.10	10.67	6.67	80.38	0.00
MF5C2R3.	0.19	2.29	12.19	9.33	76.00	0.00
MF5C2R4.	0.00	2.10	10.67	7.43	79.81	0.00
MF5C2R5.	0.19	2.67	13.14	84.00	0.00	0.00
MF5C2R6.	0.38	3.62	20.76	13.90	61.33	0.00
MF6C2R1.	0.38	3.05	11.81	6.48	78.29	0.00
MF6C2R2.	0.57	4.00	16.19	8.95	70.29	0.00
MF6C2R3.	0.76	4.95	18.67	9.52	66.10	0.00
MF6C2R4.	0.57	3.24	14.48	8.95	72.76	0.00
MF6C2R6.	0.76	5.33	20.95	11.81	61.14	0.00
MF5C3R1.	0.00	1.71	9.90	6.10	82.29	0.00
MF5C3R2.	0.19	2.10	10.67	7.24	79.81	0.00
MF5C3R3.	0.19	2.29	12.19	9.52	75.81	0.00
MF5C3R4.	0.19	2.67	13.14	84.00	0.00	0.00
MF5C3R5.	0.38	3.62	21.52	13.14	61.33	0.00
MF6C3R1.	0.57	2.86	11.62	7.05	77.90	0.00
MF6C3R2.	0.57	3.43	11.81	8.19	76.00	0.00
MF6C3R3.	0.76	3.81	13.14	8.57	73.71	0.00
MF6C3R5.	0.95	5.14	20.76	12.95	60.19	0.00

SOUTH SASKATCHEWAN RIVER BELOW SASKATOON

APRIL - OCTOBER
PERCENT OF TIME IN EACH FLOW ZONE (m^3/s)

	GREATER 1000.0	1000.0 400.0	400.0 150.0	150.0 60.0	60.0 42.5	LESS THAN 42.5
MF5C4R1A	0.00	2.29	9.71	4.57	83.43	0.00
MF5C4R2A	0.19	2.67	13.14	8.95	75.05	0.00
MF5C4R2B	0.19	2.67	10.86	86.29	0.00	0.00
MF5C4R2C	0.19	2.67	8.76	85.52	1.14	1.71
MF5C4R3A	0.19	2.86	16.38	10.67	69.90	0.00
MF5C4R3B	0.19	2.86	14.86	82.10	0.00	0.00
MF5C4R3C	0.19	2.86	11.05	83.43	0.95	1.52
MF5C4R4A	0.38	4.57	22.86	12.57	59.62	0.00
MF5C4R4B	0.38	4.38	20.95	74.29	0.00	0.00
MF5C4R4C	0.38	4.38	16.38	76.95	0.57	1.33
MF5C4R5A	0.38	4.76	28.00	18.29	48.57	0.00
MF5C4R5B	0.38	4.76	26.67	68.19	0.00	0.00
MF5C4R5C	0.38	4.57	21.90	71.43	0.57	1.14
MF6C4R1A	0.57	3.43	12.38	8.00	75.62	0.00
MF6C4R2A	0.57	4.19	16.95	8.57	69.71	0.00
MF6C4R2B	0.57	4.19	15.43	79.81	0.00	0.00
MF6C4R2C	0.57	4.19	12.19	82.29	0.38	0.38
MF6C4R3A	0.76	4.95	20.19	8.57	65.52	0.00
MF6C4R3B	0.76	4.95	18.29	76.00	0.00	0.00
MF6C4R3C	0.76	4.76	14.48	79.43	0.19	0.38
MF6C4R4A	0.95	6.10	24.76	16.95	51.24	0.00
MF6C4R4B	0.95	6.10	23.24	69.71	0.00	0.00
MF6C4R4C	0.95	6.10	17.71	75.24	0.00	0.00
MF6C4R5A	0.95	6.29	31.05	21.71	40.00	0.00
MF6C4R5B	0.95	6.29	30.10	62.67	0.00	0.00
MF6C4R5C	0.95	6.29	23.81	68.95	0.00	0.00
MF5C5R2.	0.19	2.67	13.14	8.95	75.05	0.00
MF5C5R3.	0.19	2.86	16.38	10.67	69.90	0.00
MF5C5R4.	0.38	4.57	22.86	12.57	59.62	0.00
MF6C5R2.	0.57	4.19	16.95	8.57	69.71	0.00
MF6C5R3.	0.76	4.95	20.19	8.57	65.52	0.00
MF6C5R4.	0.95	6.10	24.76	16.95	51.24	0.00
MF5C6R1.	0.00	2.29	10.10	87.62	0.00	0.00
MF5C6R2.	0.19	2.67	10.86	86.29	0.00	0.00
MF5C6R3.	0.19	2.86	14.86	82.10	0.00	0.00
MF6C6R1.	0.57	3.43	13.90	82.10	0.00	0.00
MF6C6R2.	0.57	4.19	15.43	79.81	0.00	0.00
MF6C6R3.	0.76	4.95	18.29	76.00	0.00	0.00

SOUTH SASKATCHEWAN RIVER BELOW SASKATOON

NOVEMBER - MARCH
PERCENT OF TIME IN EACH FLOW ZONE (m^3/s)

	GREATER 400.0	400.0 42.5	LESS THAN 42.5
M86BASE.	0.00	100.00	0.00
M70BASE.	0.27	99.73	0.00
M67BASE.	0.27	99.73	0.00
MF5BASE.	0.00	100.00	0.00
MF6BASE.	0.27	99.73	0.00
MF5C1R1A	0.00	100.00	0.00
MF5C1R1B	0.00	99.47	0.53
MF5C1R2A	0.00	100.00	0.00
MF5C1R2B	0.00	99.47	0.53
MF5C1R3A	0.00	100.00	0.00
MF5C1R3B	0.00	99.47	0.53
MF5C1R4A	0.00	100.00	0.00
MF5C1R5A	0.00	100.00	0.00
MF5C1R5B	0.00	99.47	0.53
MF6C1R1A	0.27	99.73	0.00
MF6C1R1B	0.27	99.47	0.27
MF6C1R2A	0.27	99.73	0.00
MF6C1R2B	0.27	99.47	0.27
MF6C1R3A	0.53	99.47	0.00
MF6C1R3B	0.53	99.20	0.27
MF6C1R5A	0.00	100.00	0.00
MF6C1R5B	0.00	99.73	0.27
MF5C2R1.	0.00	100.00	0.00
MF5C2R2.	0.00	100.00	0.00
MF5C2R3.	0.00	100.00	0.00
MF5C2R4.	0.00	100.00	0.00
MF5C2R5.	0.00	100.00	0.00
MF5C2R6.	0.00	100.00	0.00
MF6C2R1.	0.27	99.73	0.00
MF6C2R2.	0.27	99.73	0.00
MF6C2R3.	0.53	99.47	0.00
MF6C2R4.	0.27	99.73	0.00
MF6C2R6.	0.00	100.00	0.00
MF5C3R1.	0.00	100.00	0.00
MF5C3R2.	0.00	100.00	0.00
MF5C3R3.	0.00	100.00	0.00
MF5C3R4.	0.00	100.00	0.00
MF5C3R5.	0.00	100.00	0.00
MF6C3R1.	0.27	99.73	0.00
MF6C3R2.	0.27	99.73	0.00
MF6C3R3.	0.27	99.73	0.00
MF6C3R5.	0.00	100.00	0.00

SOUTH SASKATCHEWAN RIVER BELOW SASKATOON

NOVEMBER - MARCH
PERCENT OF TIME IN EACH FLOW ZONE (m^3/s)

	GREATER 400.0	400.0 42.5	LESS THAN 42.5
MF5C4R1A	0.00	100.00	0.00
MF5C4R2A	0.00	100.00	0.00
MF5C4R2B	0.00	100.00	0.00
MF5C4R2C	0.00	100.00	0.00
MF5C4R3A	0.00	100.00	0.00
MF5C4R3B	0.00	100.00	0.00
MF5C4R3C	0.00	100.00	0.00
MF5C4R4A	0.00	100.00	0.00
MF5C4R4B	0.00	100.00	0.00
MF5C4R4C	0.00	100.00	0.00
MF5C4R5A	0.00	100.00	0.00
MF5C4R5B	0.00	100.00	0.00
MF5C4R5C	0.00	100.00	0.00
MF6C4R1A	0.27	99.73	0.00
MF6C4R2A	0.27	99.73	0.00
MF6C4R2B	0.27	99.73	0.00
MF6C4R2C	0.27	99.73	0.00
MF6C4R3A	0.53	99.47	0.00
MF6C4R3B	0.53	99.47	0.00
MF6C4R3C	0.53	99.47	0.00
MF6C4R4A	0.27	99.73	0.00
MF6C4R4B	0.27	99.73	0.00
MF6C4R4C	0.27	99.73	0.00
MF6C4R5A	0.00	100.00	0.00
MF6C4R5B	0.00	100.00	0.00
MF6C4R5C	0.00	100.00	0.00
MF5C5R2.	0.00	100.00	0.00
MF5C5R3.	0.00	100.00	0.00
MF5C5R4.	0.00	100.00	0.00
MF6C5R2.	0.27	99.73	0.00
MF6C5R3.	0.53	99.47	0.00
MF6C5R4.	0.27	99.73	0.00
MF5C6R1.	0.00	100.00	0.00
MF5C6R2.	0.00	100.00	0.00
MF5C6R3.	0.00	100.00	0.00
MF6C6R1.	0.27	99.73	0.00
MF6C6R2.	0.27	99.73	0.00
MF6C6R3.	0.53	99.47	0.00

SOUTH SASKATCHEWAN RIVER BELOW ST. LOUIS

PERCENTAGE OF ALBERTA INFLOW

	HIGHEST	UPPER QUARTILE	MEDIAN QUARTILE	LOWER	LOWEST
M86BASE.	120	96	94	91	72
M70BASE.	121	96	92	88	68
M67BASE.	110	93	87	82	61
MF5BASE.	124	93	87	80	47
MF6BASE.	111	94	87	82	55
MF5C1R1A	115	86	77	63	33
MF5C1R1B	98	76	65	47	26
MF5C1R2A	109	84	76	62	33
MF5C1R2B	90	70	59	45	26
MF5C1R3A	105	81	73	62	33
MF5C1R3B	86	68	58	44	26
MF5C1R4A	127	92	85	77	40
MF5C1R5A	81	59	52	47	21
MF5C1R5B	74	46	40	34	19
MF6C1R1A	100	80	73	64	29
MF6C1R1B	100	71	53	42	25
MF6C1R2A	96	79	71	65	29
MF6C1R2B	95	67	52	41	24
MF6C1R3A	91	78	69	62	29
MF6C1R3B	89	65	49	37	24
MF6C1R5A	85	64	55	49	24
MF6C1R5B	78	51	43	34	19
MF5C2R1.	109	80	74	67	37
MF5C2R2.	105	79	73	67	37
MF5C2R3.	102	80	71	66	34
MF5C2R4.	128	92	85	78	43
MF5C2R5.	131	92	86	79	41
MF5C2R6.	84	68	62	56	26
MF6C2R1.	118	91	85	78	42
MF6C2R2.	110	92	86	80	56
MF6C2R3.	109	92	86	80	57
MF6C2R4.	108	93	88	81	49
MF6C2R6.	92	79	70	64	30
MF5C3R1.	109	83	75	63	33
MF5C3R2.	103	82	72	62	33
MF5C3R3.	101	79	71	62	29
MF5C3R4.	127	92	85	77	40
MF5C3R5.	80	57	50	43	19
MF6C3R1.	95	79	69	64	29
MF6C3R2.	92	77	68	60	29
MF6C3R3.	90	76	66	57	29
MF6C3R5.	84	63	52	45	19

SOUTH SASKATCHEWAN RIVER BELOW ST. LOUIS

PERCENTAGE OF ALBERTA INFLOW

	HIGHEST	UPPER QUARTILE	MEDIAN	LOWER QUARTILE	LOWEST
MF5C4R1A	131	93	87	80	45
MF5C4R2A	118	92	87	81	47
MF5C4R2B	133	93	86	79	45
MF5C4R2C	155	96	89	78	45
MF5C4R3A	110	91	86	81	48
MF5C4R3B	125	93	86	80	47
MF5C4R3C	147	95	89	80	45
MF5C4R4A	104	89	83	78	59
MF5C4R4B	106	90	85	79	55
MF5C4R4C	131	94	87	80	45
MF5C4R5A	104	89	84	76	62
MF5C4R5B	104	90	84	78	55
MF5C4R5C	119	93	88	81	45
MF6C4R1A	116	93	89	82	52
MF6C4R2A	111	93	87	81	58
MF6C4R2B	113	95	89	82	49
MF6C4R2C	135	96	90	83	51
MF6C4R3A	111	92	86	81	58
MF6C4R3B	113	93	86	82	53
MF6C4R3C	158	112	104	91	54
MF6C4R4A	135	106	95	87	72
MF6C4R4B	135	107	98	88	72
MF6C4R4C	147	111	104	87	50
MF6C4R5A	135	106	95	88	64
MF6C4R5B	135	106	95	87	74
MF6C4R5C	135	108	100	90	52
MF5C5R2.	118	92	87	81	47
MF5C5R3.	110	91	86	81	48
MF5C5R4.	104	89	83	78	59
MF6C5R2.	111	93	87	81	58
MF6C5R3.	111	92	86	81	58
MF6C5R4.	103	91	85	80	64
MF5C6R1.	133	93	87	79	45
MF5C6R2.	133	93	86	79	45
MF5C6R3.	125	93	86	80	47
MF6C6R1.	116	95	89	83	49
MF6C6R2.	113	95	89	82	49
MF6C6R3.	113	93	86	82	53

COTEAU CREEK POWER STATION

POWER PRODUCTION (MW.HR)

	FIRM POWER PRODUCTION			MEAN POWER PRODUCTION		
	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL	NOV. to	APR. to MAR.	TOTAL ANNUAL OCT.
M86BASE.	183063	79773	262836	691207	396399	1087606
M70BASE.	158822	77033	235855	635962	347265	983227
M67BASE.	100013	78881	178894	507280	329022	836302
MF5BASE.	84740	69370	154110	431938	240746	672684
MF6BASE.	86125	66371	152496	479724	269505	749229
MF5C1R1A	81457	64849	146306	379450	221646	601096
MF5C1R1B	74751	52227	126978	311405	194311	505716
MF5C1R2A	82019	68036	150055	369267	232590	601857
MF5C1R2B	74795	53307	128102	291978	197068	489046
MF5C1R3A	82134	69687	151821	356610	242752	599362
MF5C1R3B	74789	54773	129562	278605	202074	480679
MF5C1R4A	113383	100328	213711	406651	313786	720437
MF5C1R5A	83436	79097	162533	282870	313296	596166
MF5C1R5B	74406	44852	119258	228170	220052	448222
MF6C1R1A	80593	63684	144277	397604	241868	639472
MF6C1R1B	76651	57594	134245	317079	213731	530810
MF6C1R2A	82155	61829	143984	388432	246158	634590
MF6C1R2B	76336	57988	134324	301706	214564	516270
MF6C1R3A	82191	65421	147612	373530	259369	632899
MF6C1R3B	76667	58046	134713	285254	216348	501602
MF6C1R5A	82755	73606	156361	299985	325496	625481
MF6C1R5B	77105	55402	132507	242263	246265	488528
MF5C2R1.	107057	108022	215079	422968	307628	730596
MF5C2R2.	109523	113728	223251	415644	325955	741599
MF5C2R3.	113085	118011	231096	406023	345155	751178
MF5C2R4.	93139	82362	175501	430083	262251	692334
MF5C2R5.	115897	106649	222546	412869	329751	742620
MF5C2R6.	120478	131213	251691	341202	432634	773836
MF6C2R1.	122486	126759	249245	469071	372160	841231
MF6C2R2.	92237	74510	166747	470987	293422	764409
MF6C2R3.	94278	75772	170050	458072	309625	767697
MF6C2R4.	93897	79403	173300	477886	290638	768524
MF6C2R6.	134224	155166	289390	383761	497724	881485
MF5C3R1.	78269	68978	147247	363698	229858	593556
MF5C3R2.	81531	70034	151565	352877	240010	592887
MF5C3R3.	79317	69212	148529	334686	250852	585538
MF5C3R4.	111396	98598	209994	402320	314169	716489
MF5C3R5.	81730	74623	156353	255761	319264	575025
MF6C3R1.	74536	64429	138965	372571	249319	621890
MF6C3R2.	81465	64990	146455	363725	259843	623568
MF6C3R3.	79744	66072	145816	342841	271667	614508
MF6C3R5.	80608	72057	152665	262490	338161	600651

COTEAU CREEK POWER STATION

POWER PRODUCTION (MW.HR)

	FIRM POWER PRODUCTION			MEAN POWER PRODUCTION		
	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL
MF5C4R1A	80430	67927	148357	439091	223175	662266
MF5C4R2A	86371	70038	156409	425178	252712	677890
MF5C4R2B	90114	106493	196607	404615	311240	715855
MF5C4R2C	78565	81859	160424	339005	337192	676197
MF5C4R3A	88511	71433	159944	412714	270347	683061
MF5C4R3B	92053	103217	195270	394110	322704	716814
MF5C4R3C	78877	105774	184651	330044	372884	702928
MF5C4R4A	91850	77535	169385	370414	323117	693531
MF5C4R4B	95810	113966	209776	355742	376897	732639
MF5C4R4C	79608	107668	187276	298029	408840	706869
MF5C4R5A	92991	85487	178478	334361	369384	703745
MF5C4R5B	97220	116380	213600	323551	413404	736955
MF5C4R5C	80331	108463	188794	273633	436008	709641
MF6C4R1A	84739	69128	153867	491228	256225	747453
MF6C4R2A	87770	67317	155087	471145	281811	752956
MF6C4R2B	88605	104869	193474	448790	340591	789381
MF6C4R2C	80736	127778	208514	386924	412717	799641
MF6C4R3A	89425	68033	157458	457628	297703	755331
MF6C4R3B	93760	101473	195233	440429	351267	791696
MF6C4R3C	81696	143203	224899	374914	441827	816741
MF6C4R4A	93027	77238	170265	410549	355236	765785
MF6C4R4B	97478	110798	208276	398953	404090	803043
MF6C4R4C	98263	184887	283150	357143	516878	874021
MF6C4R5A	94550	84798	179348	369749	405847	775596
MF6C4R5B	98963	117073	216036	361818	448484	810302
MF6C4R5C	100233	187481	287714	330564	547704	878268
MF5C5R2.	86371	70038	156409	425178	252712	677890
MF5C5R3.	88511	71433	159944	412714	270347	683061
MF5C5R4.	91850	77535	169385	370414	323117	693531
MF6C5R2.	87770	67317	155087	471145	281811	752956
MF6C5R3.	89425	68033	157458	457628	297703	755331
MF6C5R4.	93027	77238	170265	410549	355236	765785
MF5C6R1.	87480	106252	193732	409849	300003	709852
MF5C6R2.	90114	106493	196607	404615	311240	715855
MF5C6R3.	92053	103217	195270	394110	322704	716814
MF6C6R1.	87989	103305	191294	458308	327432	785740
MF6C6R2.	88605	104869	193474	448790	340591	789381
MF6C6R3.	93760	101473	195233	440429	351267	791696

DUNDURN POWER STATION

POWER PRODUCTION (MW.HR)

	FIRM POWER PRODUCTION			MEAN POWER PRODUCTION		
	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL
M67C4R1.	35931	31357	67288	167495	109093	276588
M67C9R1.	35800	32428	68228	160355	114404	274759
MF5BASE.	31771	28212	59983	144730	83171	227901
MF6BASE.	32054	28191	60245	158039	92058	250097
MF5C1R1A	31402	27763	59165	128801	78920	207721
MF5C1R1B	29282	22203	51485	107566	69648	177214
MF5C1R2A	31402	28268	59670	126189	80911	207100
MF5C1R2B	29220	22203	51423	101686	69661	171347
MF5C1R3A	31455	28158	59613	121687	82921	204608
MF5C1R3B	29238	22201	51439	97211	70136	167347
MF5C1R4A	42981	40185	83166	139495	107902	247397
MF5C1R5A	31573	29870	61443	96274	101564	197838
MF5C1R5B	29238	16490	45728	80329	72014	152343
MF6C1R1A	31272	27873	59145	133599	85041	218640
MF6C1R1B	30063	24097	54160	108242	75968	184210
MF6C1R2A	31353	28280	59633	131397	86455	217852
MF6C1R2B	30131	24097	54228	104231	75424	179655
MF6C1R3A	31429	28216	59645	126553	88666	215219
MF6C1R3B	30093	23365	53458	99109	74603	173712
MF6C1R5A	31573	29220	60793	101619	105366	206985
MF6C1R5B	30087	23346	53433	84625	83411	168036
MF5C2R1.	41093	42408	83501	144629	107860	252489
MF5C2R2.	41974	43593	85567	143099	112027	255126
MF5C2R3.	42840	44785	87625	139244	117123	256367
MF5C2R4.	34812	32776	67588	144696	90885	235581
MF5C2R5.	44885	42947	87832	142648	113773	256421
MF5C2R6.	45708	49604	95312	117524	142389	259913
MF6C2R1.	46979	51107	98086	159296	130427	289723
MF6C2R2.	33760	30573	64333	156743	98325	255068
MF6C2R3.	33866	30639	64505	151778	102177	253955
MF6C2R4.	34963	32741	67704	158076	99507	257583
MF6C2R6.	51395	57886	109281	132039	161454	293493
MF5C3R1.	31297	28255	59552	125692	80382	206074
MF5C3R2.	31279	28178	59457	121245	82259	203504
MF5C3R3.	31303	28142	59445	115500	85334	200834
MF5C3R4.	42978	40178	83156	138782	108507	247289
MF5C3R5.	31456	29222	60678	88292	103914	192206
MF6C3R1.	31226	28273	59499	129248	86948	216196
MF6C3R2.	31282	28181	59463	124454	89048	213502
MF6C3R3.	31349	28160	59509	117879	91668	209547
MF6C3R5.	31473	29355	60828	90650	109102	199752

DUNDURN POWER STATION

POWER PRODUCTION (MW.HR)

	FIRM POWER PRODUCTION			MEAN POWER PRODUCTION		
	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL
MF5C4R1A	31602	28296	59898	148360	78548	226908
MF5C4R2A	31771	28135	59906	142863	85691	228554
MF5C4R2B	33743	40679	74422	137210	106199	243409
MF5C4R2C	30581	30212	60793	117125	114698	231823
MF5C4R3A	32022	28100	60122	137894	90076	227970
MF5C4R3B	33958	40140	74098	132937	109427	242364
MF5C4R3C	30639	40410	71049	113922	127492	241414
MF5C4R4A	32057	28814	60871	121989	103378	225367
MF5C4R4B	33935	40770	74705	118097	121449	239546
MF5C4R4C	30639	41283	71922	102309	136339	238648
MF5C4R5A	32012	30170	62182	109592	116339	225931
MF5C4R5B	33822	41825	75647	106759	133004	239763
MF5C4R5C	30747	41479	72226	93908	144126	238034
MF6C4R1A	31720	28223	59943	161449	87372	248821
MF6C4R2A	32054	28152	60206	156465	94350	250815
MF6C4R2B	34006	40629	74635	151164	114524	265688
MF6C4R2C	31279	49188	80467	131685	141255	272940
MF6C4R3A	32113	28069	60182	151338	98129	249467
MF6C4R3B	34006	40016	74022	146585	117226	263811
MF6C4R3C	31344	54223	85567	127372	149136	276508
MF6C4R4A	32167	29504	61671	134102	112607	246709
MF6C4R4B	34119	41101	75220	131035	129918	260953
MF6C4R4C	37968	67868	105836	121952	170468	292420
MF6C4R5A	32177	30548	62725	120103	126190	246293
MF6C4R5B	34075	42418	76493	118154	142411	260565
MF6C4R5C	38049	68115	106164	112354	178353	290707
MF5C5R2.	31771	28135	59906	142863	85691	228554
MF5C5R3.	32022	28100	60122	137894	90076	227970
MF5C5R4.	32057	28814	60871	121989	103378	225367
MF6C5R2.	32054	28152	60206	156465	94350	250815
MF6C5R3.	32113	28069	60182	151338	98129	249467
MF6C5R4.	32167	29504	61671	134102	112607	246709
MF5C6R1.	33514	40791	74305	138761	104109	242870
MF5C6R2.	33743	40679	74422	137210	106199	243409
MF5C6R3.	33958	40140	74098	132937	109427	242364
MF6C6R1.	33700	40732	74432	152689	112396	265085
MF6C6R2.	34006	40629	74635	151164	114524	265688
MF6C6R3.	34006	40016	74022	146585	117226	263811

ST. LOUIS POWER STATION

POWER PRODUCTION (MW.HR)

	FIRM POWER PRODUCTION			MEAN POWER PRODUCTION		
	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL
M67C4R1.	75547	58093	133640	367583	241068	608651
M67C9R1.	75259	59646	134905	351373	255536	606909
MF5BASE.	66583	53692	120275	321269	174564	495833
MF6BASE.	67787	55224	123011	356162	201729	557891
MF5C1R1A	66276	50334	116610	286018	161764	447782
MF5C1R1B	62984	39020	102004	239444	141920	381364
MF5C1R2A	66276	53426	119702	275831	169558	445389
MF5C1R2B	62610	39020	101630	223328	142285	365613
MF5C1R3A	66276	55279	121555	264512	177036	441548
MF5C1R3B	62610	39020	101630	212236	144211	356447
MF5C1R4A	92088	80130	172218	304170	231823	535993
MF5C1R5A	65994	57465	123459	206862	219712	426574
MF5C1R5B	62610	31045	93655	174126	154750	328876
MF6C1R1A	66276	53443	119719	300455	182558	483013
MF6C1R1B	64583	43091	107674	243880	158207	402087
MF6C1R2A	66463	54983	121446	290432	187595	478027
MF6C1R2B	64583	43091	107674	231558	157454	389012
MF6C1R3A	66276	54983	121259	277481	194069	471550
MF6C1R3B	63978	41609	105587	217924	157396	375320
MF6C1R5A	66276	57282	123558	220092	236327	456419
MF6C1R5B	63926	41567	105493	184190	179352	363542
MF5C2R1.	81720	75493	157213	308842	210642	519484
MF5C2R2.	83097	78562	161659	300040	221157	521197
MF5C2R3.	84474	80431	164905	289177	231968	521145
MF5C2R4.	71262	60703	131965	316786	185665	502451
MF5C2R5.	95108	84207	179315	308728	241191	549919
MF5C2R6.	88005	87631	175636	235582	287799	523381
MF6C2R1.	91077	88821	179898	337518	255445	592963
MF6C2R2.	70564	59530	130094	344234	215675	559909
MF6C2R3.	70951	59767	130718	331240	226518	557758
MF6C2R4.	71743	62236	133979	351514	212283	563797
MF6C2R6.	97074	100584	197658	261637	330401	592038
MF5C3R1.	66276	53451	119727	276572	167654	444226
MF5C3R2.	66276	55279	121555	264049	175269	439318
MF5C3R3.	66276	55274	121550	250634	183081	433715
MF5C3R4.	92088	79881	171969	302456	232950	535406
MF5C3R5.	65274	57465	122739	188372	228309	416681
MF6C3R1.	66276	54420	120696	286158	188269	474427
MF6C3R2.	66463	55520	121983	272612	195893	468505
MF6C3R3.	66325	55520	121845	256758	203609	460367
MF6C3R5.	65679	57465	123144	194492	248104	442596

ST. LOUIS POWER STATION

POWER PRODUCTION (MW.HR)

	FIRM POWER PRODUCTION			MEAN POWER PRODUCTION		
	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL
MF5C4R1A	66583	52964	119547	332620	163140	495760
MF5C4R2A	66707	55545	122252	312379	183802	496181
MF5C4R2B	70740	80733	151473	299531	226230	525761
MF5C4R2C	64909	59434	124343	256646	246885	503531
MF5C4R3A	66708	55787	122495	299446	194760	494206
MF5C4R3B	70740	80975	151715	288259	235787	524046
MF5C4R3C	64909	80191	145100	248137	274431	522568
MF5C4R4A	67277	57444	124721	263814	229221	493035
MF5C4R4B	71007	82344	153351	254887	267242	522129
MF5C4R4C	64909	81380	146289	221567	297562	519129
MF5C4R5A	67200	58929	126129	236313	257305	493618
MF5C4R5B	71313	83217	154530	230283	291762	522045
MF5C4R5C	64637	81663	146300	202365	314851	517216
MF6C4R1A	67787	53372	121159	368874	188880	557754
MF6C4R2A	67940	55779	123719	345817	210035	555852
MF6C4R2B	71220	81250	152470	333077	251750	584827
MF6C4R2C	66632	96289	162921	291396	306419	597815
MF6C4R3A	68163	55780	123943	332565	220925	553490
MF6C4R3B	71371	81251	152622	320965	261457	582422
MF6C4R3C	66632	109935	176567	279866	328626	608492
MF6C4R4A	67880	57727	125607	292103	257642	549745
MF6C4R4B	71982	82854	154836	285264	293773	579037
MF6C4R4C	80627	139415	220042	265518	380064	645582
MF6C4R5A	67308	59193	126501	260269	288552	548821
MF6C4R5B	71514	84070	155584	256122	320922	577044
MF6C4R5C	80627	140839	221466	243814	400076	643890
MF5C5R2.	66707	55545	122252	312379	183802	496181
MF5C5R3.	66708	55787	122495	299446	194760	494206
MF5C5R4.	67277	57444	124721	263814	229221	493035
MF6C5R2.	67940	55779	123719	345817	210035	555852
MF6C5R3.	68163	55780	123943	332565	220925	553490
MF6C5R4.	67880	57727	125607	292103	257642	549745
MF5C6R1.	70716	79387	150103	307937	218249	526186
MF5C6R2.	70740	80733	151473	299531	226230	525761
MF5C6R3.	70740	80975	151715	288259	235787	524046
MF6C6R1.	71220	80682	151902	343328	243520	586848
MF6C6R2.	71220	81250	152470	333077	251750	584827
MF6C6R3.	71371	81251	152622	320965	261457	582422

FORKS POWER STATION

POWER PRODUCTION (MW.HR)

	FIRM POWER PRODUCTION			MEAN POWER PRODUCTION		
	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL
M67BASE.	330187	365299	695486	1033788	1324765	2358553
MF5BASE.	305471	343678	649149	952432	1223994	2176426
MF6BASE.	310444	347904	658348	1005236	1259421	2264657
MF5C1R1A	298113	343678	641791	895568	1212808	2108376
MF5C1R1B	291044	343678	634722	827229	1202445	2029674
MF5C1R2A	300921	343397	644318	883956	1216310	2100266
MF5C1R2B	291044	343397	634441	804925	1200979	2005904
MF5C1R3A	304141	341387	645528	871101	1219747	2090848
MF5C1R3B	291044	340795	631839	789207	1199941	1989148
MF5C1R4A	338200	371930	710130	924664	1290195	2214859
MF5C1R5A	303410	347833	651243	788864	1279135	2067999
MF5C1R5B	297335	347005	644340	741407	1229682	1971089
MF6C1R1A	300921	348212	649133	918887	1237987	2156874
MF6C1R1B	291044	348212	639256	831251	1221243	2052494
MF6C1R2A	304141	348212	652353	907626	1241379	2149005
MF6C1R2B	291044	348212	639256	813783	1219404	2033187
MF6C1R3A	304141	348212	652353	889523	1248597	2138120
MF6C1R3B	291044	348212	639256	795349	1220329	2015678
MF6C1R5A	301985	347789	649774	805795	1297299	2103094
MF6C1R5B	297335	347945	645280	753817	1248753	2002570
MF5C2R1.	322758	369582	692340	930591	1269872	2200463
MF5C2R2.	323013	371608	694621	916432	1279438	2195870
MF5C2R3.	327344	371905	699249	903366	1289824	2193190
MF5C2R4.	309581	351850	661431	943532	1237906	2181438
MF5C2R5.	342210	377009	719219	930839	1302394	2233233
MF5C2R6.	338175	392576	730751	833013	1373385	2206398
MF6C2R1.	336000	397962	733962	971262	1337541	2308803
MF6C2R2.	315425	353263	668688	989338	1276203	2265541
MF6C2R3.	319142	353349	672491	974034	1287661	2261695
MF6C2R4.	317372	357756	675128	999949	1274203	2274152
MF6C2R6.	350019	410675	760694	868938	1426211	2295149
MF5C3R1.	300921	337536	638457	884988	1209551	2094539
MF5C3R2.	298175	336599	634774	864507	1213863	2078370
MF5C3R3.	301447	334152	635599	848690	1219953	2068643
MF5C3R4.	337933	370743	708676	921959	1290791	2212750
MF5C3R5.	307232	347789	655021	767520	1289459	2056979
MF6C3R1.	304141	348212	652353	901768	1243046	2144814
MF6C3R2.	301269	348212	649481	879441	1250854	2130295
MF6C3R3.	302623	348155	650778	858454	1259088	2117542
MF6C3R5.	305669	348272	653941	774016	1310873	2084889

FORKS POWER STATION

POWER PRODUCTION (MW.HR)

	FIRM POWER PRODUCTION			MEAN POWER PRODUCTION		
	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL
MF5C4R1A	305471	326549	632020	968527	1192613	2161140
MF5C4R2A	308691	343397	652088	942866	1231041	2173907
MF5C4R2B	310034	373940	683974	920237	1285446	2205683
MF5C4R2C	302178	393530	695708	859763	1363208	2222971
MF5C4R3A	309512	341387	650899	925292	1241867	2167159
MF5C4R3B	312039	371930	683969	906225	1294184	2200409
MF5C4R3C	308456	406959	715415	853970	1383483	2237453
MF5C4R4A	315317	335842	651159	879488	1276045	2155533
MF5C4R4B	320633	366426	687059	866921	1324762	2191683
MF5C4R4C	308456	406884	715340	816209	1409289	2225498
MF5C4R5A	313447	359057	672504	838669	1335708	2174377
MF5C4R5B	314325	387704	702029	825221	1377763	2202984
MF5C4R5C	309679	428033	737712	790567	1453439	2244006
MF6C4R1A	310444	341734	652178	1023264	1238285	2261549
MF6C4R2A	315208	347991	663199	995089	1268250	2263339
MF6C4R2B	315267	384537	699804	972415	1327153	2299568
MF6C4R2C	316651	451907	768558	921138	1449695	2370833
MF6C4R3A	317800	347733	665533	978526	1279731	2258257
MF6C4R3B	319579	384371	703950	959311	1337127	2296438
MF6C4R3C	316651	452003	768654	904798	1458741	2363539
MF6C4R4A	318056	357480	675536	921513	1330859	2252372
MF6C4R4B	324223	390527	714750	912216	1379103	2291319
MF6C4R4C	325326	464239	789565	873158	1494274	2367432
MF6C4R5A	316118	362652	678770	875164	1376990	2252154
MF6C4R5B	320966	395026	715992	868216	1419326	2287542
MF6C4R5C	322411	467463	789874	839400	1522839	2362239
MF5C5R2.	308691	343397	652088	942866	1231041	2173907
MF5C5R3.	309512	341387	650899	925292	1241867	2167159
MF5C5R4.	315317	335842	651159	879488	1276045	2155533
MF6C5R2.	315208	347991	663199	995089	1268250	2263339
MF6C5R3.	317800	347733	665533	978526	1279731	2258257
MF6C5R4.	318056	357480	675536	921513	1330859	2252372
MF5C6R1.	307524	374221	681745	929667	1279106	2208773
MF5C6R2.	310034	373940	683974	920237	1285446	2205683
MF5C6R3.	312039	371930	683969	906225	1294184	2200409
MF6C6R1.	315267	384436	699703	986957	1318227	2305184
MF6C6R2.	315267	384537	699804	972415	1327153	2299568
MF6C6R3.	319579	384371	703950	959311	1337127	2296438

NIPAWIN POWER STATION

POWER PRODUCTION (MW.HR)

	FIRM POWER PRODUCTION			MEAN POWER PRODUCTION		
	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL
M86BASE.	273513	236414	509927	793126	880238	1673364
M70BASE.	255396	236660	492056	754683	852001	1606684
M67BASE.	211063	236506	447569	661870	836622	1498492
MF5BASE.	195050	221365	416415	609391	778524	1387915
MF6BASE.	198999	225696	424695	644109	800154	1444263
MF5C1R1A	190386	221365	411751	572924	771714	1344638
MF5C1R1B	185703	221365	407068	528888	765238	1294126
MF5C1R2A	192490	221157	413647	565760	773674	1339434
MF5C1R2B	185703	221157	406860	514573	764259	1278832
MF5C1R3A	194680	219876	414556	557553	775653	1333206
MF5C1R3B	185703	219502	405205	504445	763612	1268057
MF5C1R4A	216444	239382	455826	591819	818481	1410300
MF5C1R5A	194018	225577	419595	504519	812227	1316746
MF5C1R5B	190015	225024	415039	474002	783848	1257850
MF6C1R1A	192490	225778	418268	588220	788565	1376785
MF6C1R1B	185703	225778	411481	531513	778679	1310192
MF6C1R2A	194680	225778	420458	581100	789653	1370753
MF6C1R2B	185703	225778	411481	520295	777281	1297576
MF6C1R3A	194680	225778	420458	569399	792970	1362369
MF6C1R3B	185703	225778	411481	508425	777563	1285988
MF6C1R5A	193127	225534	418661	515388	821551	1336939
MF6C1R5B	190015	225655	415670	481967	793271	1275238
MF5C2R1.	206413	237907	444320	595603	807968	1403571
MF5C2R2.	206642	239170	445812	586568	813129	1399697
MF5C2R3.	209512	239364	448876	578190	819020	1397210
MF5C2R4.	197973	226584	424557	603951	787489	1391440
MF5C2R5.	218806	242627	461433	595569	825941	1421510
MF5C2R6.	215606	254148	469754	532125	870503	1402628
MF6C2R1.	214859	257570	472429	621681	850750	1472431
MF6C2R2.	202547	229089	431636	634229	808664	1442893
MF6C2R3.	204264	229186	433450	623621	815236	1438857
MF6C2R4.	203229	231987	435216	640482	809800	1450282
MF6C2R6.	223553	265684	489237	555503	901974	1457477
MF5C3R1.	192490	217432	409922	566408	769610	1336018
MF5C3R2.	190662	216801	407463	553180	771512	1324692
MF5C3R3.	192795	215239	408034	542988	774738	1317726
MF5C3R4.	216076	238621	454697	589882	818569	1408451
MF5C3R5.	195735	225534	421269	490126	817223	1307349
MF6C3R1.	194680	225778	420458	577312	790713	1368025
MF6C3R2.	192753	225778	418531	562874	793576	1356450
MF6C3R3.	193690	225753	419443	549394	797583	1346977
MF6C3R5.	195227	225823	421050	494776	829046	1323822

NIPAWIN POWER STATION

POWER PRODUCTION (MW.HR)

	FIRM POWER PRODUCTION			MEAN POWER PRODUCTION		
	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL
MF5C4R1A	195050	210464	405514	619748	759154	1378902
MF5C4R2A	197240	221157	418397	603356	782063	1385419
MF5C4R2B	198184	240663	438847	588911	817662	1406573
MF5C4R2C	192855	249561	442416	549814	863947	1413761
MF5C4R3A	197762	219876	417638	591972	787744	1379716
MF5C4R3B	199697	239382	439079	580059	821666	1401725
MF5C4R3C	197153	260219	457372	546304	878050	1424354
MF5C4R4A	201537	216375	417912	562500	806772	1369272
MF5C4R4B	204165	235916	440081	553676	838196	1391872
MF5C4R4C	197153	260222	457375	521993	891362	1413355
MF5C4R5A	200997	229966	430963	536998	843130	1380128
MF5C4R5B	200984	249662	450646	527820	872277	1400097
MF5C4R5C	198048	275450	473498	505676	921181	1426857
MF6C4R1A	198999	220190	419189	655715	786054	1441769
MF6C4R2A	201755	225726	427481	637275	803518	1440793
MF6C4R2B	201865	249057	450922	622779	841974	1464753
MF6C4R2C	202350	290690	493040	589445	919206	1508651
MF6C4R3A	203052	225604	428656	626153	810088	1436241
MF6C4R3B	203965	248979	452944	613599	847266	1460865
MF6C4R3C	202350	290446	492796	578880	923357	1502237
MF6C4R4A	202854	229139	431993	589017	838163	1427180
MF6C4R4B	206808	252492	459300	583071	871539	1454610
MF6C4R4C	207893	298438	506331	558430	944577	1503007
MF6C4R5A	201583	230910	432493	559264	865514	1424778
MF6C4R5B	204683	253323	458006	554817	894743	1449560
MF6C4R5C	206028	301947	507975	536785	963541	1500326
MF5C5R2.	197240	221157	418397	603356	782063	1385419
MF5C5R3.	197762	219876	417638	591972	787744	1379716
MF5C5R4.	201537	216375	417912	562500	806772	1369272
MF6C5R2.	201755	225726	427481	637275	803518	1440793
MF6C5R3.	203052	225604	428656	626153	810088	1436241
MF6C5R4.	202854	229139	431993	589017	838163	1427180
MF5C6R1.	196589	240871	437460	594993	814651	1409644
MF5C6R2.	198184	240663	438847	588911	817662	1406573
MF5C6R3.	199697	239382	439079	580059	821666	1401725
MF6C6R1.	201865	249023	450888	632126	838866	1470992
MF6C6R2.	201865	249057	450922	622779	841974	1464753
MF6C6R3.	203965	248979	452944	613599	847266	1460865

E.B. CAMPBELL POWER STATION

POWER PRODUCTION (MW.HR)

	FIRM POWER PRODUCTION			MEAN POWER PRODUCTION		
	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL
M86BASE.	237352	197798	435150	675512	748954	1424466
M70BASE.	223242	199493	422735	644916	725066	1369982
M67BASE.	185530	200459	385989	567775	712897	1280672
MF5BASE.	172119	185115	357234	524612	650365	1174977
MF6BASE.	176100	191351	367451	553651	674485	1228136
MF5C1R1A	169421	185115	354536	495830	643907	1139737
MF5C1R1B	167563	185115	352678	461702	637741	1099443
MF5C1R2A	170112	184995	355107	488999	646888	1135887
MF5C1R2B	167563	184995	352558	449982	637930	1087912
MF5C1R3A	171817	183925	355742	482341	649502	1131843
MF5C1R3B	167563	183918	351481	441753	638278	1080031
MF5C1R4A	189597	197008	386605	510422	683373	1193795
MF5C1R5A	171330	189711	361041	438909	683865	1122774
MF5C1R5B	168292	190033	358325	413983	657650	1071633
MF6C1R1A	170112	191465	361577	507231	662457	1169688
MF6C1R1B	167526	191465	358991	463663	652515	1116178
MF6C1R2A	171817	191465	363282	501382	664750	1166132
MF6C1R2B	167526	191465	358991	454495	652230	1106725
MF6C1R3A	171817	191465	363282	491966	669349	1161315
MF6C1R3B	167526	191465	358991	444849	653345	1098194
MF6C1R5A	170389	191064	361453	447648	697451	1145099
MF6C1R5B	168255	191238	359493	420460	669259	1089719
MF5C2R1.	181437	195861	377298	513355	671595	1184950
MF5C2R2.	181489	196697	378186	505887	677372	1183259
MF5C2R3.	183795	196582	380377	499131	683287	1182418
MF5C2R4.	174755	188503	363258	520407	656761	1177168
MF5C2R5.	191566	199112	390678	513538	689262	1202800
MF5C2R6.	188531	209077	397608	461074	729855	1190929
MF6C2R1.	188508	213028	401536	534801	710789	1245590
MF6C2R2.	179096	193727	372823	545764	683868	1229632
MF6C2R3.	179949	193661	373610	536758	691529	1228287
MF6C2R4.	178658	195657	374315	549797	681369	1231166
MF6C2R6.	195267	218267	413534	480512	761922	1242434
MF5C3R1.	170112	181861	351973	489530	642565	1132095
MF5C3R2.	168441	181389	349830	478585	645897	1124482
MF5C3R3.	170129	180085	350214	470302	649775	1120077
MF5C3R4.	189280	196379	385659	508828	683722	1192550
MF5C3R5.	172751	189678	362429	427008	689577	1116585
MF6C3R1.	171817	191465	363282	498326	665571	1163897
MF6C3R2.	169949	191465	361414	486287	670212	1156499
MF6C3R3.	170423	191417	361840	475083	675880	1150963
MF6C3R5.	171810	191311	363121	430306	706315	1136621

E.B. CAMPBELL POWER STATION

POWER PRODUCTION (MW.HR)

	FIRM POWER PRODUCTION			MEAN POWER PRODUCTION		
	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL	NOV. to MAR.	APR. to OCT.	TOTAL ANNUAL
MF5C4R1A	172119	175969	348088	533016	633481	1166497
MF5C4R2A	173824	184995	358819	519677	655079	1174756
MF5C4R2B	175263	198078	373341	508463	680754	1189217
MF5C4R2C	173562	198406	371968	478981	711572	1190553
MF5C4R3A	174265	183925	358190	510555	661496	1172051
MF5C4R3B	176034	197008	373042	500910	686065	1186975
MF5C4R3C	174289	208454	382743	473436	725926	1199362
MF5C4R4A	177695	180803	358498	486887	680943	1167830
MF5C4R4B	179426	193949	373375	479153	703577	1182730
MF5C4R4C	174289	208464	382753	453609	740988	1194597
MF5C4R5A	176878	192178	369056	465440	711389	1176829
MF5C4R5B	176959	205944	382903	457930	732395	1190325
MF5C4R5C	174635	222388	397023	439726	766891	1206617
MF6C4R1A	176100	185401	361501	563054	660301	1223355
MF6C4R2A	178293	191432	369725	548100	680209	1228309
MF6C4R2B	177878	207751	385629	535707	708281	1243988
MF6C4R2C	178411	236440	414851	508462	765623	1274085
MF6C4R3A	179164	191212	370376	539048	687908	1226956
MF6C4R3B	179298	207605	386903	528094	715361	1243455
MF6C4R3C	178411	235382	413793	499968	771162	1271130
MF6C4R4A	178566	193631	372197	508455	715416	1223871
MF6C4R4B	181843	209962	391805	503541	739757	1243298
MF6C4R4C	182382	242834	425216	482833	794293	1277126
MF6C4R5A	177362	193556	370918	483762	736797	1220559
MF6C4R5B	179923	209894	389817	480072	758655	1238727
MF6C4R5C	180871	247097	427968	465033	812225	1277258
MF5C5R2.	173824	184995	358819	519677	655079	1174756
MF5C5R3.	174265	183925	358190	510555	661496	1172051
MF5C5R4.	177695	180803	358498	486887	680943	1167830
MF6C5R2.	178293	191432	369725	548100	680209	1228309
MF6C5R3.	179164	191212	370376	539048	687908	1226956
MF6C5R4.	178566	193631	372197	508455	715416	1223871
MF5C6R1.	173915	198198	372113	513325	676669	1189994
MF5C6R2.	175263	198078	373341	508463	680754	1189217
MF5C6R3.	176034	197008	373042	500910	686065	1186975
MF6C6R1.	177878	207751	385629	543273	702744	1246017
MF6C6R2.	177878	207751	385629	535707	708281	1243988
MF6C6R3.	179298	207605	386903	528094	715361	1243455

3.0 SSEWS RESULTS

The SSEWS is a manmade water delivery system which has been expanded as needed to meet growing needs. Therefore the range of alternatives is relatively limited. The results for all of the scenarios studied were conveniently presented in the attached two page summary.

3.1 CURRENT CONDITIONS (1986)

SE86BASE - This scenario models the canal and reservoir system as it exists at present.

3.2 SHORT-TERM SCENARIOS (YEAR 2000)

SE00BASE - This scenario models the system as it is currently operated but with the projected increases in demand anticipated by the year 2000.

SE00C1R1 - The operating range of Broderick reservoir was reduced by one metre.

SE00C2R1 - The operating range of Brightwater Reservoir was reduced to 0.8 m.

SE00C4R1 - The irrigation duty was increased for every year to the duty that was experienced in the drought year 1988.

3.3 LONG-TERM SCENARIOS (YEAR 2020)

SE20BASE - The system was assumed to be operated as it currently is operated but with the projected increases in demand anticipated by the year 2020.

SE20C1R1 - This was a demand management scenario in which the consumptive uses were assumed to be reduced by 40 percent.

SE20C1R2 - This demand management scenario provided for a 20 percent reduction in consumptive uses.

SE20C2R1 - This scenario considered the increase in supply which could be obtained if the M1 Canal capacity was increased to 20 m^3/s.

3.4 SYSTEM LIMIT SCENARIO

For the SSEWS, the system limit scenarios were applied to test how much more water could be delivered to irrigation, municipal or industrial projects if the remaining capacity of the system was exclusively devoted to each of these options. The developments were assumed to occur first near the upstream end of the system.

SEF5C1R1 - In this scenario it was assumed that only irrigation would expand after the year 2000.

SEF5C2R1 - In this scenario it was assumed that only municipal water use would expand after the year 2000.

SEF5C3R1 - In this scenario it was assumed that only industrial water use would expand after the year 2000.

BLACKSTRAP LAKE ELEVATIONS (Jan. - Dec.)

PERCENT OF TIME IN EACH ELEVATION ZONE (m)

	GREATER FSL	534.47 534.20	534.20 533.40	533.40 525.80	LESS THAN 525.80
SE86BASE	8.67	66.56	24.78	0.00	0.00
SE00BASE	8.11	66.78	25.11	0.00	0.00
SE00C1R1	8.11	66.56	25.22	0.11	0.00
SE00C2R1	8.11	66.78	25.11	0.00	0.00
SE00C4R1	8.11	61.56	23.89	6.44	0.00
SE20BASE	7.11	56.89	27.89	8.11	0.00
SE20C1R1	7.67	68.00	24.33	0.00	0.00
SE20C1R2	7.22	65.11	26.44	1.22	0.00
SE20C2R1	7.11	61.89	28.33	2.67	0.00
SEF5C1R1	8.11	78.33	11.44	2.11	0.00
SEF5C2R1	0.22	61.67	36.89	1.22	0.00
SEF5C3R1	0.56	58.78	36.89	3.78	0.00

LITTLE MANITOU LAKE ELEVATIONS (Jan. - Dec.)

PERCENT OF TIME IN EACH ELEVATION ZONE (m)

	GREATER FSL	497.20 493.47	493.47 492.56	LESS THAN 492.56	
SE86BASE	0.00	93.78	6.22	0.00	0.00
SE00BASE	0.00	89.89	10.11	0.00	0.00
SE00C1R1	0.00	89.44	10.56	0.00	0.00
SE00C2R1	0.00	89.89	10.11	0.00	0.00
SE00C4R1	0.00	85.00	15.00	0.00	0.00
SE20BASE	0.00	83.00	17.00	0.00	0.00
SE20C1R1	0.00	94.00	6.00	0.00	0.00
SE20C1R2	0.00	88.22	11.78	0.00	0.00
SE20C2R1	0.00	86.56	13.44	0.00	0.00
SEF5BASE	0.00	90.00	10.00	0.00	0.00
SEF5C1R1	0.00	86.11	13.89	0.00	0.00
SEF5C2R1	0.00	81.33	18.67	0.00	0.00
SEF5C3R1	0.00	83.33	16.67	0.00	0.00

EAST SIDE PUMPING STATION DIVERSION

(Jan. - Dec.)

	Median Diversion Volume (dam^3)
SE86BASE	124354
SE00BASE	141093
SE00C1R1	141109
SE00C2R1	141093
SE00C4R1	173105
SE20BASE	168099
SE20C1R1	119073
SE20C1R2	150275
SE20C2R1	172386
SEF5BASE	141093
SEF5C1R1	164239
SEF5C2R1	200045
SEF5C3R1	202292

SYSTEM LIMIT DEMANDS (ADDITIONAL WATER USE)

	Irrigation In Hectares	Municipal in Dam^3	Industrial in Dam^3
Broderick	3 000	39 000	31 000
Brightwater	100	3 000	15 000
Blackstrap	1 900	18 000	11 000
Bradwell	–	–	1 000

4.0 SWIFT CURRENT CREEK RESULTS

The Swift Current Creek area has been heavily developed for irrigation. Duncairn Reservoir provides control of the major flows of Swift Current Creek in all but flood years and the system of canals, smaller reservoirs and irrigation projects provide water for farm irrigation and municipal use.

In recent drought years irrigation projects have rationed water because of the inadequate supply. Therefore a moratorium on new irrigation has been in place to prevent the frequency and severity of shortages worsening.

4.1 CURRENT CONDITIONS (1986)

SC86BASE - This scenario models the existing uses and operating rules.

4.2 SHORT-TERM SCENARIOS (YEAR 2000)

SC00BASE - For this scenario, the existing operating rules were unchanged. Uses were increased to projected year 2000 demands. The moratorium on irrigation was assumed to continue so only the municipal demand increased.

SC00C1R1 - The normal operating range of Duncairn Reservoir was reduced by one metre.

SC00C2R1 - The normal operating range of Duncairn Reservoir was increased by one metre.

SC00C2R2 - The normal operating range of Duncairn Reservoir was increased by two metres.

SC00C2R3 - The normal operating range of Duncairn Reservoir was increased until the supply of water to users in addition to irrigation projects was placed in jeopardy. A minimum elevation for the normal.operating range was found to be 799.25 m, slightly over four metres below the currently accepted normal range.

SC00C3R1 - The normal operating range of Highfield Reservoir was increased by one metre.

SC00C4R1 - SC00C2R1 and SC00C3R1 were combined.

SC00C4R2 - SC00C2R2 and SC00C3R1 were combined.

SC00C4R3 - SC00C2R3 and SC00C3R1 were combined.

SC00C5R1 - Operation of Duncairn Reservoir was modified to permit an additional one metre of drawdown for irrigation water use in the April to June period.

SC00C5R2 - Operation of Duncairn Reservoir was modified to permit an additional two metres of drawdown for irrigation water use in the April to June period.

4.3 LONG-TERM SCENARIO (YEAR 2020)

Two types of long-term scenarios were studied. The first set were operation scenarios and the second set were development scenarios.

4.3.1 Operational Scenarios

SC20BASE to SC20C5R2 - These scenarios were identical to the short-term scenarios and demonstrate that if no additional storage reservoirs are added and the moratorium on irrigation continues, the growth in municipal demand to the year 2020 can be satisfied under all of these operating scenarios.

4.3.2 Development Scenarios

The existing level of irrigation water is resulting in significant shortages in about 24 percent of the years. Only shortages that exceed 10 percent of the demand were considered significant. If the operation continues as in the past and municipal demand grows to the anticipated year 2000 and year 2020 levels, irrigation shortages will increase to about 25 and 26 percent of the years respectively. However, if the increase in the normal operating range of two metres described by Scenario SC20C2R2 was implemented, the frequency of shortages would drop to 13 in 75 years or 17 percent of the years. For this study it was assumed that this adjustment in operation of this existing reservoir would precede major investments in new storage reservoirs. Therefore SC20C2R2 was considered to be the base case for comparison of the development scenarios.

Two types of development opportunities were studied: Additional water storage projects and pipelines. These projects could increase the supply of water to existing irrigation projects, thereby reducing their shortages, or they could permit additional areas to be irrigated with similar frequency of shortages.

SC20C6R1 - The usable storage capacity of Duncairn Reservoir was increased by raising the FSL from 807.22 m to 808.90 m. The added storage was used to reduce shortage to existing projects.

SC20C6R2 - SC20C6R1 with the extra storage used for new irrigation projects at shortages of 17 percent.

SC20C7R1 - An additional reservoir upstream of Duncairn (Site SC1) with a capacity of 60 000 dam^3 was added. The added storage was used to reduce shortages to existing projects.

SC20C7R2 - SC20C7R1 with the extra storage used for new irrigation projects at shortages of 17 percent.

SC20C7R3 to SC20C7R4 - Similar to SC20C7R1 and SC20C7R2 with a storage capacity of 100 000 dam^3.

SC20C7R5 to SC20C7R6 - Similar to SC20C7R1 and SC20C7R2 with a storage capacity of 150 000 dam^3.

SC20C8R1 - A small reservoir with a capacity of 1 240 dam^3 was added a short distance downstream of Swift Current (Site 8B). The added storage was used to reduce shortages to existing projects.

SC20C8R2 - SC20C8R1 with the extra storage used for new irrigation projects at shortages of 17 percent.

SC20C8R3 - A reservoir with a capacity of 14 000 dam^3 downstream of Swift Current (Site 7B) was added. Since this site is too far downstream to serve existing irrigation projects, only the option of new irrigation at shortages of 17 percent was practical.

SC20C9R1 - An additional reservoir with a capacity of 40 000 dam^3 was added upstream of Highfield Reservoir on Rush Lake Creek (Site RL1). The additional Storage was used to reduce shortages to existing projects.

SC20C9R2 - SC20C9R1 with the extra storage used for new irrigation projects at shortages of 17 percent.

SC20CAR1 - The combined effect of raising the FSL of Duncairn Reservoir and added reservoirs at Sites SC1, 7B and 8B were studied. The additional storage was used to reduce shortages to existing projects.

SC20CAR2 - SC20CAR1 with the extra storage used for new irrigation projects at shortages of 17 percent.

SC20CBR1 - A pipeline from Duncairn Reservoir to the City of Swift Current would eliminate the minimum flow requirements below Duncairn Dam from October to March. The water saved could reduce the shortages to existing irrigation projects.

SC20CBR2 - SC20CBR1 with the water saved, used for new irrigation projects at shortages of 17 percent.

SC20CCR1 - A pipeline from Lake Diefenbaker to the City of Swift Current could eliminate the City demands on Swift Current Creek water and the minimum flow requirements in winter. The water saved could reduce the shortages to existing irrigation projects.

SC20CCR2 - SC20CCR1 with the water saved, used for new irrigation at shortages of 17 percent.

SC20CDR1 -	In this scenario the effect of removing the moratorium on irrigation after the year 2000 and permitting the irrigated area to expand at a rate similar to past trends was studied.
SC20CDR2 -	Scenario SC20CDR1 resulted in a dramatic increase in the frequency of shortages. Scenario SC20CDR2 identified the amount of storage that would be needed to return the frequency of shortages to 17 percent. It was found that it would be necessary to raise the FSL at Duncairn Reservoir, add 150 000 dam^3 at SC1 and to add the 7B and 8B reservoirs to the system.
SC20CER1 -	This scenario investigated demand management strategies that reduced demands by 40 percent.
SC20CER2 -	This scenario considered demand reduction of 10 percent.
SC30CER3 -	This scenario considered demand reduction of 20 percent.

4.4 SYSTEM LIMIT SCENARIOS

Only one system limit scenario was studied. In this scenario, SC20CFR1, the possibility of raising the FSL of Duncairn Reservoir and adding a 150 000 dam^3 reservoir at site SC1 in order to maximize the firm supply at the City of Swift Current was studied. The existing irrigation was retained.

REID LAKE ELEVATIONS (JAN. - DEC.)

PERCENT OF TIME IN EACH ELEVATION ZONE (m)

	GREATER FSL	807.72 803.72	803.72 801.00	801.00 790.80	LESS THAN 90.80
SC86BASE	0.00	78.67	21.33	0.00	0.00
SC00BASE	0.00	77.78	22.22	0.00	0.00
SC00C1R1	0.00	99.22	0.78	0.00	0.00
SC00C2R1	0.00	72.22	27.78	0.00	0.00
SC00C2R2	0.00	69.89	27.78	2.33	0.00
SC00C2R3	0.00	53.22	43.56	3.22	0.00
SC00C3R1	0.00	77.00	23.00	0.00	0.00
SC00C4R1	0.00	71.44	28.56	0.00	0.00
SC00C4R2	0.00	69.78	27.78	2.44	0.00
SC00C4R3	0.00	63.89	22.67	13.44	0.00
SC00C5R1	0.00	75.78	24.22	0.00	0.00
SC00C5R2	0.00	74.33	24.56	1.11	0.00
SC20BASE	0.00	77.44	22.56	0.00	0.00
SC20C1R1	0.00	99.00	1.00	0.00	0.00
SC20C2R1	0.00	71.67	28.33	0.00	0.00
SC20C2R2	0.00	67.78	29.44	2.78	0.00
SC20C2R3	0.00	61.11	23.22	15.67	0.00
SC20C3R1	0.00	76.78	23.22	0.00	0.00
SC20C4R1	0.00	71.11	28.78	0.11	0.00
SC20C4R2	0.00	67.33	29.67	3.00	0.00
SC20C4R3	0.00	61.00	23.11	15.89	0.00
SC20C5R1	0.00	75.11	24.89	0.00	0.00
SC20C5R2	0.00	73.56	25.22	1.22	0.00
SC20C6R1	25.22	51.22	21.22	2.33	0.00
SC20C6R2	19.56	41.78	35.44	3.22	0.00
SC20C7R1	0.00	80.33	16.44	3.22	0.00
SC20C7R2	0.00	71.00	25.00	4.00	0.00
SC20C7R3	0.00	81.11	16.00	2.89	0.00
SC20C7R4	0.00	70.78	25.22	4.00	0.00
SC20C7R5	0.00	82.56	14.56	2.89	0.00
SC20C7R6	0.00	72.22	24.11	3.67	0.00
SC20C8R1	0.00	70.22	27.56	2.22	0.00
SC20C8R2	0.00	68.67	28.56	2.78	0.00
SC20C8R3	0.00	67.78	29.67	2.56	0.00
SC20C9R1	0.00	69.11	28.22	2.67	0.00
SC20C9R2	0.00	67.56	29.44	3.00	0.00
SC20CAR1	53.11	32.78	12.11	2.00	0.00
SC20CAR2	38.56	31.33	26.44	3.67	0.00
SC20CBR1	0.00	74.22	24.33	1.44	0.00
SC20CBR2	0.00	67.00	31.44	1.56	0.00
SC20CCR1	0.00	87.67	12.33	0.00	0.00
SC20CCR2	0.00	69.44	29.78	0.78	0.00
SC20CDR1	0.00	49.33	46.89	3.78	0.00
SC20CDR2	45.89	26.56	23.78	3.78	0.00
SC20CER1	0.00	93.11	6.67	0.22	0.00
SC20CER2	0.00	64.11	32.67	3.22	0.00
SC20CER3	0.00	73.89	24.33	1.78	0.00
SC20CFR1	31.44	22.78	28.11	17.67	0.00

MAJOR AND IRRIGATION DEMANDS

	No. Years With Shortages	January - December Annual Average Shortage	Number of Months With Shortages One Month	Two Months	Three Months	Four-> Months
SC86BASE	18	1850	0	3	0	15
SC00BASE	19	2144	0	2	0	17
SC00C1R1	23	3101	0	2	0	21
SC00C2R1	14	1520	0	2	1	11
SC00C2R2	11	1134	0	5	0	6
SC00C2R3	6	650	0	2	0	4
SC00C3R1	20	1938	0	5	0	15
SC00C4R1	14	1364	0	4	1	9
SC00C4R2	11	1025	0	5	0	6
SC00C4R3	6	522	0	2	1	3
SC00C5R1	20	1756	0	3	1	16
SC00C5R2	21	1587	0	2	2	17
SC20BASE	20	2411	0	1	1	18
SC20C1R1	25	3330	0	4	0	21
SC20C2R1	15	1732	1	1	1	12
SC20C2R2	13	1318	0	3	1	9
SC20C2R3	6	662	0	2	0	4
SC20C3R1	21	2184	0	5	0	16
SC20C4R1	15	1571	1	2	0	12
SC20C4R2	13	1202	0	6	1	6
SC20C4R3	6	607	0	2	0	4
SC20C5R1	22	1972	0	3	1	18
SC20C5R2	23	1815	0	3	1	19
SC20C6R1	7	1032	0	1	1	5
SC20C6R2	12	1682	0	2	0	10
SC20C7R1	7	950	0	0	0	7
SC20C7R2	12	1443	1	4	0	7
SC20C7R3	7	881	0	0	0	7
SC20C7R4	12	1489	0	4	0	8
SC20C7R5	6	760	0	0	0	6
SC20C7R6	12	1320	0	4	0	8
SC20C8R1	12	1104	0	6	0	6
SC20C8R2	13	1300	0	5	0	8
SC20C8R3	13	1245	0	2	0	11
SC20C9R1	12	1344	0	3	1	8
SC20C9R2	12	1391	0	2	1	9
SC20CAR1	5	478	0	2	0	3
SC20CAR2	13	1316	0	4	0	9
SC20CBR1	5	614	0	0	0	5
SC20CBR2	13	987	0	2	2	9
SC20CCR1	2	136	0	0	0	2
SC20CCR2	13	833	0	4	0	9
SC20CDR1	24	3364	1	5	0	18
SC20CDR2	12	1646	0	3	0	9
SC20CER1	0	0	0	0	0	0
SC20CER2	14	1749	0	0	0	14
SC20CER3	5	756	0	0	0	5
SC20CFR1	29	4565	1	4	0	24

SWIFT CURRENT CREEK AT THE MOUTH

January - December
Median Annual Volume (dam3)

SC86BASE	25804
SC00BASE	24405
SC00C1R1	26299
SC00C2R1	22478
SC00C2R2	22478
SC00C2R3	22023
SC00C3R1	24405
SC00C4R1	22478
SC00C4R2	22478
SC00C4R3	22478
SC00C5R1	24405
SC00C5R2	24405
SC20BASE	22389
SC20C1R1	24983
SC20C2R1	22025
SC20C2R2	22025
SC20C2R3	22025
SC20C3R1	22025
SC20C4R1	22025
SC20C4R2	22025
SC20C4R3	22025
SC20C5R1	22197
SC20C5R2	22197
SC20C6R1	22025
SC20C6R2	21569
SC20C7R1	24528
SC20C7R2	22029
SC20C7R3	24983
SC20C7R4	22071
SC20C7R5	24983
SC20C7R6	23304
SC20C8R1	20814
SC20C8R2	20814
SC20C8R3	9711
SC20C9R1	22025
SC20C9R2	22025
SC20CAR1	24893
SC20CAR2	21586
SC20CBR1	20736
SC20CBR2	18630
SC20CCR1	27516
SC20CCR2	18630
SC20CDR1	20841
SC20CDR2	22919
SC20CER1	33270
SC20CER2	22219
SC20CER3	25366
SC20CFR1	17324

ADDITIONAL DEVELOPMENT USED IN THE VARIOUS SCENARIOS

The additional development in dam^3 for each scenario was determined to two significant figures or nearest 100 dam^3 by trial and error.

Scenario	Location of Demand	Additional Development (in dam^3)	
SC20C6R2	REID LAKE	3 100	
SC20C7R2	REID LAKE	2 600	
SC20C7R4	REID LAKE	3 700	
SC20C7R6	REID LAKE	4 400	
SC20C8R2	REID LAKE	800	
SC20C8R3	7B RESERVOIR	12 000	
SC20C9R2	HIGHFIELD RESERVOIR	400	
SC20CAR2	REID LAKE	6 800	(Note: Up stream irrigation development was maximized first.)
	7B RESERVOIR	8 500	
SC20CBR2	REID LAKE	4 400	
SC20CCR2	REID LAKE	10 000	
SC20CFR1	SWIFT CURRENT	19 000	

Technical appendix III - the framework plan

SSRBS no.70 1991