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THE HYDROLOGY AND IMPACTS OF THE RAFFERTY-ALAMEDA PROJECT

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Abstract

The Rafferty-Alameda Project is a water management project in Southeastern Saskatchewan consisting of two dams, a diversion canal, and various mitigation measures. The objectives of the project are to provide flood-control for downstream communities, principally Minot, North Dakota, cooling water for the Shand and Boundary power plants, municipal water supplies for downstream communities in Saskatchewan, recreation, and water for irrigation.

The project will allow Saskatchewan to use 50 or 60% (depending on supply) of the water that originates in the basin; this means that there will be less flow available downstream in North Dakota and Manitoba. The need for stable water levels for recreation, an adequate supply of water in the summer months for irrigation, and water year round for the power plants means that the natural distribution of flow throughout the year will be changed to some degree. These changes in the hydrologic regime will cause impacts within the basin.

This paper describes the project, outlines its major impacts, and relates these to the changes in the hydrologic regime. The reduction in flow availability during the high flow season will impact on the water quality within the Souris River. The channelization downstream of the Rafferty reservoir will affect the availability of wetlands which are important in waterfowl production; the changes in the flow variability with season will affect the water quality which will have impacts on waterfowl production, irrigation, fisheries, and municipal water supply in Saskatchewan. Because of fluctuation in reservoir levels, the quality of shoreline for waterfowl breeding purposes is not expected to be high. In North Dakota, the reduction in quantity of water available will have negative impacts on the waterfowl and fisheries production characteristics of the wildlife refuges along the main stem of the Souris there. Furthermore, North Dakota could have greater difficulty in maintaining water quality of flows into Manitoba, resulting in probable negative impacts on municipal water usage and fisheries in that province. Expected conflicts between various uses are outlined. The paper concludes that the project has the potential for negative impacts which require mitigation and monitoring, but that overall impacts will probably not be severe, assuming past hydrologic regimes will reoccur in the future. However, monitoring and careful water management will be required to minimize the negative impacts.

Résumé

Rafferty-Alameda est un projet de gestion des eaux qui se trouve dans le sud-est de la Saskatchewan. Il comprend deux bassins de retenue, un canal de dérivation et de diverses mesures d'atténuation. Ses objectifs sont d'abord, d'assurer la prévention des inondations pour les communautés en aval, principalement à

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Minot, au Dakota du Nord; ensuite, d'approvisionner les centrales thermiques de Shand et de Boundary avec de l'eau de refroidissement; troisièmement, d'alimenter les communautés en aval, en Saskatchewan, avec de l'eau; et, en dernier lieu, de satisfaire aux besoins des débouchés récréatives et d'irrigation.

Le projet permettra à la Saskatchewan l'usage de 50 ou 60% (tout dépendant de la réserve) de l'eau venant du bassin; cela entraînera une disponibilité réduite de l'écoulement des eaux en aval au Dakota du Nord et au Manitoba. Le besoin d'un niveau stable d'eau pour des fins récréatives, le besoin d'une réserve adéquate d'eau, pendant les mois d'été, pour l'irrigation et, le besoin d'eau, à l'année longue, pour les centrales thermiques changeront tous, à un degré quelconque, la distribution naturelle de l'écoulement des eaux pendant l'année. Ces changements au régime hydrologique auront des impacts conséquents à l'intérieur du bassin.

Cet article décrit le projet, esquisse ses impacts les plus importants, et établit un rapport entre ceux-ci avec les changements au régime hydrologique. Une disponibilité réduite de l'écoulement des eaux pendant la saison des écoulements élevés aura un effet sur la qualité de l'eau à l'intérieur du la rivière Souris. La canalisation en aval du réservoir Rafferty affectera la disponibilité des marécages importants dans la production des oiseaux aquatiques; les changements à la variabilité de l'écoulement et de saisons auront un effet sur la qualité de l'eau qui aura des effets conséquents sur la production des oiseaux aquatiques, l'irrigation, les pêcheries et, l'approvisionnement des eaux communautaires en Saskatchewan. On s'attend à ce que la qualité des rives, pour des fins reproductrices des oiseaux aquatiques, ne soit pas très bonne et cela serait due aux fluctuations de niveaux des réservoirs. Au Dakota du Nord, la qualité diminuée de l'eau disponible aura des effets négatifs sur les caractéristiques de production des oiseaux aquatiques et des pêcheries trouvés dans les réserves le long de la rivière Souris. De plus, le Dakota du Nord pourrait avoir plus de difficultés à maintenir la qualité de l'eau de l'écoulement allant au Manitoba, ce qui occasionneraient des impacts probablement négatifs sur l'usage de l'eau communautaire et sur les pêcheries de cette province. L'article conclue que le projet a un potentiel d'impacts négatifs qui exigeront l'atténuation et la surveillance, mais que les effets cumulatifs ne seront probablement pas sévères, tout en assumant que les anciens régimes hydrologiques réapparaîtront à l'avenir. Cependant, une surveillance et une gestion attentives de l'eau seront nécessaires afin de minimiser les effets négatifs.

Introduction

The Basin, the Project and Project Objectives

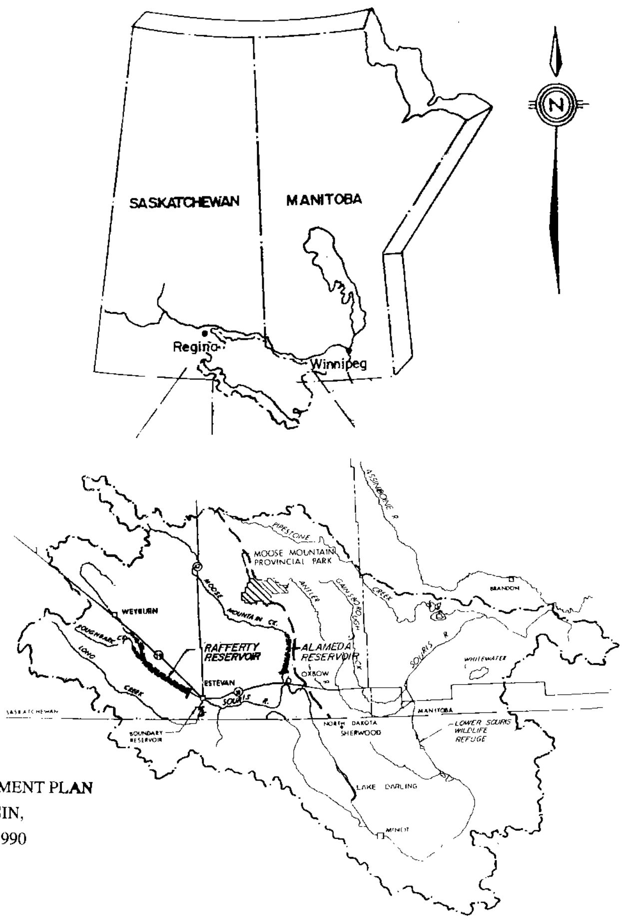
The Rafferty-Alameda project in Southeastern Saskatchewan has generated controversy in the area of environmental impact assessment (EIA) since the project was proposed in 1986. The reasons for this lie not so much in the environmental impacts of the project as in the timing of the project relative to rapid changes in public and judicial perceptions regarding the importance of environmental assessments. The controversy has often obscured the purpose of the project which is to alleviate some of the water supply problems of southern Saskatchewan.

This paper will describe the features of the project, the purpose of its several components, and how they will impact the hydrology of the Souris River downstream of the project. In particular, attention will be paid to how the alteration of the hydrologic regime required to fulfil the purposes of the project will impact the ecosystems in the downstream regions in Saskatchewan, North Dakota, and Manitoba. The paper will conclude with an overall summary of the environmental impact of the project.

The report by the Rafferty-Alameda federal Environmental Impact Assessment Panel, released in September, (FEARO, 1991a) gives a succinct description of the basin, the project, and its objectives and is thus reproduced in revised form here.

Watershed Description

The Souris River is a tributary of the Nelson River system draining into Hudson Bay. Originating in undulating prairie lands southeast of Regina, it flows past Estevan and into North Dakota. The river loops back to the northeast near the city of Minot and crosses the North Dakota/Manitoba border near Westhope. It then meanders north across southwestern Manitoba until it joins the Assiniboine River southeast of Brandon (Figure 1). About one-third of the annual flow from the 62 120 km^2 drainage basin above this junction comes from Saskatchewan with about equal amounts arising from the drainage in both N. Dakota and Manitoba. The annual flow in the Souris River at Sherwood, the border



SOURCE: "WATER MANAGEMENT PLAN FOR THE SOURIS RIVER BASIN, SASKATCHEWAN", SBDA, 1990

Figure 1: Location Plan, Souris River Basin

crossing into North Dakota, is derived approximately equally from Long Creek, the Souris River above Rafferty, Moose Mountain Creek, and the local drainage into the Souris River between Rafferty and the border.

Long Creek and Moose Mountain Creek are the principal tributaries in the Saskatchewan portion of the Souris watershed. These creeks and the main stem of the Souris River meander through flat valleys incised into the gently rolling prairie landscape of the basin. Des Lacs, Wintering and Deep rivers are the important North Dakota tributaries. In Manitoba, the major tributaries are Plum Creek, Gainsborough Creek and Antler River.

A semi-arid continental climate prevails throughout much of the watershed. Drought, occasional thunderstorms and intense temperature variations are typical of the climate. Snowmelt in the spring can generate over 80 per cent of the annual streamflow and causes most of the flooding. At times, periodic droughts eliminates streamflow completely.

The Souris basin ecology reflects the semi-arid prairie climate and topography. The natural upland vegetation of the Souris basin is a mixed grass prairie, although some species that are characteristic of tall grass prairie vegetation are found in certain locations. There are trembling aspen groves in depressional uplands, especially in the eastern portion of the area. Manitoba maple, green ash and various shrubs grow on river levees and in sheltered locations at the edge of the flood plain. Wetlands are found along the shores of rivers, creeks, small lakes and reservoirs in the basin. Most of the uplands and parts of the valleys are now under intensive cultivation, while much of the remainder is used as hayland or pasture.

Segments of the local population and some provincial agencies have been promoting water-based development to diversify the local economy and to strengthen the economic base of rural communities. Since the turn of the century, coal mining and coal-fired water-cooled thermal power generation has been a major contributor to the local economy. Oil production since the 1950s has added further to the industrial base.

There are eight smaller reservoirs in the Souris River basin upstream of the North Dakota border which provide municipal, agricultural and industrial water supplies, as well as some recreation. The total combined storage of these and about 4 900 farm dugouts is 116 100 dam^3. This is about one-fifth of the combined storage of the Rafferty and Alameda reservoirs. The largest existing reservoir, created by Boundary Dam on Long Creek, is southwest of the Rafferty Reservoir. It supplies cooling water for thermal power generation and municipal water to the City of Estevan. The next largest reservoir in the study area, Nickle Lake, is downstream of Weyburn and supplies water to that city.

Important developments in the North Dakota portion of the basin include the Upper Souris (Lake Darling) and J. Clark Salyer National Wildlife Refuges. Both refuges provide important habitats for a variety of migraty waterfowl. In addition, Lake Darling is a valued local fishery. The City of Minot, south of the refuges, is built on a flood plain and has been subject to severe flooding from the Souris in the past.

In Manitoba, the Souris is a source of municipal water for the towns along its main stem and is used for recreation, including fishing.

Project Description

Rafferty Dam is the larger of the two dams. It is a 20 m high earth-fill dam located 6 km northwest of Estevan. When full, Rafferty Reservoir will stretch 57 km upstream, have a surface area of 4 900 ha and store 440 000 dam^3 of water. Weirs in three areas upstream of the main dam will be used to control water levels for waterfowl and fish production.

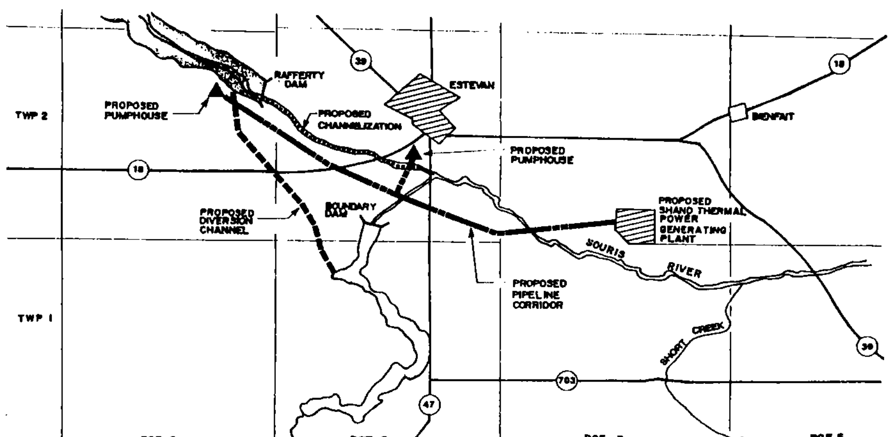
The Alameda Dam is a 38 m high earth-fill dam on Moose Mountain Creek north of the town of Oxbow, relatively near the border with North Dakota. It will eventually create a 105 000 dam^3, 1 240 ha reservoir extending 25 km upstream from the dam. This reservoir, though smaller than Rafferty Reservoir, will be considerably deeper. Consideration is being given to using weirs to promote development of waterfowl habitat at four upstream locations.

There are a number of other projects associated with the development of the two dams (Figure 2). There is a diversion channel connecting the Rafferty Reservoir to the nearby Boundary Reservoir to allow movement of water in either direction and joint operation of the two reservoirs. The value of the diversion canal lies in the fact that the storage capacity of the Boundary Reservoir is inadequate to hold back the major flows on Long Creek, thus forcing spillage of the excess water into the Souris River. This represents both a loss of valuable water for other purposes and also an addition to the flood potential on the Souris River during spring snowmelt. The canal allows the diversion of excess water generated in the Long Creek watershed to the Rafferty Reservoir where it can be stored and released to supply the various needs of the project. The addition of the diversion canal adds to the complexity of operating the project.

Additional features of the project include a pipeline from the Rafferty Reservoir which will supply cooling water to the new Shand thermal power station 10 km southeast of Estevan. Channelization of 16 km of the meandering river course below Rafferty Dam is intended to alleviate local flooding problems and to reduce losses of water to seepage or evaporation. The present Dr. Mainprize Regional Park, south of Midale, will be inundated by reservoir waters. The park is being relocated to an area further upstream. A weir upstream of the Rafferty Dam will supply municipal water to Midale.

All construction associated with the project was carried out under the authority of the Souris Basin Development Authority (SBDA).

It is interesting to note that the project is not a large one either in terms of the costs involved or the amount of storage in the reservoirs. However, an important feature of the overall project is its operating complexity. The two new reservoirs are to be operated in concert with the existing Boundary Reservoir to meet a number of objectives, many of which are in direct competition. Furthermore, the scheme involves inter-reservoir water transfers, a multi-reservoir operating regime, two national, one state and two provincial gov-



SOURCE: "WATER MANAGEMENT PLAN FOR THE SOURIS RIVER BASIN, SASKATCHEWAN", SBDA, 1990

Figure 2: New Facilities Associated with Rafferty Reservoir

ernments, and their respective agencies.

It can thus be expected that the project will have complex impacts on the downstream ecosystems and human developments. Innundation by the dams of the stream valleys along the Souris River and Moose Mountain Creek has the potential of disrupting important ecosystems. However, the changes in the hydrology of the basin downstream of the dams are responsible for the impacts on the ecosystems there; these changes are the most critical because they impact on North Dakota and Manitoba. It is thus important to look at the changes in the hydrology of the basin caused by this project. However, first it is essential to specify its objectives.

Project Objectives

The objectives of the project, as specifically spelled out in the Panel report (FEARO, 1991a), are reproduced, in modified form, below. They are to:

> Comply with the terms of the 1989 Agreement between Canada and the United States of America for water supply and flood control in the Souris River basin. This agreement covers water management criteria and reservoir operating criteria for apportionment and flood control including flood protection at Minot, North Dakota, for the 100-year flood.
>
> Provide an assured long-term water supply to the Shand power station. The Shand power station is a new coal-fired generating station near Estevan, Saskatchewan which incorporates much of the latest technology in its design. Its requirement for cooling water will be partially fulfilled by treated effluent from the town of Estevan, and pumping from Rafferty Reservoir. Shortfalls in these supplies will be met by pumping from groundwater. The use of the treated effluent from the town of Estevan represents a benefit to the Souris River since this effluent presently increases the nutrient loading of the stream and hence impacts negatively on its aesthetics and water quality.
>
> Provide an adequate water supply for existing authorized water users in Saskatchewan, including existing municipal, irrigation, domestic and industrial water users.
>
> Provide an adequate water supply for new developments in the Souris River basin which could include up to 4800 ha of new irrigation development, 3200 ha in the flood plain of the Souris River and 1600 ha in the uplands near the Alameda Reservoir.
>
> Operate the Rafferty Reservoir and the Alameda Reservoir to provide recreational benefits.
>
> Provide flood protection to urban and rural areas downstream of the Rafferty and Alameda Dams. Operate a flow regime in the Souris River and Moose Mountain Creek which will maintain acceptable water quality, and when possible, enhance fish habitat and aquatic wildlife habitat. Instream flows should be supplied by water designated to meet Saskatchewan's apportionment obligations as dictated by the 1909 Boundary Waters Treaty and the 1959 Interim Measures Agreement which stipulates that about one-half the natural flow at the border be passed on to North Dakota without water quality degradation that is detrimental to North Dakota's interest.
>
> Provide an adequate water supply for wildlife enhancement measures. This will include approximately 1 000 ha of wetlands development within and alongside the Rafferty and Alameda reservoirs.

How these objectives are met when reservoir operating regimes are developed will, in part, reflect the legal obligations that are binding on the water management authority of the system. The 1989 Agreement between the governments of Canada and the United States sets out terms related to water apportionment and water quality at the international border. The U.S. water entitlement is defined by a set of rules based on the amount of storage in Lake Darling in North Dakota and the natural streamflow at the border. The rules specify that 50 per cent of the natural streamflow at the border be passed to North Dakota in dry years and 40 per cent in other years. The timing of the releases is stipulated to be that which would have occurred in a state of nature, but, to the extent possible, also to coincide with periods of beneficial use in North Dakota, mainly for waterfowl production. These two criteria for timing are assumed to be nearly synonymous.

In addition to the operating objectives listed above, and under the terms of the 1989 Agreement, the Souris River Basin International Water Quality Objectives were developed by the Water Quality Objectives Task Force of the Souris River Bilateral Water Quality Monitoring Group (1991). The objectives apply to Souris River waters as they cross both the Saskatchewan/North Dakota border and the North Dakota/Manitoba border.

The intention of the water quality objectives is to protect and provide sufficient water quality in the Souris River so that instream uses, such as domestic consumption, fish and wildlife resources, irrigation, livestock watering and industrial consumption, are maintained. The numerical values for the water quality objectives for the Souris River at the two boundary sites were arrived at through a process that considered the objectives, guidelines and/or standards of the participating agencies, the historical water quality and the monitoring capabilities of the various agencies.

Hydrologic and Ecological Impacts

Hydrologic and associated impacts occur in each of Saskatchewan, North Dakota and Manitoba. These will be detailed for each jurisdiction in turn.

Saskatchewan

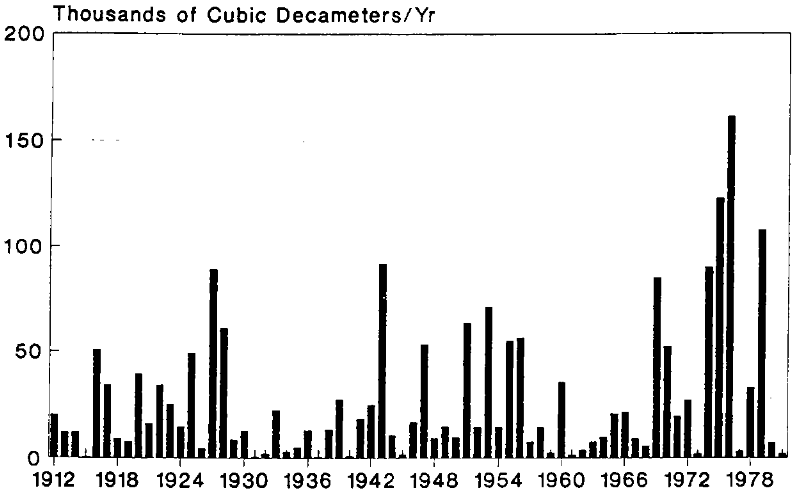
General: An important characteristic of the hydrologic regime of the Souris River basin is indicated by Figure 3 and 4; Figure 3 shows the total annual runoff of the Souris River near Rafferty for the years of record up to 1980, taking out the effects of all upstream development such as the drainage of the Yellowgrass Marsh and the impoundments of the river upstream of this point. The variability in the flow from year to year is extreme; the maximum annual runoff is of the order of 170 000 dam^3, the minimum annual runoff is 260 dam^3 and the mean annual runoff is 29 000 dam^3. Figure 4 shows this same extreme variability on a monthly basis.

Another feature shown by Figure 3 is the duration of the drought and wet cycles. It is shown that there was a very extended drought period from 1929 to 1942 during which the total annual runoff never reached the mean annual runoff of about 30 000 dam^3. On the other hand, a wet period occurred between 1969 to 1979. The last three years of this cycle were all very wet, producing flooding in each of these years. The damage caused by the flooding throughout this cycle was a significant factor that influenced the American interest in supporting the project.

The persistence of the dry cycles leads to the necessity for large reservoirs in order that a sufficient volume of water be carried over from year to year to supply a multi-year deficit. For this reason, and to handle the flow from Long Creek as well, the Rafferty Reservoir storage capacity is very large compared to the mean annual runoff from the Souris River at that location.

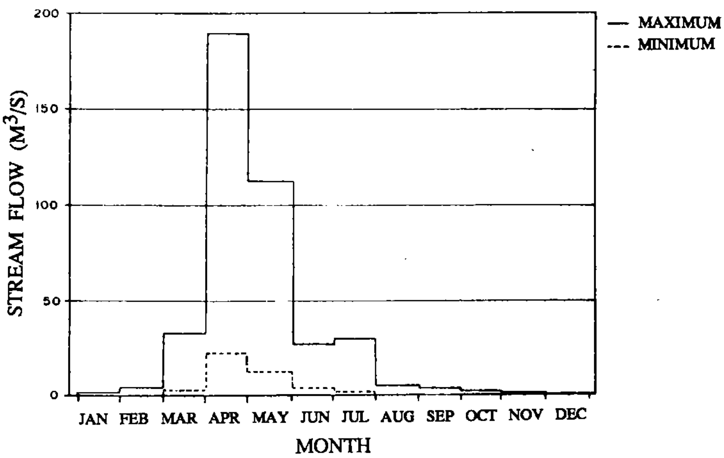
The efficiency of the project is impacted in a major way by the amount of evaporation that could be expected in the Southeast part of the province. The average annual evaporation in the Saskatchewan part of the Souris basin is about 910 mm/yr whereas the precipitation is a bit less than 400 mm/yr, leaving a deficit of 500 mm/yr or more. Maintaining the reservoir levels during years when annual runoffs are minimal results in significant losses of water to evaporation. However, this is a common condition pertaining to all reservoirs in the prairies. Water storage, and its attendant benefits, necessarily entails significant losses of water to evaporation.

Water Balance: A federal environmental impact assessment panel, of which the



SOURCE : FEARO (1991)

Figure 3: Souris River near Rafferty, Naturalized Flows



SOURCE: SBDA (1990)

Figure 4: Recorded mean Monthly Flow, Souris River near Sherwood

author was a member, reviewed the project in consultation with a technical review committee and presented the assessment of the water balance of the project given in Tables 1 and 2. Table 1 shows the water balance for the 3 reservoirs assuming that the basin is in the midst of a wet cycle with high water levels existing in all three reservoirs. Surface areas for the reservoirs were found accordingly and the volumes of evaporation calculated. Runoffs representative of wet, average, median and dry years were assumed to apply and the deductions required for evaporation, groundwater loss as estimated by the SBDA, and water supply for the Shand

Table 1: Water Banance for Rafferty, Alameda and Boundary Reservoirs for High Storage Levels

(A) Evaporation Fluxes

Reservoir	Surface area ($10^6 m^2$)	Net Evaporation (mm)	Net Evaporation Volume (dam^3)
Rafferty	50	534	26 700
Alameda	11	528	5 808
Boundary	?	534	2 500

(B) Water Balance (all values indicated in dam^3)

Reservoir	Water Balance Component	High Flow Yr. (dam^3)	Average Flow Yr. (dam^3)	Median Flow Yr. (dam^3)	Low Flow Yr. (dam^3)
Rafferty	Inflow	100 000	29 390	14 649	3 000
	Net Evaporation	-26 700	-26 700	-26 700	-26 700
	Groundwater Loss	-260	-260	-260	-260
	Shand Power Stn	-3 410	-3 410	-3 410	-3 410
	Net	69 630	-980	-15 721	-27 370
Alameda	Inflow	85 000	28 664	16 264	3 000
	Net Evaporation	-5808	-5 808	-5 808	-5 808
	Groundwater Loss	?	?	?	?
	Net	79 192	22 856	10 456	-2 808
Boundary	Inflow	100 000	31 900	19 163	3 000
	Net Evaporation	-2 500	-2 500	-2 500	-2 500
	Groundwater Loss	?	?	?	?
	Boundary Power Stn.	-6 510	-6 510	-6 510	-6 510
	Net	90 990	22 890	10 153	-6 010

power plant were made. As such, the estimates for the wet and dry years are not exact in any sense. It should be noted that additional losses to increased irrigation are not included in this table. Some of the values are unknown, such as groundwater loss for the Boundary and Alameda reservoirs.

The data shows that with the Rafferty reservoir nearly full, losses due to evaporation, groundwater flow and for cooling water would cause a flow deficit at that location in more than 50% of the years, indeed for all years in which the runoff is average or less. The Alameda and Boundary reservoirs show a net surplus for all but the dry years. The surplus of the Boundary Reservoir would be routed to the Rafferty Reservoir via the diversion canal to augment the supplies there, thus making the deficit at the Rafferty site somewhat less important. The surplus at the Alameda site would be used for apportionment purposes, leaving more of the water supply available for local rather than downstream uses. A similar analysis was performed for the same inflows but for the case where the reservoir was at a lower level. It showed that runoff at the Rafferty site would still be deficient for more than 50% of the years but that the Alameda reservoir would have a surplus for even the dry year

Table 2: Summary of Water Balance for Souris Basin in Saskatchewan for High Initial Storage Levels

	High Flow Year	Average Flow Year	Median Flow Year	Low Flow Year
Net release from Rafferty	69 630	-980	-15 721	-27 370
Net release from Alameda	79 192	22 856	10 456	-2 808
Net release from Boundary	90 990	22 890	10 153	-6 010
Interflow	57 600	29 581	23 453	300
Loss of Estean effluent (to be evaporated)	-1 500	-1 500	-1 500	- 1 500
Domestic	-1 483	-1 483	-1 483	-1 483
Irrigation Projects (exsisting)	-3 009	-3 009	-3 009	-3 009
Wildlife and Recreation	-1 339	-1 339	-1 339	-1 339
Municipal	-8 686	-8 686	-8 686	-8 686
Net Available Water (without changing storage)	281 395	58 330	12 324	-51 905
Water Needs for Apportionment	137 040	47 814	29 412	4 650
Change to Reservoir Storage	144 355	10 516	-17 088	-56 555
Comment	Apportionment can be met by flows alone	Apportionment can be met by flow alone	Apportionment can be met only by drawing reservoirs down	Apportionment can be met only by drawing reservoirs down

- all values in dam^3
- Interflow calculated as flows recorded on Souris River at Sherwood minus flows of Souris River near Rafferty, Long Creek and Moose Mountain Creek

and the Boundary reservoir would have a surplus for all but the dry year scenario.

Table 2 is a summary of the information for the total basin above the border given the runoff surpluses and deficits described above. Included in this table are the net surpluses at the three reservoirs, the flow generated along the portion of the Souris River basin proper downstream of the Rafferty site, and the loss of Estevan effluent. The loss occurs because the effluent, instead of being released into the Souris River, will be used by the Shand power plant. The table also includes water needs for domestic purposes, presently licensed irrigation, municipal needs and wildlife and recreational uses. Presently licensed uses yield high values since actual use is significantly below licensed use in some cases. In addition, account is taken of the requirement that either 40% or 50% of the runoff must be passed on to North Dakota. The 50% value applies for only the dry year.

Table 2 shows that, for high initial storage levels, over 50% of the years would show a deficit, meaning that flow would have to be released from storage to supply the water required for current needs. It should be noted that the addition of 4800 ha of irrigation would increase the deficit, i.e. decrease reservoir storage, or reduce storage increase. Similar data for the case where initial storage is low indicates that the project would result in a net increase in storage in the three-reservoir system in more than 50% of all years.

Overall, it can be concluded from these

tables that the hydrologic regime of the streams within the project is adequate to provide the water source for the purposes stipulated, but that the addition of more irrigation to the load on the system may be questionable. In particular, this would be true if the hydrologic regime in the next decade or so were to be on the dry side. Under these conditions, the reservoir system would remain in a condition of inadequate water supply for a considerable period of time during which many of the envisioned uses of the reservoir could not be implemented.

The fact that the annual runoffs are highly skewed decreases the impact of the condition that so many years result in a net depletion of storage. The high flow years result in such major additions to storage as to be able to supply the needs of several years when flows are below average.

Figure 5 shows the reservoir levels of the Rafferty Reservoir for conditions where the 1912 to 1980 flows in the basin were assumed to apply with the reservoir system in place. It can be seen that the reservoir is subjected to several cycles of drought, namely 1912 to 1925, 1929 to 1941, 1956 to 1969 and once again throughout the 1980s. There are also three refilling cycles: in the late 1920s, during the 1940s and early 1950s and again in the late 1960s and the 1970s. It can be noted that the long dry cycle in the 1930s resulted in the drainage of the reservoir and the inability to supply the water needs of either the planned irrigation or the Shand Power plant. It should be noted it was assumed that the revervoir was filled at the start of the period being considered. If these past hydrologic conditions had been imposed on an initially empty reservoir, the reservoir would not have been useable for a significant portion of the first 15 years or so.

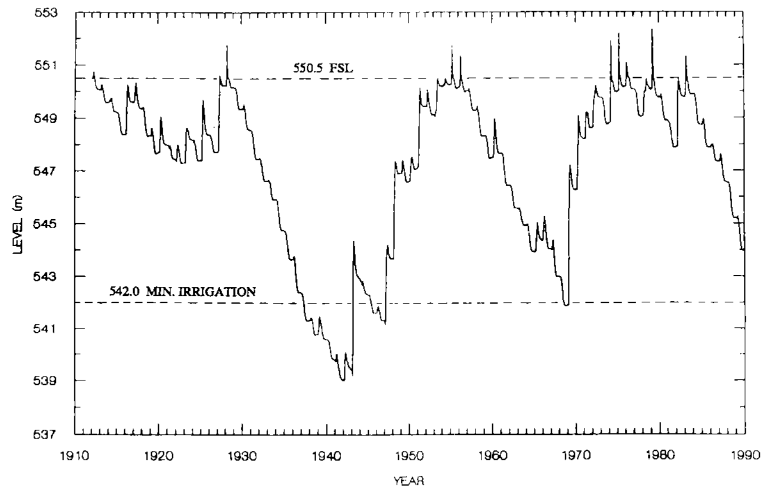
Figure 6 shows a frequency analysis of the length of time required for the Rafferty Reservoir to fill. Since the reservoir will be initially empty, it is logical to assume that the top line of the graph applies, i.e. an initial filling level of 535 m. It should be noted that there is a 50% chance that it will take 20 years or more for the reservoir to fill and that there is about a 70% chance that the filling period will exceed 10 years. Thus, it is anticipated that reservoir levels will take a long time to reach full supply level. The analysis is based on data excluding the drought in the 1980s. Inclusion of this data would present an even worse scenario.

There will be significant reservoir fluctuations from year to year. The operating plan for the reservoir is designed to guarantee no more than a 1 or 2 m fluctuation in reservoir levels during any one summer. The fluctuations from year to year have significance with respect to waterfowl production while the intrayear fluctuation has more of an impact on the recreational value of the reservoir. It is thus apparent that recreational uses have had an impact on the design of the operating plan. Fluctuations in water levels from year to year cannot be prevented in any case.

Flooding: The effect of the project on flooding is shown in Figure 7 and 8. Figure 7 shows the flood hydrographs of four major floods under natural conditions. It can be seen that the hydrographs rise rapidly and recede just as rapidly. Flows in the stream approach zero by June, even during the high flow years.

The effect of the project on the 100 year hydrograph is shown in Figure 8. It can be noted that the peak of the hydrograph is reduced by a factor of 3 and that the duration of the hydrograph is increased but not by much. This is because releases for apportionment govern the shape of the hydrograph; the operating rules for the project more or less guarantee that the apportionment releases will be made during the flood season.

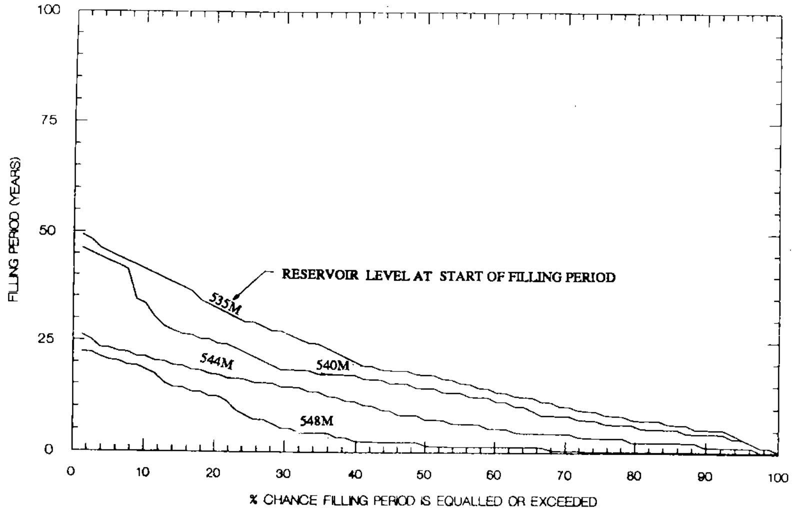
Water Quality: Water quality along the Souris River, particularly that measured by dissolved oxygen, nitrogen, phosphorus, and total dissolved solids, is very important for many reasons. One of the most significant is the terms of the Boundary Waters Treaty. Another reason is the need for water along the Souris River in Saskatchewan for irrigation, water supply, recreation and fisheries.



NOTE: ASSUMPTIONS INCLUDE
- RESERVOIRS ARE FULL AT BEGINNING OF SIMULATION
- SHAND POWER PLANT WATER DEMANDS BASED ON FULL DEVELOPMENT
- WATER DEMANDS INCLUDE 4800 HA OF NEW IRRIGATION
- RAFFERTY RESERVOIR FSL = 550.5

SOURCE: W-E-R ENGINEERING (1990)

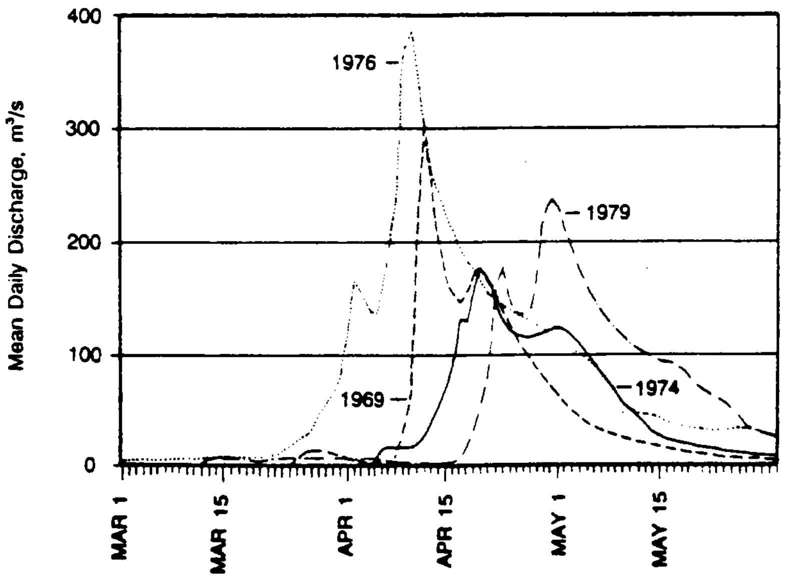
Figure 5: Rafferty Reservoir Levels



NOTES:
- THE ANALYSIS IS BASED ON THE PERIOD 1912 TO 1989
- RESERVOIR STARTS AT LEVEL INDICATED
- NO NEW IRRIGATION UNTIL LEVEL REACHES 542 m
- PHASED IMPLEMENTATION OF SHAND POWER PLANT
- RAFFERTY RESERVOIR FILLED TO 549.5 m

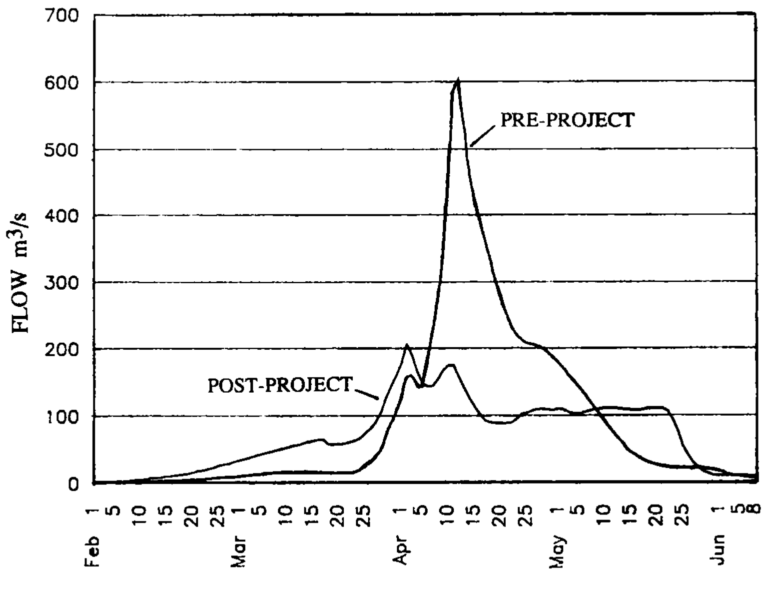
SOURCE: W-E-R ENGINEERING (1990)

Figure 6: Probability of Rafferty Reservoir Filling for any Starting Level and Filling Period



SOURCE: ENVIRONMENT CANADA (1989)

Figure 7: Recorded Hydrographs, Souris River near Sherwood - 05ND007



SOURCE: SBDA, 1987

Figure 8: Souris River below Sherwood Pre - and Post - Project 1:100 Hydrographs

The following discussion on the impacts of the project on water quality in the basin are based on the EIS (SBDA, 1987),the Water Management Plan (SBDA, 1990), the Federal Environmental Assessment Panel Report (FEARO, 1991a), the Report by its Technical Review Committee (FEARO, 1991b), the reports by Environment Canada (Environment Canada, 1989 and 1991), and the Report by W-E-R Engineering (W-E-R Engineering, 1990).

The water quality in the Souris has traditionally been poorer than that in Moose Mountain Creek. This is particularly true for total dissolved solids and nutrients. For that reason it can be expected that the water quality in the Alameda reservoir will be better than that in Rafferty Reservoir. As an example, Figure 9 shows the predicted frequency of releases from Rafferty Reservoir of anoxic water, as a function of the time during the year and the flow level. It can be noted that at low flow levels, it can be expected that releases from Rafferty will be anoxic, at least if the predictions are accurate.

Because of the expected generally poorer water quality in the Rafferty Reservoir, it is planned that the water from Alameda Reservoir will be used to maintain the water quality of the releases to North Dakota. However, Alameda Reservoir also has the problem that, since it is a fairly deep reservoir, a substantial hypolimnion can form, as shown in Figure 10. According to this figure, the hypolimnion can reach up to 5 m above the bottom in August, high enough so that the low-level outlet from the reservoir would draw off anoxic water. To counteract this, a high-level outlet has been constructed in the Alameda dam, paid for by residents of Minot, N. Dakota, which will allow the drawing off of high quality water from higher elevations to enhance the quality of apportionment water.

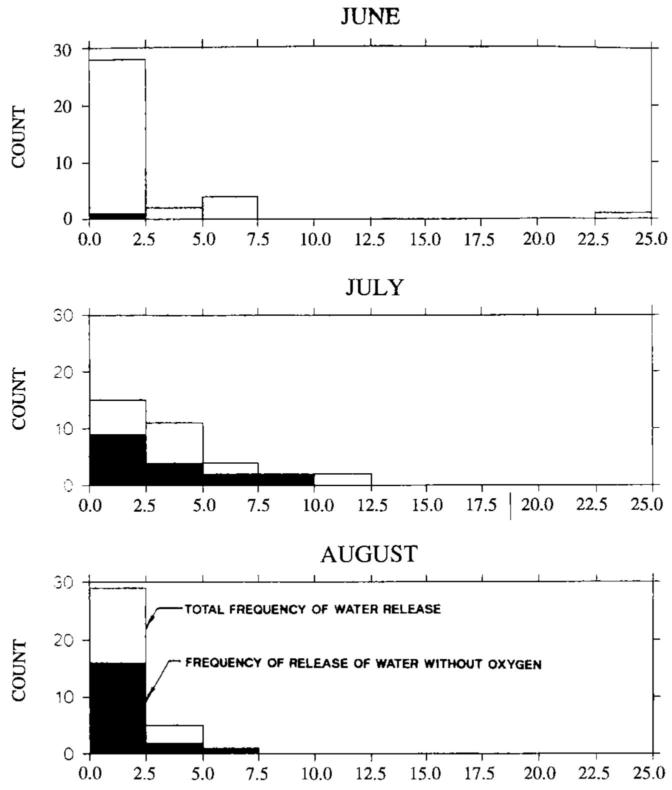
Waterfowl production in Saskatchewan will be negatively impacted by the inundation of the flood plain upstream of Rafferty and by channelization. Some of this negative impact can be mitigated by constructing a series of pools in the channelized areas. Furthermore, it is possible that the reservoirs themselves may provide some waterfowl breeding habitat though irregular water level fluctuations would likely prevent the shore plant growth required for good habitat. However, the reservoirs will provide a good staging area for migrating waterfowl. This may increase hunting success in Saskatchewan and reduce it in North Dakota.

North Dakota

The impacts in North Dakota of retaining approximately half the water generated in Saskatchewan for use in Saskatchewan will be significant. It has already been mentioned that the quality of the water crossing the border is protected by law. However, even if the quality of the water crossing the border does not deteriorate, the reduction in the volume of water available will have an impact. It is expected that though the minimum quality of the water will not decrease, a greater percentage of releases will be at this minimum value.

The major water retention structure in North Dakota is Lake Darling, which has considerable storage but a large surface area so that the mean depth of the lake is not great. Because of its relatively shallow depth, the oxygen levels in the lake can drop to very low values in the winter, and occasionally in the summer resulting in substantial fish kills. This has serious implications for the fishery along the entire Souris River from headwaters to mouth since it is suspected that the fishery in Lake Darling supplies fish to the entire system during high flow years. The fact that the Rafferty and Alameda Reservoirs, when filled, would provide considerably better fish habitat in Saskatchewan than existed there previously is a positive factor in this regard and may make up for some of the negative impact in North Dakota.

A possibly more serious impact in North Dakota would be the reduction in water availability and its impact on water quality in the waterfowl breeding areas. The reduced water levels would reduce the quality of the vegetation and conse-



SOURCE: W-E-R ENGINEERING (1990)

NOTE: BASED ON SIMULATION FROM 1955 TO 1989

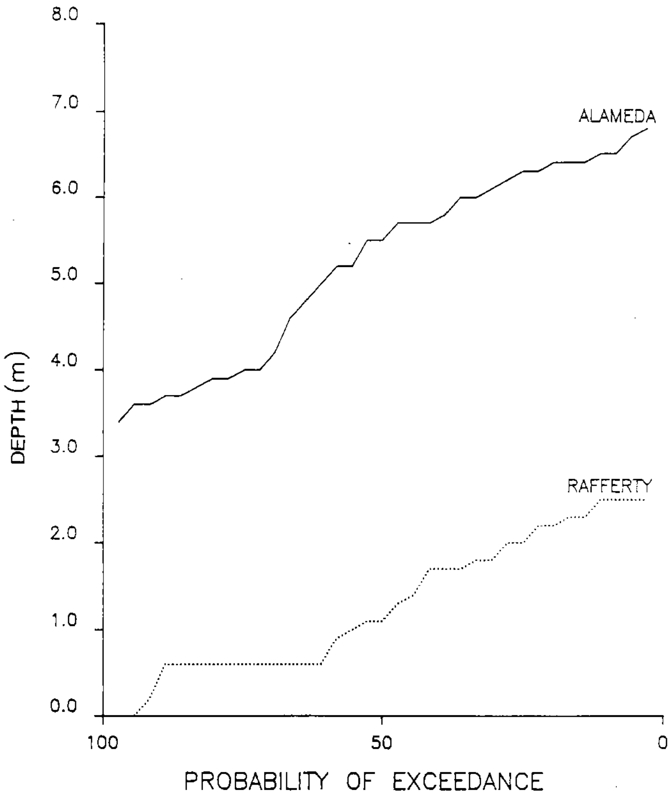
Figure 9: Total Frequency of Water Release from Rafferty and Release without Oxygen

quently the breeding environment for waterfowl. In addition, the lowered oxygen levels would reduce the quality of the environment during the growing period of the waterfowl and enhance the frequency of avian botulism, a major cause of waterfowl mortality in the marshes.

Manitoba

The impacts in Manitoba relate mainly to the flooding regime and to the water supply quantity and quality. The impact of the project on flooding in Manitoba would not be great but would be generally beneficial, serving to reduce the flood maxima and resulting in a more rapid decrease in flood levels. However, under some conditions the presence of the project could cause some disbenefits to farmers because flood levels may drop more slowly and thus impact on the timing of the draining of the floodwater from the land.

The impact of the project on the quality of the water in the Souris River in Manitoba would be a result of the factors discussed with respect to impacts in North Dakota. The reduction in the quantity of water available for the marshes in North Dakota



SOURCE: W-E-R ENGINEERING (1990)

Figure 10: Frequency of Mean Hypolimnetic Depth During August

would likely result in poorer quality water being released into Manitoba. This could cause problems since there are several communities in Manitoba which use the Souris as a water supply and a reduction in water quality would be of great importance to them. The reduced water quality in Manitoba would also impact the sport fishery there which, though not of great monetary significance, is still a valued recreational resource. It is important to note here that the Boundary Waters Treaty requires North Dakota to guarantee the quality of water passing into Manitoba. Thus, to fulfil its part of the agreement, North Dakota would have to make adjustments to its operating policies.

In a year when snowmelt runoff in Saskatchewan is predicted to be high, preflood releases in late winter would cause problems throughout the system. The quality of water released from the project would be poor. In turn, releases from North Dakota to Manitoba would also be of poor quality.

Summary And Conclusions

The Rafferty Alameda project is not a large project either in physical or in financial terms; nevertheless, it attempts to fulfil a large suite of needs, few of which are complementary. Thus, to maximize the benefits in Saskatchewan, considerable thought will have to be taken into how to run the project so that the needs for cooling water for the Shand power plant are met, irrigation development can proceed when appropriate, recreational needs within the basin are met, and environmental damage is avoided. It will be particularly important that the timing and quality of releases for apportionment be optimized so that the negative impacts on the waterfowl production capacity in the wildlife refuges in North Dakota are kept to a minimum. In addition it is important that the quality of the water passing into Manitoba not deteriorate to the point where the water could not be used for municipal and human consumption needs and fisheries become unsustainable.

The Rafferty Alameda project has the potential of providing significant benefits to Saskatchewan but it also has the potential of causing disbenefits to downstream jurisdictions, and even to Saskatchewan, if its operation is less than optimal. It will require considerable study and monitoring to guarantee that the latter does not occur.

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