

# **GENERIC ENVIRONMENTAL IMPACTS IDENTIFIED FROM WATER IMPOUNDMENT PROJECTS IN THE WESTERN CANADIAN PLAINS REGION**

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## **INTRODUCTION**

Environmental impact assessment (EIA) is generally defined as an exercise to predict, interpret, and communicate possible environmental and related social impacts of a proposed activity. EIA is potentially an effective tool in ensuring an integrated approach to the planning of development projects, programs, and policies. It is generally agreed that if applied in a focused, efficient and credible fashion, EIA can be a key factor in anticipating and preventing the degradation of environmental quality (Sadar, McEwen, and Fyfe 1994).

In Canada, the federal government and all the provincial and territorial governments have enacted legislation requiring EIA for any proposal that must be approved by the government(s). As practiced in Canada today, EIA is an institutionalized, structured activity, designed to identify and estimate the effects that a proposed human action is likely to have on the physical environment, the ecosystem(s), and, through these effects, on human health, well-being, or prosperity (Roots 1992). The Canadian EIA processes, procedures, and practices were initiated in 1973; since then they have matured considerably. A critical evaluation of the Canadian experience

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points to the need for further improvements in the current EIA processes and practices (Sadar and McEwen 1992; Gibson 1993).

Canada is an enormous country, endowed with almost one-quarter of the world's fresh water resources. These resources, however, are unevenly distributed throughout the large Canadian land mass. During the past three decades, a number of watershed modification projects have been undertaken in Canada to produce electricity or to meet increasing water consumption demands for domestic and agricultural purposes. These projects were conceived, planned, and implemented under varying circumstances; during different stages of the EIA evolutionary process; and in different regions of Canada. Consequently, the manner and degree in which environmental and related social impacts associated with each project were predicted and/or dealt with were significantly different from one another (Dirschl, Novakowski, and Sadar 1992).

Predicting long-term and cumulative environmental impacts on any ecosystem with reasonable accuracy and precision is a challenging task indeed (Damman, Cressman, and Sadar 1994; Spaling 1994; Lawrence 1994). It requires, among other things, adequate baseline data and a good understanding of the ecosystem components, their dynamic interrelationships and the validity of predictive models employed. With respect to watershed modification projects, the situation is particularly complex and difficult because the anticipated impacts are most likely to occur over large temporal and spatial scales. In addition, the uncertainties associated with variabilities and trends in the climatic and hydrological cycles need to be factored into the impact prediction, evaluation, and mitigation processes.

There are, however, many common and readily predicted impacts associated with the impounding of streams. Building dams on any river located anywhere in the world will have certain biophysical and related social impacts associated with the creation of the upstream reservoirs as well as the modification of the flow regime in the downstream channels. In addition to these generic impacts, there are various site-specific impacts that depend upon the actual location, nature and size of the watershed (Baxter and Glaude 1980; Dirschl, Novakowski, and Sadar 1992).

The generic environmental effects identified and briefly described in this paper are based primarily on the authors' participation in the recent EIA processes carried out for the Rafferty-Alameda and Oldman River dam

projects in the western Canadian prairie region. In addition, we have drawn on our experience derived from earlier impact studies of Canadian impoundment projects (Dirschl 1972; Dirschl, Dabbs, and Gentle 1974; Peace-Athabasca Delta Project Group, 1973), as well as a review of the relevant literature. The findings of our comparison of the two cases are in Table I. We shall limit our discussion to a description of the geographic, political, and administrative setting, as we believe Table 1 speaks for itself.

### **BRIEF BACKGROUND OF THE RAFFERTY-ALAMEDA AND OLDMAN RIVER PROJECTS**

The prairie region of Canada, which encompasses the southern portions of the provinces of Manitoba, Saskatchewan, and Alberta, forms the northern part of the vast Great Plains of North America. A semi-arid continental climate prevails through most of the region, characterized by low and variable precipitation, frequent thunderstorms, and intense temperature variations. Snowmelt in the spring can generate as much as 80 percent of the annual streamflow, and cause heavy flooding. At times, periodic droughts eliminate streamflows altogether (Rafferty-Alameda Project 1991).

The Rafferty-Alameda Project site is located in the southern part of the province of Saskatchewan, just north of the 49th parallel which forms the border between Canada and the United States of America. It is located within the 62,120 km<sup>2</sup> drainage basin shared by the provinces of Saskatchewan and Manitoba and the state of North Dakota. The main purpose of the project was to control seasonal flooding which occurred periodically and caused heavy damages downstream, particularly to the city of Minot, North Dakota. Another objective was to store spring runoff water for various uses during the dry season (Rafferty-Alameda Project 1991; Stolte and Sadar 1993).

Under this project, two earth-fill dams were constructed. The larger of the two, Rafferty Dam, is 20 m high and built on the main stem of the Souris River. When full, Rafferty Reservoir stretches 57 km upstream with a surface area of 4900 ha and a storage capacity of 440,000 m<sup>3</sup>. The second structure, Alameda Dam, is a 38-m-high dam on Mountain Creek, a tributary of the Souris River. It has created a 1240 ha reservoir extending 25 km upstream with a storage capacity of 105,000 m<sup>3</sup>. The Alameda reservoir, though smaller than the Rafferty Reservoir, is considerably deeper and contains higher quality water.

The Oldman River Dam is located in the southern part of Alberta, the most westerly of the three prairie provinces of Canada. It is an earth- and rock-fill dam, 76 m high and 3070 m long. The reservoir is 24 km long, has a surface area of 24.2 km<sup>2</sup>, and is capable of storing 490 million m<sup>3</sup> of water (Oldman River Dam Project 1992). The main function of the Oldman River Dam is to store spring runoff water for gradual release during the year for irrigation and provision of drinking water.

## REASONS FOR COMPARATIVE EVALUATION

The environmental assessment review processes for the Rafferty-Alameda and Oldman River dam projects took place almost simultaneously but there were significant procedural differences that affected the outcome of the two processes. A brief comparison of the manner in which they were carried out, and the findings, conclusions, and recommendations of the two review processes will serve to assess their relevance and effectiveness.

### EIA Process-Related Aspects

- ▶ The Oldman River Dam proposal was initially assessed and approved under the Provincial EIA Process of Alberta (Oldman River Dam project, 1992, p.3).
- ▶ The Rafferty-Alameda proposal was first assessed and approved under the Saskatchewan provincial process (Rafferty-Alameda project, 1991, p.3).
- ▶ The federal EIA process was imposed on the Oldman River Project by the federal court of appeal in March 1990 and on Rafferty-Alameda in February 1991.
- ▶ The public (panel) reviews commenced, not at the project planning stage, but when the two projects were near completion.
- ▶ The two panels started their respective missions almost simultaneously and completed their reports within eight months of each other. Specifically, the Rafferty-Alameda panel submitted its report in September 1991 and the Oldman River report was issued in May 1992.
- ▶ Theoretically speaking, both assessments were conducted under the federal environmental assessment and review process (EARP) (see Sadar and Stolte (1994) for a description of EARP). It should be noted, however, that EARP is supposed to be applied at the planning stage **before** irrevocable decisions are made.
- ▶ Both panel review processes were administered by a public agency, the Federal Environmental Assessment Review Office (FEARO). (FEARO

has recently been renamed the Canadian Environmental Assessment Agency (CEAA)).

- ▶ The Canadian Minister of the Environment, in consultation with his respective provincial counterparts, appointed the members of both panels.
- ▶ The Rafferty-Alameda Panel submitted its report to the Canadian Minister of Environment. The Oldman River Panel directed its report jointly to the Canadian Ministers of Environment, Department of Fisheries and Oceans, and Transport Canada.
- ▶ The Canadian minister(s) made the reports public and, later on, responded publicly to the two reports. After a couple of months' review, the Rafferty-Alameda report was accepted in its entirety. The Oldman River Dam report, on the other hand, was promptly rejected.

### **Some Project Similarities and Notable Differences**

- ▶ The Souris River Basin, site of the Rafferty-Alameda Project, is an international waterway that rises in southeastern Saskatchewan, flows across the Canada-United States boundary into **North Dakota**, and recrosses the international boundary into the province of Manitoba to join the Assiniboine River. Water management of the Souris River watershed, therefore, is subject to discussions under the Boundary Waters Treaty between Canada and the United States. The course of the Oldman River, on the other hand, lies entirely within Canada, from its headwaters in the Rocky Mountains to its juncture with the South Saskatchewan River.
- ▶ The watershed regions are inhabited mostly by farming communities expressing a strong need for additional and reliable water supplies.
- ▶ In completing their reviews, panels relied heavily on the information provided by the proponents, which was mostly duplicated from the documents prepared for earlier provincial reviews.
- ▶ Provincial governments were totally supportive of the two projects.
- ▶ In the case of the Oldman River Dam, there existed strong opposition to the project from the Native population of the Peigan Indian Reserve. With respect to Rafferty-Alameda, on the other hand, no Native groups were present in the affected area.

To summarize, two projects with similar goals, located in similar biophysical and social environments, were assessed separately under the provincial EIA processes. This was followed by separate reviews by two independent panels established by the federal government of Canada. The facilities and areas were visited by both the federally and provincially appointed panels or

committees. These panels conducted public hearings in the same communities and consulted the same public.

**As** noted earlier, the federal panels started their review when the projects were already near completion. The federal reviews were basically put in place to comply with court orders and not in order to approve or reject the proposals. Since the federal panels could not influence the construction process, their primary focus was in improving the dams' operating regimes.

### **GENERIC BIOPHYSICAL AND SOCIOECONOMIC IMPACTS ASSOCIATED WITH WATER IMPOUNDMENT PROJECTS**

All biophysical and socioeconomic impacts associated with water impoundment projects can be divided into two categories, namely those upstream and those downstream of the dam. Obviously, the significance of such impacts is closely related to the site and location of the project as well as the nature of the society. There are, however, a number of generic impacts, that is, they are likely to occur regardless a project's location. Table I lists and identifies such impacts, their causative agents, and possible remedial measures, as put forward in the review processes for the Rafferty-Alameda, Oldman River, and other water impoundment projects.

### **PAST EXPERIENCE AS A GUIDE FOR DESIGNING FUTURE WATERSHED MODIFICATION PROJECTS**

**As** is evident from the summary of generic impacts given in Table 1, a considerable number of impacts, 'especially of a biophysical nature, are common to all water impoundment projects. The degree of significance of each impact depends on such factors as—

- . the size of the project and the affected watershed,
- the location of the project and the nature of the surrounding environment,
- the socioeconomic condition of the community or country,
- . the nature of relevant legislation and regulatory requirements,
- the professional strength and resourcefulness of the regulatory enforcement body(ies), and
- societal values, public awareness, and commitment to the environment.

This comparative evaluation of the Rafferty-Alameda and Oldman River projects, as well as previous study of other watershed modification projects (Dirschl, Novakowski, and Sadar 1992), indicates that many biophysical impacts can be mitigated to a considerable extent. Prior knowledge of adverse impacts in some cases enables 'avoidance' which usually is the best form of mitigation. Future planners of watershed modification projects can benefit from past experience to ensure the use of precious natural resources in a more sustainable fashion.

On the other hand, the nature and significance of socioeconomic impacts is much more closely tied to the site and society-specific circumstances of a given project. The responsible authorities and decision makers have to deal with such impacts in a fair and equitable fashion. Any decision that lacks justice, fairness, and compassion will not, indeed cannot, add to the stability of the society. In dealing with socioeconomic impacts, it is very important to maintain a reasonable balance in the distribution of risks and benefits.

Here again, one can benefit from past experience. For example, almost all watershed modification projects involve the displacement of people, the flooding of farmland, and changes in land use and transportation patterns. These are very difficult issues, but they can be dealt with through monetary and other forms of compensation as well as through appropriate mitigation (Goodland 1995).

Obviously one cannot employ every Canadian practice or solution when dealing with similar situations in other lands. The Canadian experience is nevertheless valuable to be examined for approaches that work and for pitfalls to be avoided.

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**Table 7. Generic impacts of water impoundment projects**

IMPACTS	CAUSATIVE AGENTS	POTENTIAL MITIGATIVE MEASURES
<b>I. UPSTREAM AND WITHIN-IMPOUNDMENT IMPACTS</b>		
<b>A. Physical Impacts</b>		
Erosion of reservoir shoreline affecting land use of immediate surroundings	Wind & wave action within the reservoir especially during drawdown	Rapid drawdowns & rises which will result in less erosion as compared to slow water level changes
Increased sedimentation which decreases the reservoir lifespan	Dam causes the flow of water to <b>slow</b> & to deposit fine-textured sediments in reservoir	Effect not mitigable while dam is in operation: dredging may extend life of project
Sedimentation of tributaries entering reservoir & formation of in-stream mudbanks or islets	<b>As</b> a consequence of river valley inundation, flow in tributaries is slowed & sediments occur	Periodic lowering of reservoir levels results in deepening of channels & transport of silt deposits into reservoir proper
Effects of changed flow regime on groundwater	Reservoir acts as a recharge area for aquifers below river valley & affects quantity & quality of groundwater downstream	Water level & water quality management in reservoir may reduce deleterious effects on groundwater
Seepage from reservoir into groundwater reduces reservoir's storage capacity	Hydrostatic pressure of the water column forces water into porous strata beneath the impoundment	Careful examination of the geological structure of the valley before dam location is fixed, may reduce amount of seepage
Stratification of water decreasing water quality & affecting biota	Circulation within reservoir is controlled by inflow & outflow which create density gradients	Management of inflow (if possible) & outflow by adjusting flow volume or releasing water from various strata within reservoir

IMPACTS	CAUSATIVE AGENTS	POTENTIAL MITIGATIVE MEASURES
Evaporation from reservoir surface reduces storage capacity	Solar radiation & dry winds can cause significant evaporation losses from reservoirs	Project design should take into consideration that evaporation rate is related to surface area: impact on narrow, deep reservoirs is less than on wide, shallow ones. Water levels should be kept high during dry season
Renewal time for surface water is higher than for deeper strata & may impact on water quality & biota	Surface water in the impoundment is usually warmer & less dense than in- or outflowing waters	Inflow & outflow systems could be designed to mimic natural lake regimes more closely
<b>B. Chemical Impacts</b>		
Oxygen depletion in deeper parts of reservoir	Decomposition of flooded vegetation	Selective removal of vegetation & topsoil prior to inundation reduces subsequent oxygen depletion: mechanical aeration of bottom water can be useful
Build-up of reduced chemical compounds in reservoir waters	Consequence of anoxic water present in deepest part of reservoir	Aeration techniques may reduce degree of stratification & amount of reduced chemical compounds in deeper part of reservoir
Build-up of methyl mercury in reservoir water	Decomposition of flooded organic matter (vegetation & topsoil) produces low concentrations of soluble methyl mercury	Removal of organic matter prior to filling is the only effective way to minimize concentrations of this contaminant, & its subsequent impact on fish through bioaccumulation
Other chemical contaminants impair water quality in reservoir	Previous land uses, e.g., use of persistent agricultural pesticides can have long-term effects on water quality	Prior removal of contaminated topsoil may be effective in reducing amount of chemical pollutants

IMPACTS	CAUSATIVE AGENTS	POTENTIAL MITIGATIVE MEASURES
Excess dissolved nutrients producing eutrophication effects such as algal blooms	Agricultural fertilizer runoff or manure leaching into the reservoir may impair water quality through increased nitrate or phosphate concentrations	Restriction of access to reservoir & inflow streams by livestock & wildlife, & avoidance of runoff from fields, feedlots, etc.. can reduce or minimize eutrophication
<b>C. Biotic Impacts</b>		
Excessive growth of plankton & algae	Decreased flow rates & increased supply of nutrients	Limiting some land uses adjacent to reservoir & inflow streams to reduce nutrient input may decrease eutrophication: keeping adequate flow rates during growing season may avoid algal blooms
Reduced or delayed development of littoral vegetation	Repeated flooding & drawdowns destroy emergent & shoreline vegetation	Constant water levels during growing season are needed to protect littoral plant communities
Loss of riparian vegetation in reservoir area	Vegetation in & around the reservoir area is destroyed as reservoir is filled	Appropriate water management can achieve partial mitigation by replacing flooded riparian vegetation with a healthy littoral vegetation community
Loss of spawning habitat for fish	Spawning grounds of river fish species within reservoir are destroyed through flooding & drawdowns	No direct mitigation possible except for introduction of species adaptable to the reservoir environment
Bioaccumulation of mercury in fish	Methylization of mercury as a consequence of decomposing plant material within the reservoir	Removal of vegetation & topsoil may reduce production of methyl-mercury; Hg concentration in fish will decrease in time

IMPACTS	CAUSATIVE AGENTS	POTENTIAL MITIGATIVE MEASURES
Loss or change in wildlife habitat within flooded area	Flooding & altered water regime during all phases of the project will eliminate habitat for terrestrial wildlife but may create habitat for species such as aquatic furbearers & waterbirds	Lost habitat may be partially replaced through vegetation management, or creation of artificial nesting sites
Reduced waterfowl production	Rapid increases in water levels during the reproductive season destroy nests of waterfowl, & thus results in reduced population levels	Maintaining reservoir water levels fairly constant during the short incubation period of important waterfowl species can greatly reduce such losses
Reduced aquatic furbearer populations	Rapid increases in water levels within the reservoir prior to freeze-up may destroy winter shelters of such species as beaver & muskrat, & result in population declines	Required maximum water storage capacity should be accomplished sufficiently early in the autumn to enable aquatic furbearers to adjust in time to these water levels
<b>II. DOWNSTREAM IMPACTS</b>		
<b>A. Physical Impacts</b>		
Erosion of river channel below dam	Sediment-free water below dam has an increased capacity to gauge out bottom & erode sides of river channel	Effect is not fully mitigable. Physical protection measures just below dam location & avoidance of abrupt heavy discharges can reduce rapid channel erosion
Decrease in annual variation in water level of river	Reservoir operations abate natural fluctuations in seasonal flows in river below dam	As a primary design function of most reservoirs, this cannot be mitigated
Lack of recharge of floodplain wetlands in downstream river reaches	Absence of seasonal floods causes drying (& declining nutrient levels) in floodplain wetlands	Subsidiary structures & timed releases from reservoir can provide partial mitigation

IMPACTS	CAUSATIVE AGENTS	POTENTIAL MITIGATIVE MEASURES
<b>B. Chemical Impacts</b>		
Impaired water quality downstream of dam	Water quality impacts described for reservoir may apply downstream, particularly if reservoir is stratified	Management of releases, particularly through multi-level outlets, can reduce downstream water quality problems
<b>C. Biotic Impacts</b>		
Loss of vegetation downstream	Fluctuations/decreases in flow of water or sudden releases from reservoir	Subsidiary structures (e.g., small dams or weirs) & timed releases from reservoir can provide partial mitigation
Changes in vegetational succession patterns	Some plant species require seasonal flooding for reproduction & survival	Subsidiary structures & timed releases from reservoir can provide partial mitigation
Loss of wildlife habitat downstream	Due to changes in plant communities through water regime modifications	For some species, creation of new habitat is feasible through structural improvements such as small dams & artificial nesting sites
Reduced waterfowl production	Rapid waterlevel rises during the reproductive season destroys nests on the banks of river reaches below the dam, & reduces annual waterfowl production	Avoidance of massive releases during the incubation period will avoid such losses in waterfowl
Losses in aquatic furbearers population	Rising water levels in outflow channels in late fall or early spring may flood bank burrows of aquatic furbearers such as muskrat or beaver, & cause temporary declines in population levels	Avoidance of rapid discharges from the reservoir in early spring & late fall will avoid such detrimental impacts on bank-burrowing aquatic furbearers
Dynamics of wetlands changed	Consequence of altered surface & groundwater flows within the drainage basin	Creation of new wetlands may compensate for those lost. Emulation of natural flow patterns (as feasible) may be helpful

IMPACTS	CAUSATIVE AGENTS	POTENTIAL MITIGATIVE MEASURES
Fish can no longer <b>return</b> to upstream spawning grounds	Dam blocks fish from moving upstream & downstream	The construction of fish ladders enabling fish to bypass the dam may improve access to upstream spawning grounds
<b>Loss</b> of fish habitat in reaches below the dam	Due to modification of downstream flows or erosion/sedimentation of river channels	For some species, artificial spawning locations can be created
Fish mortality due to gas super-saturation	Water discharged from the reservoir is superoxygenated in the plunge pool	No direct mitigation possible: impact is only of limited areal extent
Reduced natural variability of river may affect fish populations	Minimum flows needed to sustain healthy populations are seasonally lacking	Maintaining minimum flows to ensure survival of valued fish populations
Mercury contamination of fish downstream	Discharge of contaminated water <b>or</b> migration of contaminated fish from the reservoir	Only feasible form of mitigation is through prior removal of vegetation & topsoil from reservoir site
Elevated concentration of other contaminants in fish	Usually a function of poor water quality within reservoir <b>or</b> the movement of contaminated fish downstream from the reservoir	Measures to improve water quality in reservoir itself can reduce downstream fish contamination
<b>III. REGIONAL IMPACTS</b>		
<b>A. Health and Safety Impacts</b>		
Drinking of contaminated water	Water quality in reservoir & downstream is affected by specific chemical & biological pollutants	Implementation of a public advisory system to avoid consumption of untreated water & provision of alternative potable water supplies

IMPACTS	CAUSATIVE AGENTS	POTENTIAL MITIGATIVE MEASURES
Consumption of contaminated fish	Bioaccumulation of mercury, heavy metals or pesticides in food fish can provide conditions hazardous to human health	Implementation of a public advisory system on hazards & safe consumption limits; provision of alternative safe food (e.g., fish farming)
Transmission of water-borne diseases such as fecal parasites, botulism, & (in tropical areas) diseases such as bilharzia, malaria, etc.	Slow-flowing waters of impoundments provide conditions for parasites & disease hosting organisms, e.g., schistosomes, snails, blue-green algae, mosquitoes	Implementation of a public advisory programme on disease hazards; some potential measures for eradication exist but usually very costly
<b>B. Socio-economic Impacts</b>		
Loss of Sustenance from renewable resources	Creation of reservoir often eliminates source of country—food for inhabitants of area	Not readily mitigable; monetary compensation is often used. Game & fish farming is sometimes feasible as a mitigative measure
Property ownership issues in the project area	Construction & flooding of land before ownership disputes are resolved	Ownership of land should be clarified & disputes resolved before construction commences
Displacement & relocation of area residents	Loss of dwellings & productive lands through construction & filling of reservoir	Mitigation usually impossible; compensation provided
Aesthetic impacts of dam construction & reservoir operation	construction activities, flooded trees & exposed mudflats during drawdowns produce negative visual impacts	Mitigation usually not feasible
Immigration affects area residents	Influx of immigrant workers & dependents into the area may produce ethnic or cultural conflicts	Establishment of community liaison committees to help maximize local opportunities & reduce negative impacts

IMPACTS	CAUSATIVE AGENTS	POTENTIAL MITIGATIVE MEASURES
Impact on local economy of construction	Income boost to local businesses & wage earners during the construction phase; detrimental economic effects on other residents	Establishment of community liaison committees to help maximize local opportunities & reduce negative impacts
Long-term effects of project on area economy	Distribution of costs & benefits may greatly differ on national & local scales	Long-term economic consequences must be objectively examined before project is approved; consultation with area groups can help to maximize local opportunities
<b>C. Impacts on Prehistoric and Historic Features</b>		
Loss of known or unknown archaeological sites	Archaeological sites within the area flooded by the reservoir will become inaccessible & ultimately destroyed by the inundation. In many cases, their existence <b>may</b> remain totally unknown, in other cases, their value may not have been fully appreciated or explored	Mitigation potential is rather limited as archaeological field <b>work</b> is generally more time consuming than the period available prior to reservoir filling. A rapid archaeological survey scheme carried out as soon as the extent of the inundation area is determined, may enable salvage operations or, possibly, structural adjustments to protect particularly valuable sites
Loss of historic habitations or landscape elements	Filling of the reservoir can destroy historic villages, cemeteries, bridges & other man-made features of a bygone era	Mitigation potential is limited. Individual houses of historic value & gravestones can sometimes be moved beyond the inundation area

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