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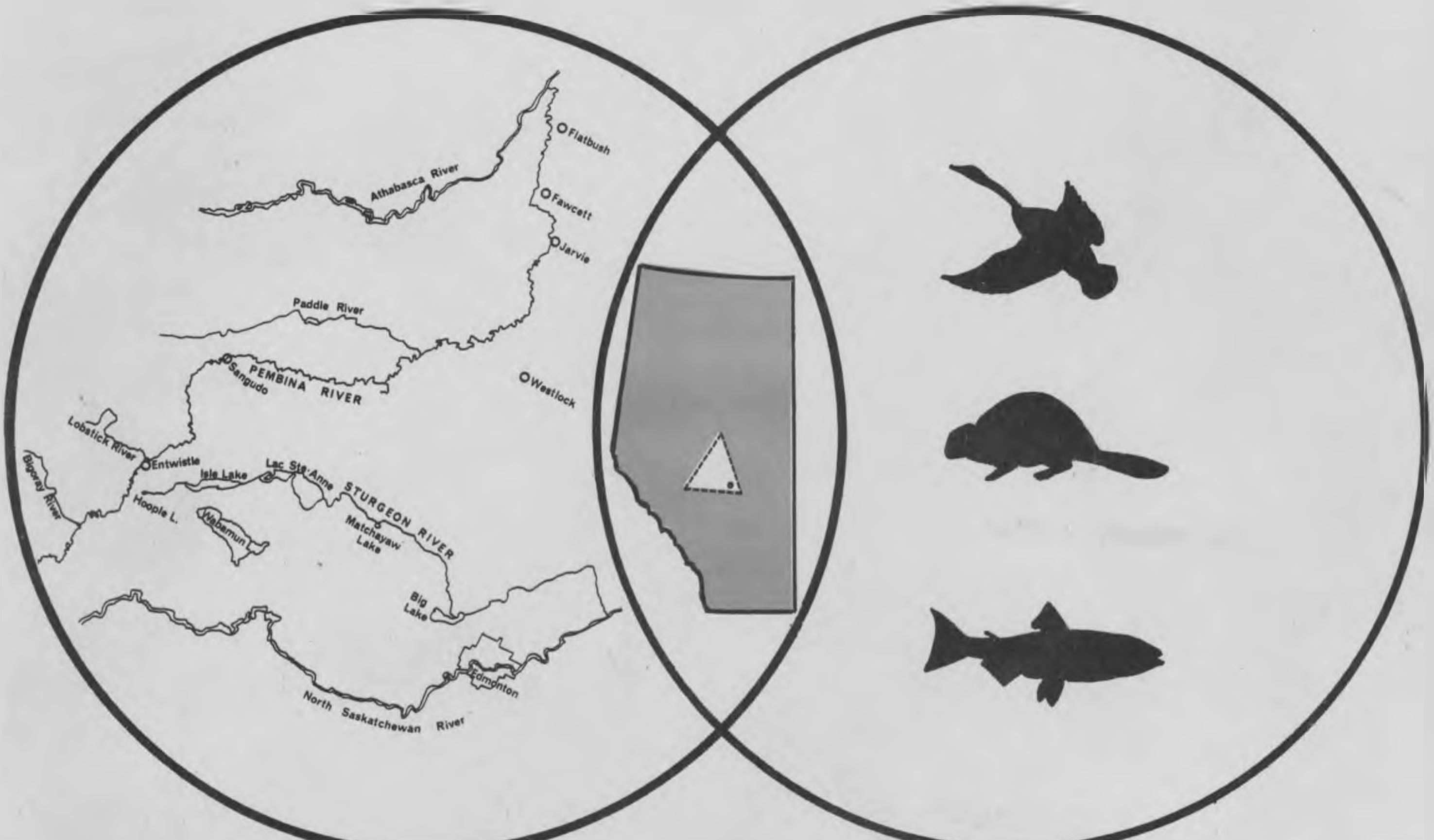
AN ECOLOGICAL STUDY OF WILDLIFE AND FISHERIES IN THE PEMBINA AND STURGEON RIVER BASINS

— Volume 2 —

AN EVALUATION OF
THE IMPACT OF
PROPOSED WATER RESOURCE DEVELOPMENTS



PREPARED FOR

Water Resources Division
ALBERTA DEPARTMENT OF THE ENVIRONMENT

BY

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PREFACE

Volume I of this report has presented results of comprehensive ecological studies of the Pembina and Sturgeon river basins. This volume presents assessments of the significance of various alternative water developments and recommendations for minimizing adverse ecological impacts.

In addition to the impact projections, management recommendations have been made on the most desirable water regimes for the maintenance, and enhancement of fish and wildlife populations.

The discussions presented herein are based on the large body of data summarized in Volume I which should be consulted for technical details and specific results of studies conducted.

A. Introduction:

Prior to a consideration of the impacts of proposed developments along the Sturgeon and Pembina rivers, it should be pointed out that both river basins have been seriously modified by several land use practices which are destructive to fish and wildlife habitat and the aesthetic attributes of the rivers. This is particularly true in the case of the Sturgeon River.

Land clearing has considerably reduced the amount of big game and upland bird habitat and in addition, has seriously modified flow regimes and water quality of the two rivers. Faster snow melt in spring and a higher percentage of the runoff occurs as surface flow rather than ground flow. This, in turn has created extreme fluctuations in water levels of the streams and associated lakes. The detrimental effects of extreme water level fluctuations will be discussed later in the report.

Rapid surface runoff results in sheet erosion of cultivated land which carries large quantities of silt into the river. This leads to highly turbid water with a consequent reduction in light penetration required for photosynthesis, a reduction in the dissolved oxygen content of the water and siltation of substrates which reduces the productivity of a river. Silt and nutrients from the surrounding land are deposited in the lakes downstream. Thus, the rate of eutrophication of both rivers and lakes has been increased as a result of intensive land clearing for agriculture.

In many cases, vegetative cover has been removed to the edge of the stream (Photo 1). Streams with denuded banks have a high propensity to reach and maintain high water temperatures, which can affect gamefish directly by excluding them from the stream or indirectly by influencing other features of the chemical environment, e.g.; dissolved oxygen. Adequate bank cover is important in rivers such as the Pembina and Sturgeon which have lengthy reaches of low gradient water and which frequently experience periods of low flow in mid-summer. Bank vegetation stabilizes the bank thereby reducing the degree of erosion and the contribution of silt to the system. In addition, bank cover is a necessary habitat requirement to many gamefish species.

In some cases, the land clearing operation directly adds silt as illustrated in Photo 2, where it appears that logs and soil were pushed into the river. One consequence of pushing logs into the river has been the formation of numerous log jams downstream on the Sturgeon River. The extent to which these log jams reduce present flow capacity of the Sturgeon River is unknown. A portion of one log jam in the Sturgeon River just upstream from Big Lake is illustrated in Photo 3.

Several other practices associated with agriculture have reduced the quality of the Sturgeon and Pembina watersheds.

Photo 1: The above photo is an example of land clearing along the Sturgeon River. Removal of natural vegetation in the watershed and along the river bank is destructive of upland bird game and big game habitat. In addition, water quality is reduced and the physical nature of the stream channel is altered, which results in habitat of low utility for gamefish.

Photo 2: Logs and debris pushed into the Sturgeon River Channel in connection with a land clearing operation. This results in increased turbidity and the occurrence of log-jams downstream.

Photo 3: Aerial view of a log jam in the Sturgeon River just upstream from Big Lake. This is probably the result of land clearing practices such as those illustrated in Photo 2. Numerous log jams were observed along the length of the Sturgeon River.

The effects of heavy cattle grazing were frequently observed along both rivers. Cattle trample shrubs required for food and cover by big game and upland birds. Destruction of vegetation and compaction of the soil also leads to increased surface runoff and reduced ground flow. An example where livestock have trampled the vegetation bordering streams to the point where significant erosion was occurring is shown in Photo 4. Farms situated adjacent to the Sturgeon River sometimes had stock pens which included part of the river channel.

Apparently uncontrolled use of fire has destroyed vegetation along river banks (Photo 5) and has reduced spring nesting cover for sharp-tailed grouse, pheasants, and Hungarian partridge.

Modifications of the stream ecosystems have resulted from land use practices other than those associated with agriculture. An observation was made of an area where a pipeline has been laid across the Sturgeon River valley. There was no apparent attempt to revegetate the construction site and a good deal of erosion of the river banks had resulted.

Strip mining of coal on the banks of the Pembina River is illustrated in Photo 6. No apparent attempt has been made to revegetate the denuded slopes which increases the incidence and severity of bank erosion and decreases the aesthetic value of the river.

Canalized sections of river are characteristically steep-banked and are extremely susceptible to bank erosion (Photo 7).

Photo 4: The above photograph illustrates watershed abuse on the Pembina River. Complete removal of material vegetation to the stream edge increases the susceptibility of the bank to erosion. The situation is aggravated further by cattle grazing, particularly when the cattle are allowed complete access to the stream. Continual disturbance of the vegetation by cattle retards growth and soil stabilization. In addition, land use practices of this type reduce the recreational potential of a stream.

Photo 5: Cultivation almost to the edge of the Pembina River with the remaining strip of forest cover having been burned. Burning temporarily destroys vegetation, and thus its ability to check erosion. Nesting cover for upland game birds is also reduced.

Photo 6: View of a coal mining operation on the west bank of the Pembina River downstream from Entwistle. While natural succession of vegetation on overburden spoil banks has started, gully erosion is still occurring. Revegetation of such spoil banks would minimize erosion and slumping of material into the river.

Photo 7: A canalized section of the Pembina River, near Dapp, September 1971. Altered sections are characteristically steep banked and are extremely susceptible to bank erosion. They are devoid of littoral vegetation and aquatic rooted plants. Uniformity of the channel resulting in low habitat diversity for aquatic biota is another feature of altered sections. Canalized sections are of little or no value to fish and wildlife species.

In most cases they are devoid of rooted aquatic plants. The above features preclude any use of canalized sections by wildlife species. The channel uniformity of altered sections also reduces the habitat suitability for gamefish.

In several locations along the Sturgeon River, trash including old car bodies had been dumped over the banks (Photo 1).

The marsh ecosystems of the major lakes, besides being affected adversely by poor land use practices upstream, have been altered by cottage development. In most cases, the littoral zone along developed shorelines is devoid of emergent vegetation (see Photo 8).

In summary, it is evident that the ecosystems of the Sturgeon and Pembina River basins have already been significantly changed from their pristine condition. The impact of proposed water resource developments must be considered in the light of existing alterations of the ecosystems.

B. Predicted Impacts of Proposed Water Management Projects on Wildlife Habitat and Populations:

Proposed water management projects include the construction of dams on the Pembina River and in the Magnolia area east of the Pembina River. These dams will form reservoirs in the two areas. Water will be diverted via these reservoirs to the Sturgeon River while a constant riparian flow of 100 cfs

Photo 8: Cottage development on the shore of Isle Lake. Note the lack of emergent vegetation along this section of shoreline. No cover is available for waterfowl or muskrats.

will be maintained downstream in the Pembina River.

Alternatives for diversion are as follows:

1.) A constant flow of 200 cfs to the Sturgeon River diverted via an open cut canal from the Pembina Reservoir.

2.) A flow of 300 cfs diverted via a tunnel from the Pembina Reservoir.

3.) A flow of 400 - 500 cfs diverted if the Magnolia Reservoir is available.

To enable the Sturgeon River to accommodate increased flows, widening, deepening, straightening, and diking of the channel will be required at specific locations. Stabilization of water levels in Isle Lake, Lac Ste. Anne, and Big Lake is proposed.

The proposed water management projects will have environmental impacts due to the following factors: construction activities, land clearing, inundation, bank sloughing, canalization, fluctuations in water levels, changes in the water regime, and changes in water quality.

A discussion of the impacts of each of these factors upon wildlife habitat and populations in the areas affected by the various projects follows.

1.) Impacts of Pembina and Magnolia Reservoirs:

a.) Magnolia Reservoir:

Terrestrial wildlife habitat in the reservoir areas will be permanently eliminated in the area enclosed by the full supply levels of the reservoirs. Land clearing and associated construction activity would first drive wildlife from the area and subsequent inundation of the reservoirs would preclude further use, particularly for terrestrial species.

The area proposed for the Magnolia reservoir encloses 7,900 acres (Water Resources Division). Within this area, waterfowl habitat consists of Hoople Lake, a few small potholes, and the upper portion of the Sturgeon River. Sixty-three breeding pairs of waterfowl, mostly diving ducks, were observed using Hoople Lake in the spring of 1971. In addition, 50 ducks were observed on the Sturgeon River in this area. These, and the waterfowl using the potholes would be displaced by the reservoir and although they may be assimilated by waterfowl populations in adjacent areas, production from the area would be lost.

The reservoir itself would have little value for breeding waterfowl. Extreme water level fluctuations (approximately 15 feet annually according to data presented by Water Resources Division) would, along most of the new shoreline, preclude the development of emergent or submergent vegetation, a primary requirement for waterfowl habitat.

The effect of large fluctuations in water levels of lakes and reservoirs has been documented by several authors. Bellrose and Brown (1941) reported that in the Illinois River valley, Siebolt Lake may fluctuate as much as 12 feet during the year with the result that there is a paucity of aquatic and semi-aquatic vegetation and a low muskrat population. Johnsgard (1956) found that around the O'Sullivan reservoir (in Washington) which is characterized by maximum annual fluctuations of 19 feet, potholes subjected to a rise in water level sufficient to flood most emergent vegetation were left with few or no emergent aquatics.

Newly formed potholes formed by annual flooding of depressions near the full supply level of the reservoir could conceivably develop some marsh vegetation of benefit to waterfowl. Johnsgard (1956) reported that three years after completion of the O'Sullivan reservoir, such newly formed potholes had not developed any marsh vegetation. Harris and Marshall (1963) stated that too-frequent drawdowns or annual heavy replacement of water in a pool may lead to a decline in fertility through the flushing away of nutrients. This would probably occur in any potholes formed around the edge of the Magnolia reservoir with the result that poor waterfowl habitat if any would be formed. Commenting on the impact of water resource development in southern Alberta, Snipe (1970) stated that the quality of waterfowl nesting habitat that would be created is inversely related to the degree of seasonal fluctuations of water levels.

In a study of the impact of the Libby dam and reservoir project, the report on fish and wildlife resources affected by the dam states that the establishment of emergent vegetation on the reservoir edge is improbable. With reference to the proposed Rampart Canyon dam and reservoir, the U.S. Department of the Interior Fish and Wildlife Service stated that annual drawdown on relatively steep banks would expose houses and burrows of beaver and muskrats and limit formation of the shoreline vegetation necessary for muskrat food. They also state that wave and ice action on such a large body of water would damage shelters and vegetation. These factors would be instrumental in preventing the development of waterfowl, muskrat, and beaver habitat on the Magnolia and Pembina reservoirs.

The reservoir created may, however, sustain use as a resting area by waterfowl during migration periods.

Upland bird habitat will also be destroyed in the inundated area of the Magnolia reservoir. In terms of the present population of ruffed grouse, this habitat loss would represent a loss of 390 - 465 drumming male ruffed grouse or a fall population of approximately 2,225 - 2,650 grouse. Losses would probably also be incurred in areas peripheral to the inundated area since some woodlots would undoubtedly be bisected so as to render them unsuitable as ruffed grouse habitat. That is, they may no longer provide all requirements of a ruffed grouse home range.

Sharp-tailed grouse, the second most important upland game bird species in the area would also be adversely affected. At least one lek* is presently located within the proposed reservoir area. A second lek presently on a hill above the 2550' elevation would, in future, be located on a narrow peninsula. This would probably preclude its use as a dancing ground. The loss of these dancing grounds would result in the loss of approximately 50 adult sharp-tailed grouse. This loss would represent the loss of a fall population of approximately 150 - 175 grouse.

The average yearly losses of ruffed grouse and sharp-tailed grouse would probably be somewhat lower than the losses estimated on the basis of present populations since present populations are near peak levels.

Losses of furbearers would include a loss of a minimum of four colonies of beaver. Muskrat habitat quality in the area is fair. Several muskrats were seen in the area and a few were taken by trappers. An accurate estimate of the numbers of muskrats in the area is not possible on the basis of available data. Coyotes, ermine, and squirrels were also trapped in the area. Their populations are not considered to be particularly large.

Big game losses would probably include a loss of approximately 37 deer and two or three moose.

* dancing (mating) ground

b.) Pembina Reservoir:

The area inundated by the Pembina reservoir will be approximately 4,500 acres (Pembina Flood Control Project Report). Wildlife habitat within this area will be eliminated by inundation and bank sloughing of adjacent areas. According to the Pembina Flood Control Project Report the full extent of the retreat, which will take many years, may be 1,500 feet in some sections of the reservoir. The following predicted losses of wildlife due to the Pembina reservoir are minimum values since they are based on the 4,500 acres of inundated area and do not include losses of habitat which may result from sloughing or borrow areas used to obtain fill for dam construction.

Since the Pembina River was found to have poor waterfowl habitat, losses of waterfowl would be insignificant.

A significant amount of good quality ruffed grouse habitat occurs in the area of the reservoir. Losses are estimated to be approximately 225 - 265 drumming males or a fall population of approximately 1283 - 1511 ruffed grouse.

Sharp-tailed grouse were observed only once in the Pembina reservoir area. However, the habitat is not particularly suitable for this species because of its characteristic steep topography. Losses of sharp-tailed grouse are not expected to be significant.

The population densities of furbearers in the Pembina reservoir area are similar to those of the Magnolia site. Approximately ten colonies of beaver would be displaced. Muskrat habitat is negligible in this area.

Populations of big game presently using the Pembina reservoir area and which would be displaced due to inundation include approximately 21 deer and two moose. These estimates are based on general population density figures determined by the Alberta Fish and Wildlife Division. Fish and Wildlife Division survey data indicate that considerably more may use the proposed reservoir area in winter. The reservoir may influence big game populations beyond its boundaries by introducing a barrier to the movements of animals.

An accurate estimate of the effect of populations of animals displaced from the reservoir upon surrounding animal populations is difficult to assess. If surrounding populations are at the carrying capacity of their habitat, competition would affect both populations. Segments of both displaced and adjacent populations would likely be forced into unfavorable habitat or sustain reduced survival as a result of competition.*

If surrounding animal population densities were not at the carrying capacity of the habitat, (e.g. if ruffed grouse were at the low point in their "cycle"), the effect on both the displaced populations and surrounding populations would be minimal.

In any case, the loss of the present populations of animals in the reservoir areas constitutes a minor part of the annual loss of animals which will result from the loss of the area as

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* The net result would be stabilization of populations to former levels of carrying capacity in adjacent areas, and a net loss of populations represented by affected habitat.

productive wildlife habitat. Total annual production losses are estimated as follows:

Waterfowl: A yearly loss of at least 125 ducks (based on 25% of 100 pairs of ducks successfully raising 5 ducklings per pair).

Ruffed Grouse: A yearly loss of approximately 1,750 grouse (based on average yearly population being 75% of present population, a 1:1 sex ratio, and 50% of the females successfully raising 7 chicks each year).

Sharp-tailed Grouse: A yearly loss of 65 sharp-tailed grouse (based on average yearly population being 75% of present population, a 1:1 sex ratio, and 50% of the females successfully raising 7 chicks each year.

Beaver: A yearly loss of approximately 35 beaver (based on fourteen colonies producing an average of 2.5 kits per colony per year).

Deer: A minimum yearly loss of approximately 18 deer (assuming a 30% turnover rate).

Moose: A yearly loss of 1 or 2 moose.

Yearly losses of other wildlife cannot be estimated due to the lack of accurate population data.

2.) Impact of Channel Modification and Increased Flow in the Sturgeon River:

Channel modification has been proposed in reaches of the river with a present tendency to flood. These include reaches downstream from Lac Ste. Anne, Matchayaw Lake, and Big Lake, as well as a reach at the confluence with the Riviere Qui Barre. Environmental impacts will result from clearing of forest cover in the river valley, meander cutoffs, changes in the gradient of the river, and siltation resulting from construction of new river channels and cleaning and widening of the existing channel.

The noise resulting from construction activity may temporarily drive animals from a localized area surrounding construction sites. The animals affected would probably reinhabit the area after construction to the extent that their habitat is left intact.

Waterfowl and muskrat habitat comprises the major portion of the wildlife habitat to be affected by channel modification. Marsh vegetation in reaches of the river proposed for modification is generally more abundant than in the rest of the river. The shallow gradient in these reaches reduces flow velocity to the point where it resembles standing water. This is a condition required for good growth of aquatic vegetation. In addition, since flow is reduced, these reaches have a tendency to flood. The timing of floods, their periodicity, and degree of drawdown are important factors involved in the maintenance of the marsh. This is true, for example, in the Peace-Athabasca Delta (Fuller and La Roi, 1971) and anywhere that vigorous stands of marsh vegetation are maintained. One section of the river where channel modification is proposed, the reach at the confluence with the Riviere Qui Barre, does not presently support a growth of marsh vegetation. This is probably a result of the overriding effect of siltation in this section of the river (see Photo 9). The reduction of plant growth in turbid water through blockage of light necessary for photosynthesis has previously been pointed out. An additional factor adversely affecting plant growth and operating in conjunction with the siltation factor is the tendency of this reach of the river to experience violent fluctuations in water level at any time during the spring or summer. Fluctuations in this reach of river are greatly exaggerated relative to fluctuations in other sections of the Sturgeon for the following reasons:

a.) the flow of the Riviere Qui Barre is contributed to this reach of the Sturgeon River,

b.) both the section of the Sturgeon River upstream from the reach in question and the Riviere Qui Barre are characterized by surrounding land cleared of forest cover which contributes to a large amount of runoff and siltation when precipitation occurs, and

Photo 9: Turbid water in the Sturgeon River downstream from its confluence with the Riviere Qui Barre. Turbidity reduces light penetration required for photosynthesis with the result that few emergent or submergent plants required by waterfowl and muskrats were found in this reach of the river.

c.) the distance of the reach in question from natural reservoirs is farther than the other reaches where channel modifications are proposed i.e. the other reaches are at the outlets of Lac Ste. Anne, Matchayaw Lake, and Big Lake.

Reservoirs have a dampening effect on water flow and flooding (Gunter, 1957). The dampening effect of Big Lake on flows in the Sturgeon River was well illustrated in July 1971. The peak flow at Villeneuve was 1060 cfs on July 14 while the peak at Fort Saskatchewan for July was only 624 cfs on July 27 (flow data from Water Survey of Canada, Department of Environment). The resulting violent fluctuations in water levels are not tolerated by marsh vegetation, a fact which has been well documented and was discussed above. With specific reference to rivers, Edwards (1969) stated that rapid runoff of rainfall is a characteristic feature of a denuded South African landscape which causes large fluctuations in river levels with a consequent reduction of aquatic plants.

Considering all reaches of the river where channel modification is proposed (including the reach at the confluence with the Riviere Qui Barre, and the section from Hoople Lake to Lake Isle) an average of 15.6 indicated* breeding pairs were observed per mile. Sections where channel modification is not proposed averaged 11.1 indicated breeding pairs per mile. Brood

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* indicated breeding pairs includes all pairs observed some of which may not actually breed in the current year.

production, although low in 1971, was higher in the reaches where channel modification is proposed. The difference in waterfowl use of the two areas would be much more pronounced if data on the sections from Hoople Lake to Isle Lake and at the confluence with the Riviere Qui Barre were left out since neither section received significant use by waterfowl.

The extent of losses of waterfowl resulting from channel modification and increased flows will depend upon the extent of the loss of habitat. Straightening of the river channel by cutting off meanders will reduce the total length of the river. In the reach downstream from Big Lake, channel straightening would reduce the length of the reach by approximately one-half. Generally, however, the frequency of meanders in the sections where modification is proposed is not as great as in the remainder of the river.

Oxbows resulting from channel straightening would probably be of little benefit to waterfowl. Since the reaches where modification is proposed are in relatively flat terrain, the area of the individual watersheds of the oxbows would rarely exceed the standing water area and evapotranspiration is expected to exceed precipitation. Van der Valk (1970) found that oxbows along the Pembina River which did not flood experienced an annual net loss of 150 - 400 mm. of water. Since the purpose of channel modification is to enable the Sturgeon River to handle increased flows without flooding, the oxbows formed along the Sturgeon River would not be replenished by periodic flooding. Without periodic flooding, marsh vegetation would not be maintained in the oxbows and a pattern of succession similar to that in the drier oxbows along the Pembina River would probably result. The ultimate successional phase of oxbows would likely be balsam poplar forest.

The elimination of periodic flooding in the Sturgeon River would also retard growth of marsh vegetation in the reaches of the river where modification occurs. Existing marsh vegetation in channels subject to cleaning, widening, and diking would be destroyed during construction and would not be readily replaced. At most, following canalization, vegetation may develop to the degree that it presently inhabits reaches where no canalization is required. However, this would be inferior waterfowl habitat. Waterfowl use and production in such a case would be reduced to an intensity similar to that on the remainder of the river. However, in all likelihood, vegetation would not develop to the degree that it inhabits the remainder of the river, and probably the vegetation in the remainder of the river would be adversely affected. General observations of previously canalized portions of the Sturgeon River indicate a lack of emergent vegetation (see Photo 10). The banks are too steep for emergent vegetation and the substrate resulting after construction may have been unsuitable for the development of both emergent and submergent vegetation.

Siltation caused during canal construction may destroy the submergent vegetation downstream from each canalized section of the river as far as the first downstream lake where silt would

Photo 10: A canalized section of the Sturgeon River downstream from Big Lake. No emergent or submergent vegetation was present along the canalized section. As a result, the section is of little use to waterfowl and muskrats.

probably settle out. Submergent vegetation would thus be either destroyed or substantially altered along the entire length of the Sturgeon River downstream from Lac Ste. Anne. There are several reasons why vegetation which is destroyed may not be replaced following construction. First, the increased gradient and discharge would cause increased current velocity which is detrimental to the establishment of vegetation in any river. The increase in discharge resulting from the diversion of water in the Sturgeon River would be accommodated by an increase in width, depth, and velocity of the water (Leopold, 1962). Second, the increased current velocity would pick up silt and keep it suspended leading to increased turbidity of the water. This would in turn reduce light penetration required for photosynthesis (Ellis, 1936). Third, the incidence of erosion and consequent siltation would be increased as a result of a reduction in forest cover along the stream. Straightening of the channel would reduce the length of forested channel. Since much of the forest cover is restricted to the river channel, new channel constructed to effect meander cutoffs would in many cases pass through fields with no forest cover. Where channels are cut through forested sections, construction would result in a reduction of remaining forest cover. In addition, the cessation of floods adjacent to the river may encourage agricultural use of the land leading to a further reduction in vegetative cover. Leopold (1962) noted that in order to accommodate an increase in discharge, the channel enlarges in width and depth by erosive action. Also, "the width-depth ratios of rivers of comparable size have a great consistency". Therefore, one might expect that erosion of the Sturgeon River bed and banks would occur until the width-depth ratio is comparable to rivers with the same discharge as the Sturgeon following diversion of water from the Pembina River.

The increased silt load carried by the Sturgeon River and resulting from the factors discussed above would probably be diluted by the increased discharge resulting from the Pembina River diversion. This may reduce the turbidity of the water to a level the same or less than current levels. However, the volume of silt in the water would not be changed by dilution and the increased depth of turbid water through which light would have to penetrate to enable photosynthesis would probably compensate for the decrease in turbidity. The length of time for the river to achieve a stable condition with respect to turbidity is unknown, but siltation due to channel degradation will likely continue for a period of several years.

On the basis of the foregoing discussion, and data acquired on vegetation in this study, it appears that the major portion of waterfowl habitat along the Sturgeon River, presently utilized by an estimated 1,700 indicated breeding pairs of ducks, would be destroyed. On the basis of the low observed production of slightly less than one brood per mile of stream, this would indicate an approximate yearly loss of 135 broods on the Sturgeon River.

Assuming a constant diversion flow and channel modification at the outlets of the lakes to exactly compensate for the increased flow, canalization would likely have little effect on the lakes. The rate at which Matchayaw Lake and Big Lake are being filled in by silt deposition would increase due to the increased silt load of the river. If channel modification at the outlets of lakes under-compensates for the increased discharge of the river, water level fluctuations would increase to the detriment of waterfowl and muskrat habitat and waterfowl nesting success. If channel modification over-compensates for the increased discharge, lake levels would drop and fluctuate less. Presumably, however, control structures at the outlets of lakes will insure that lake levels are not lowered by the increased capacity of the outlet channel to drain them.

Although waterfowl would be most affected by environmental changes resulting from channel modification, other wildlife would be affected as well. Ruffed grouse would be affected to the extent that forest cover is removed in conjunction with channel modification. The ecological density of ruffed grouse populations along the Sturgeon River would be similar to the population density in the proposed reservoir areas. Since less mixed forest occurs along the Sturgeon River, the density may be somewhat lower. However, recent studies of ruffed grouse survival (Gullion and Marshall, 1968; Rusch and Keith, 1971) have indicated that benefits to ruffed grouse resulting from shelter provided by conifers may be outweighed by disbenefits due to increased predation since conifers serve as a hunting cover for the major predators of grouse. Actual losses of ruffed grouse could be computed only on the basis of a knowledge of the amount of forest cover which will be removed. However, losses are not expected to be large in terms of numbers, and would likely range in the order of a few hundred birds.

Sharp-tailed grouse, pheasants, and Hungarian partridge would be similarly affected to the extent that cover is removed along the Sturgeon River. The populations of these species fluctuate considerably and no current data are available on populations. For example, in the past pheasants were relatively abundant along the river, then declined to marginal levels. At present, their numbers appear to be increasing. Removal of cover would, however, restrict the capacity of the area to support populations at densities achieved in the past.

Significant beaver populations in the Sturgeon River would be reduced as a result of the reduction in length of the river channel and the removal of forest cover along the edge of the river. The minimum population density of beaver along the Sturgeon River was approximately 0.30 colonies per mile. If, for example 50 miles of existing river channel was shortened and denuded of adjacent forest cover, the loss would be approximately 15 beaver colonies. An average yearly production of 38 beavers would be lost.

Muskrat habitat is almost identical to waterfowl habitat. This habitat, as has been previously stated, would probably be nearly eliminated from the Sturgeon River, and muskrat production would be reduced accordingly.

White-tailed deer would be influenced by losses of cover resulting from canal construction, although deer numbers at present are low as a result of limited habitat. Annual losses would be low and insignificant.

3.) Impact of Lake Level Stabilization:

In general, lake level stabilization within certain limits would be beneficial to waterfowl and muskrat populations. Townsend (1969) recommended that water levels in marshes bordering Lake Winnipeg be stabilized so that most of the time, water levels would vary within two feet. He stated that with natural fluctuations, in 75% of the years, there is a sufficient rise in water to destroy perhaps 60% of the nests; while nest losses of this magnitude would occur in only 30% of the years if water levels were regulated. The detrimental effect of unstable water levels during the nesting season of waterfowl has been documented by several other authors (Johnsgard, 1956; Keith, 1961; Rogers, 1964; Townsend, 1966; Snipe, 1970). These authors reported that nesting success can be reduced by either flooding or drought.

Muskrat populations are also adversely affected by large fluctuations in water levels. Bellrose and Brown (1941) and

Bellrose (1950) found that muskrats in the Illinois River valley were both directly affected by fluctuating water levels and indirectly affected through alteration of the composition of the vegetative habitat. Donohoe (1966) reported that greater populations of muskrats occurred in Lake Erie marshes in which water levels were controlled than in those in which there was no control.

The adverse effect of large fluctuations in water levels on vegetation has been previously discussed. However, several studies have shown that some fluctuation in water levels is necessary for the maintenance of marsh vegetation. Harris and Marshall (1963) found that in Agassiz National Refuge in north-western Minnesota, drawdowns of one or two years duration at five- to ten-year intervals were necessary to maintain the emergent marshes. They suggest that "some species of aquatic plants which are regarded as desirable in marshes have developed adaptations for survival in response to these natural fluctu-ations, even to the point where these plants may actually require such fluctuations for continued survival and seed production". They noted, for example, that cattail and sedges persisted only in shoreline evaporation zones and were gone from continuously flooded areas in 4 - 5 years. Harris and Marshall cited several studies in which it was found that prolonged stabilized water levels have detrimental effects on most species of emergent aquatics. McLeod (1949) suggested that the decline of marsh plants under static or increasing water levels was a result of a loss of fertility and lack of reproduction, and hence a loss of vigour on the part of the plants. Stagnation of vegetation can be detected by the open growth formation of the stand and by the brown color of leaves and stalks of the plants (McLeod et al, 1951). In August, 1971, flooded sedges (plants characteristic of the evaporation zone) and bulrush in Big Lake exhibited these symptoms (see Photos 11 and 12).

With reference to submergent aquatics, Robel (1962) reported a 10% increase in the submergent vegetation crop following a 3-inch rise in the water level of a marsh in Utah. Harris and Marshall (1963) reporting on the effects of a drawdown in a marsh in Minnesota noted a heavy growth of submergents in the first year of reflooding, a moderate to heavy growth in the second year, and a rapid decline in growth in the third and fourth years.

More recently, Fuller and La Roi (1971) stated that the maintenance of productive marsh habitat in the Peace-Athabasca Delta apparently requires periodic fluctuations in water levels as well as complete drawdowns.

Other authors have recommended periodic seasonal drawdowns to expose marsh bottom to improve the quality of waterfowl habitat (Ducks Unlimited, 1963) and muskrat habitat (McLeod, 1949; McLeod et al, 1951).

The proposed reduction in water level fluctuations of Isle Lake and Lac Ste. Anne to within a range of two feet would

Photo 11: A sedge stand showing symptoms of stagnation as a result of prolonged flooding. One symptom is the brown color of the leaves. Another is the open growth formation of the stand--a condition which is incidentally beneficial to waterfowl since it provides a good interspersion of cover and open water.

Photo 12: Evidence of a stand of bulrush having been pushed shoreward by water levels higher than previous years. Bulrush in the deeper zone has been reduced to a sparsely stocked group of broken-off stems.

likely result in an increase in nesting success by waterfowl. The present magnitude of nest losses resulting from flooding alone could only be determined by conducting detailed studies of this problem. However, it is expected that nest losses by certain divers may be significant since Keith (1961) found that the average distance of 18 canvasback nests, 15 ruddy duck nests, and 21 redhead nests were 0 feet, 2 feet, and 4 feet respectively from water. Townsend (1966) found that canvasback, ring-necked duck, and lesser scaup nests in the Saskatchewan River delta averaged 1 - 2 feet from nearest water while mallard and blue-winged teal nests were 6 feet and 17 feet respectively from nearest water.

Muskrats would also probably directly benefit from the reduced fluctuations (Bellrose and Brown, 1941).

The effects of the proposed reduction in lake level fluctuations of Isle Lake and Lac Ste. Anne on their fringe vegetation may be a reduction in the width of the emergent vegetation zone. Previous drawdowns in Isle Lake have been approximately one foot lower than the proposed minimum level. Previous drawdowns in Lac Ste. Anne have been almost two feet below the proposed minimum level. These drawdowns have probably allowed the restoration of soil fertility (through aerobic decomposition of resulting mud flats) of a wider zone around the lakes than will ever be exposed after stabilization. The result would be that soil fertility beyond the proposed minimum level would deteriorate and hence the emergent vegetation occupying the zone would deteriorate. It is not possible to predict the exact amount of the reduction in width of the emergent zone since the edge of the zone does not exactly correspond with the border of the deepest drawdown. After a drawdown occurs, seeds of emergent plants germinate on the mudflat. Subsequent flooding results in a zonation of the different associations depending upon the tolerance of each to varying depths of water. Bulrush, occupying the deepest zone, extends into water beyond the border of the drawdown, usually by asexual reproduction. This extension would probably be reduced by a smaller drawdown.

Submergent vegetation would probably also be reduced by smaller drawdowns. Harris and Marshall (1963) suggested that lowering the water level may modify various factors such as temperature, light intensity, rate of photosynthesis, and growth, any of which may increase fruit production. A decrease in the frequency and depth of drawdown would probably decrease this possibility of fruit production.

Within the proposed fluctuation range of two feet, long term stability of water levels would result in deterioration of marsh vegetation. However, as long as a full two-foot or deeper drawdown is allowed or naturally occurs at least once every 5 years, marsh vegetation would be maintained with little or no losses. The frequency and amount of drawdown necessary to maintain the maximum amount of waterfowl habitat could only be determined during studies done concurrently with actual water-level control.

The overall effect of the proposed lake level stabilization of Isle Lake and Lac Ste. Anne on waterfowl production would depend upon the difference in benefits arising from reduced nest losses due to flooding versus disbenefits from habitat deterioration from stabilized water levels if provisions for drawdowns were not made. It is quite possible that reduced nest loss would compensate for the reduction in habitat with the net result of no change in waterfowl production or an increase in some species (e.g. grebes, scaup). In summary, a managed fluctuation regime as outlined above would in the long term likely increase waterfowl production.

Muskrat use of Isle Lake and Lac Ste. Anne may be presently limited more by wave and ice action than by the amount of marsh vegetation present. The benefits from a reduction in losses due to flooding of lodges would probably outweigh any losses accruing from a reduction in the amount of marsh vegetation.

Although the maximum and minimum allowable levels of Big Lake have not yet been determined in existing projections of the Water Resources Division, it should be noted that Big Lake is one of the best waterfowl production and staging lakes in Alberta and planning to maintain its status is warranted in the formulation of flow and level regime design. The large vegetated shallow portions of the lake provide excellent waterfowl and muskrat habitat. Static water levels over a long term would be detrimental to the maintenance of this habitat. However, existing "natural" fluctuations have become excessive and "unnatural" as a result of flash floods which in turn have resulted from the relatively recent reduction in forest cover in the watersheds of the Sturgeon River and Riviere Qui Barre. Some control of the fluctuations to compensate for these flash floods is therefore warranted. Present fluctuations in water level undoubtedly cause significant losses of waterfowl nests.

The primary aim of water-level control in Big Lake should be to maintain an optimum vegetative cover of the shallow portions of Big Lake (the deltas of the Sturgeon River and Atim Creek) and to minimize nest losses from flooding. In order to maximize the vegetated portion of the lake, the water level should be controlled so that the minimum level which would expose the maximum area of the present shallow portions (2,137') is approximately two to three feet lower than the maximum level (2,140') which would flood the majority of the lake basin. A complete late summer drawdown would be required approximately every five years. The remainder of the time, the water level should remain relatively stable with a drawdown roughly equivalent to the average annual difference between precipitation and evaporation taking place each summer i.e. approximately nine inches.

In order to minimize waterfowl nest losses, the lake level should be kept as stable as possible throughout the nesting season which in 1971 occurred from approximately April 10 to July 30.

The effects of water level control if implemented should be closely monitored with studies of the effects on vegetation and wildlife.

4.) Impact of Reduced Flow in the Pembina River:

Reduced flows in the Pembina River by reducing current velocities would tend to create conditions more favorable than at present for the growth of aquatic and semi-aquatic vegetation. Assuming that if thermal stratification of water occurs in the reservoir, water is expelled from a clear water layer, a reduction in siltation is expected. This would lessen the turbidity of the river making conditions still more favorable for aquatic plant growth. The effects of reduced current velocity and turbidity will probably not be particularly significant since a large part of the Pembina River's water and silt are added below the site of the proposed reservoir. However, the reduced current velocity and reduced turbidity in combination with a reduction of violent water-level fluctuations in the river would undoubtedly improve plant growth in the Pembina River. This improvement may compensate for some of the loss of waterfowl habitat in the Sturgeon River. However the present status of the Pembina for waterfowl is negligible and improvements will not likely be significant.

The reduced flow would probably result in a smaller channel being cut by erosion after some time with the consequent encroachment of bank vegetation. The result would be the gradual transformation of the Pembina River,at least in the reach immediately downstream from the reservoir,into a stream more like the Sturgeon River. This transformation would likely take at least two or three decades.

A loss of waterfowl habitat along the Pembina River will gradually result from non-replenishment of water in oxbows adjacent to the river in the lower reaches. Van der Valk (1970) showed that the maintenance of marsh vegetation in these oxbows was dependent upon periodic floods of the Pembina River. If the floods are discontinued, the rate of succession toward communities tolerant of drier conditions will be increased. It is not known how many waterfowl or muskrats would be affected by this gradual reduction of habitat. However, it is estimated that numbers affected would range in the order of 1,000 - 2,000 ducks and a few hundred muskrats.

Upland bird game, big game and beaver would not likely be affected significantly by reduced flows in the Pembina River. However, these species may be indirectly affected by the extension of agricultural use of land no longer subject to flooding.

5.) Summary of Environmental Impacts of the Dam-Diversion Project:

The formation of reservoirs on the Pembina River and at the Magnolia site will result in the loss of over 12,400 acres of habitat for wildlife. Losses of waterfowl, ruffed grouse, sharp-tailed grouse, muskrats, beaver, mule deer, white-tailed deer, and moose will result in addition to losses of other wildlife species such as small mammals characteristic of the communities to which the above-mentioned animals belong. Although the losses may appear relatively small, they take on a greater significance when considered in terms of the yearly losses in production of each species. When considered in terms of the existing trend towards reduction of wildlife habitat and populations in close proximity to the city of Edmonton these losses take on a still greater significance from a human utilization standpoint.

Changes in the ecology of the Sturgeon River resulting from channel modification and the introduction of water from the Pembina River will result in a deterioration of existing waterfowl and muskrat habitat. Beaver, grouse and big game will be adversely affected to the extent that forest cover is removed along the river. Beaver will also be affected by reductions in the length of the river channel.

The actual losses of current numbers of wildlife are small, however, cumulative losses of annual production are more significant.

Lake level stabilization would result in benefits to waterfowl and muskrats if properly controlled. Potential benefits resulting from water-level control on Big Lake could compensate for at least some of the losses elsewhere. However, stabilization, resulting in water levels which are too static on any of the lakes, would result in a reduction in the amount of waterfowl and muskrat habitat over a period of years.

Reduced flow in the Pembina River will eliminate or reduce the frequency of floods. This will result in succession of the marsh vegetation in the oxbows to communities more tolerant of the drier conditions meaning a loss in waterfowl and muskrat habitat and gains for terrestrial species if succession is unaltered. Reduction of flooding along the Pembina River may encourage agricultural development of the areas no longer flooded with the result that upland habitat may be destroyed. Reduction of flooding, current velocity and turbidity may improve waterfowl habitat in the river, thus compensating for some of the losses on the Sturgeon River.

Losses resulting from each aspect of the dam-diversion project add up to a significant total when considered in the context of the relatively accessible area within 60 miles or less of Edmonton. The possibility of potential compensation for losses of waterfowl and muskrats via properly monitored lake level control should be studied carefully.

C. Predicted Impacts of Proposed Water Management Projects on the Pembina-Sturgeon Fisheries:

Proposed water management projects involving the Pembina and Sturgeon rivers, provide for the creation of reservoirs on both systems and subsequent alteration of downstream condition. Adverse ecological effects should be balanced against potential benefits to determine ecological feasibility. In order to assess probable losses and potential benefits to sport fisheries, the pre-impoundment stream quality and status of fish populations should be evaluated. Ecological studies were carried out on the Pembina and Sturgeon rivers during the open water period of 1971 to enable the prediction of probable impacts (Volume 1, 1971).

As a result of the complex nature of the water management schemes, which are extremely flexible, it is difficult to determine accurately, the probable fishery potential for a reservoir or to determine the type and severity of downstream effects. In addition, reservoirs are extremely variable in their ability to maintain a fishery, owing to differences in basin configuration, watershed characteristics, climatic conditions and most important, their prevalent water level control scheme. Certain environmental features of regulated systems are, however, typical to a large degree. Therefore it is possible to incorporate pertinent data, determined for other reservoirs, into an evaluation of the proposed Pembina and Magnolia reservoirs.

Reservoir management practices in the past have been orientated towards the provision of flood control, hydro-electric power, and storage for water diversion needs. Management to maximize recreational attributes has not been a major objective, although some reservoirs have excellent recreational capabilities, as a valuable by-product.

The ever increasing demand on existing recreational areas, which is particularly evident in the Edmonton region, necessitates critical appraisal of all water management projects which can convey large benefits, or alternatively, result in significant losses.

The following sections examine the probable fishery potential in proposed reservoirs and discuss possible adverse downstream effects. Changes in the current proposals which would create significant benefits to the fishery, are indicated.

1.) An Evaluation of Fishery Potential of Proposed Reservoirs:

The Pembina reservoir would be located south of Entwistle on the Pembina River and the Magnolia reservoir on the headwater reaches of the Sturgeon River. The Pembina reservoir would provide partial downstream flood control and a limited diversion flow to the Sturgeon River system. In conjunction with the Magnolia reservoir it will provide almost total flood control and could be established as a link in the transfer of additional Athabasca Basin water (from the McLeod River) to the North Saskatchewan River.

In order to provide benefits to fishery and recreational resources, a reservoir must have a long range value, which exceeds irreversible losses due to inundation of stream channel and adverse downstream effects.

a.) Pembina Reservoir:

1.) Losses to Inundation:

Inundation will result in the loss of approximately 30 miles of the Pembina River. The ecological study, (Volume I, 1971) indicated the presence of some good to excellent mountain whitefish habitat in the proposed reservoir site. Walleye and northern pike are also present in the proposed reservoir site. Walleye and mountain whitefish, due to the specificity of their habitat requirements, are distributed sporadically. However, both species can be locally abundant which tends to override the limited distribution. Favorable northern pike habitat is minimal and existing populations are probably not substantial.

The loss of mountain whitefish habitat in the reservoir area will have the greatest significance for two reasons: (1) the species will not contribute to a reservoir fishery, and (2) the species adds diversity to the present composition of gamefish in this section of the river, which tends to increase recreational value. Although the inundation will eliminate the riverine populations of walleye and northern pike,the losses could be tempered by successful establishment of walleye and pike fisheries in the reservoir.

The reservoir will create a barrier to movement of fish on this section of the Pembina River, although evidence to substantiate movement of fish has not been documented. This does not, however, preclude the existence of migration by mountain whitefish or walleye in search of suitable spawning or winter habitat.

This proposed reservoir site includes some of the most picturesque reaches of the entire Pembina River, a fact which contributes a great deal to its recreational potential.

2.) <u>Pertinent Data for the Proposed Pembina Reservoir</u>:

Basin configuration and water management objectives are important in determining biological productivity attributes of a reservoir. Predictions of potential productivity in the Pembina Reservoir have been based on the following criteria and operational characteristics proposed for the Reservoir.

The dam would be a zoned earth fill type which will create a reservoir some 12 miles long, with a maximum width of 2 miles and a maximum depth of approximately 175 feet (at FSL). The dam would have a crest elevation of 2600 feet (above MSL). At a maximum water level of 2595 feet the reservoir will flood 4500 acres and impound 400,000 acre feet of water. At full supply level of 2575 feet, the storage volume will be 265,000 acre feet which will flood 4050 acres. The minimum pool elevation will be either 2550 or 2500 feet depending on the amount of diversion water to be supplied. The storage volume at 2550 feet, 165,000 acre feet, would flood 3200 acres. At 2500 feet, 50,000 acre feet will flood 2500 acres. The higher minimum pool level will permit a live storage capacity of 100,000 acre feet, compared to 210,000 acre feet for the lower level.

Due to the relatively small storage capacity of the reservoir, storage volume will have to be regulated judiciously, to provide maximum flood control. Accordingly the top priority will be to maintain an adequate live storage capacity to handle floods and secondarily to maintain maximum feasible water levels to develop the benefits of diversion. As a result, it will be necessary to draw down storage volume following the spring runoff to accept flood waters in summer. The degree and rapidity of drawdown will depend on the severity of the oncoming flood, the ability of managers to make predictions in advance, and the actual level of the reservoir at the time of flood. It is also assumed that water level will be maintained at the maximum feasible level for the remainder of the year. A steady decline in water level would occur during winter resulting in a minimum annual level by spring.

3.) Factors Limiting Reservoir Productivity:

A reservoir resembles a natural lake in that it provides a basin for a large volume of standing water. However, the proposed Pembina Reservoir,because of the artificial nature of its basin and regulated water levels,will probably limit successful propogation of gamefish for several reasons which will be discussed in the following sections. The severity of limiting factors on gamefish species is variable, owing to the differences in life cycle and habitat requirements of individual species.

Reservoirs, typically exhibit a high initial fertility, in contrast to natural glaciated lakes, due to the inundation of fertile topsoil areas rich in organic materials (Ellis, 1936; Kimsey, 1958; Neel, 1963). This phenomenon has been called the "new - land effect". Decreased productivity is associated with "stratification, density currents, rapidity of water replacement, most frequent withdrawal level and prevalent operation practices..." (Neel, 1963). Reservoir fisheries in California usually responded commensurately to provide "high initial fishing success, a sharp decrease and then a gradual rise to a fishery somewhere near half the magnitude of the initial phase." (Kimsey, 1958). The various limiting factors and their relationships to fish productivity, for the Pembina reservoir, are discussed in the following sections.

Fluctuating Water Level: Fluctuating water level combined with the characteristic "flushing" of nutrients results in the leaching out of the fertility of the basin (Kimsey, 1958). In addition, large or rapid fluctuations result in the formation of sterile littoral zones.

Alternately dehydrating and flooding littoral areas (shallow shore zones) inhibits production of aquatic, semi-aquatic and terrestrial plants. Littoral vegetation combines with planktonic organisms to provide basic productivity in an aquatic ecosystem. In addition, well developed littoral areas provide habitat for numerous food organisms, spawning habitat and shelter for adult gamefish and rearing habitat for immature gamefish. A reservoir subject to large fluctuations is surrounded by a wide zone of exposed shoreline for considerable periods of time. This zone, which is flooded only at maximum storage volume, increases wind exposure and subsequent disturbance of the shore areas which further retards littoral development.

Water level fluctuations can be expected to limit the abundance and diversity of benthic invertebrate fauna in the littoral zone which will be detrimental to the establishment of a diversified, stable fishery. Fillion (1967) indicated the presence of restricted benthic fauna in the drawdown zone of three reservoirs in southwestern Alberta. Maximum abundance and diversity occurred in regions not exposed by fluctuating water levels.

The degree of fluctuation and its significance to a fishery will vary among reservoirs, depending on the life history of the gamefish and the timing and duration of drawdowns. As a general rule, however, the maintenance of water levels at maximum feasible level, throughout the year, will usually coincide with the best interests of the fishery.

The Pembina River is easily influenced by precipitation in the watershed owing in part to excessive land clearing. Continued forest removal will further increase the tendency of the Pembina River to flood. As a result, the proposed Pembina Reservoir will likely experience extreme fluctuation in water level, and will provide an unstable situation for gamefish. A drawdown, to achieve 100,000 acre feet storage capacity, will expose 850 acres of previously flooded area, which represents 20% of the surface area at full supply level. Heavy drawdown, will dehydrate littoral vegetation during the summer and expose it to freezing during the winter. Littoral development will be severely limited under these conditions.

Since northern pike are extremely dependent on the littoral zone the establishment of a substantial pike fishery cannot be expected. Although conditions in certain years may permit some littoral development it will be restricted in other years resulting in low production and survival of entire year classes. Strong year classes of pike in Lake Oahe, South Dakota, are associated with slowly rising water levels, flooded vegetation and continuation of higher water throughout early summer (Hassler, 1970). Decrease in water level, following the spring spawning period, will impose a further restriction on reproductive success in the Pembina Reservoir due to reduction of valuable rearing areas. Significant mortality at the egg stage can be caused by heavy silt deposition due to bank slumping and wave action (Hassler, 1970). The incidence of bank retreat, which might be substantial, plus the exposed nature of the littoral zone in the proposed reservoir, further decrease the likelihood of year-to-year reproductive success. Any alterations in the water management scheme which will permit permanent establishment of littoral vegetation, either aquatic or terrestrial, and maintain high water levels throughout the summer would favor the development of a pike fishery. It appears, however, that manipulation of water levels, to promote littoral development is not consistent with flood control and diversion objectives.

Walleye do not require the presence of littoral vegetation for reproductive success, however, limited littoral development is generally associated with a low diversity and abundance of forage fish, an important food source of the species. Successful establishment of walleye, however, may depend on the availability of rock, rubble, or gravel substrate. In the Pembina Reservoir, a lack of preferred substrate can be expected due to sedimentation in the basin. Potential spawning areas are present in upstream sections of the Pembina River, however, the potential of utilization by walleye is unknown. Due to excessive substrate siltation in Canton Reservoir, Oklahoma, walleye spawning is restricted to the gravel rip-rapped face of the dam (Grinstead - cited in Hall, 1971). However such an alternative will not be available to walleye in the Pembina River, since slope protection will be provided by soil cement. It appears as though walleye will be limited by drawdown, which will inhibit littoral development, and by a lack of suitable spawning area. Combined,these factors preclude the establishment of a viable walleye fishery in the reservoir.

Level of Withdrawal and Stratification: In addition to inadequate littoral development, productivity in a reservoir can be reduced by low-level withdrawal of water and certain stratification patterns. Stratification involves the formation of three layers within the water column. The epilimnion, or upper layer, is continually turbulent due to mixing currents derived from the surface winds which results in a uniform water temperature throughout. Primary production by phytoplankton is mainly restricted to the epilimnion since it is able to provide both turbulence and incident radiation. The metalimnion, or middle layer, indicates the maximum depth of mixing and acts as a barrier between the epilimnion and the hypolimnion below (Ruttner, 1952). The hypolimnion characteristically has a lower temperature and is a zone rich in "un-utilized and regenerating nutrients" (Murphy, 1962).

Stratification will likely occur in the proposed Pembina Reservoir during the summer months when withdrawal is minimal and occurring via the low level outlet. The outlet is situated at a depth of approximately 175 feet (at FSL) which will result in withdrawal of water from the hypolimnion and a subsequent decrease in the nutrient store of the reservoir.

Hypolimnial withdrawal is also effective in deepening the epilimnion which imposes limitations on the phytoplankters which are forced to inhabit waters of insufficient incident radiation for an increasing portion of their life cycle (Sverdrup, 1953 cited in Murphy 1962). Turbidity in the mixed upper layer causes a rapid decrease in depth of light penetration. The epilimnion must necessarily be shallower in turbid situations to allow maximum phytoplankton production. Turbidity could be a significant factor limiting production during part of the growing season in the Pembina Reservoir.

Removal of water from the epilimnion, on the other hand, will bring about a "thinning effect" and subsequent increased photosynthetic efficiency. Productivity would be increased even further by the mixing of deeper water, which is richer in nutrients, into the productive zone, and thereby conserving the store of basic nutrients in the reservoir (Murphy, 1962). The type and incidence of stratification, and more specifically the mixing depth, cannot be predicted accurately and will vary from year to year. A permanent low level outlet in the Pembina Reservoir will preclude maximum primary production. Murphy (1962) advocated research into the possibility of a completely flexible outlet. Removal of water from upper levels may not be feasible, however,the limitations on littoral development imposed by drawdowns increase the importance of maximum primary production in the limnetic zones (open water zones).

Sedimentation: Some of the adverse effects of sedimentation have been previously mentioned as they relate to reproductive success of gamefish and in reducing primary productivity when in suspension (turbidity). In addition, sedimentation in the reservoir will reduce its life span and could significantly alter limnological characteristics. Sedimentation can be autochthonous, i.e.; formed with the basin, due to bank retreat, or allochthonous, added from the upper watershed. Large additions of settled sediment will probably result in the formation of a delta at the upstream end of the reservoir. Down reservoir displacement of silt is brought about "by later currents or by bed and bank erosion of channels cut through the silt deposit following water level decline" (Neel, 1963). This not only results in a shallower basin, but is effective in covering over productive bottom sediments. Due to the easily erodible nature of the banks along the upper Pembina River and adjacent to the reservoir a large sediment load can be expected. This will become more evident as further land clearing is carried out resulting in more frequent and severe floods in the upper Pembina River and greater water level fluctuations in the reservoir.

Density currents are also effective in transporting sediments throughout the reservoir. During periods of thermal stratification, inflow water differing in temperature will rise or sink upon entering the reservoir to a level with a similar density. These layers form a density current and usually retain their character until they reach the dam face. Suspended sediment in the inflow increases the density often to the extent that the turbid water forms a density current which transports sediments throughout the basin. Density currents are responsible for "bottomset siltation", that affects large areas of a reservoir (Neel, 1963). Thermal stratification in the proposed Pembina Reservoir and the occurrence of summer flood discharges high in turbidity could result in transportation of sediment throughout the reservoir basin, to the detriment of the fishery.

4.) Summary:

Inundation will result in the loss of 30 miles of the

Pembina River, which will include significant losses of mountain whitefish and walleye habitat and a smaller amount of northern pike habitat. The loss of pike and walleye habitat could be tempered by the successful establishment of a pike-walleye fishery in the Pembina Reservoir. However, the present water management objectives combined with the relatively low storage capacity of the reservoir will result in an unstable environmental situation with respect to water level. Fluctuating water levels will probably preclude development of extensive littoral vegetation. This will reduce the overall productivity of the reservoir and will limit severely the reproductive success of northern pike. Heavy siltation would result in low hatching success for pike. In addition, sedimentation in the reservoir will probably further reduce the availability of preferred spawning substrate for walleye.

The low level outlet will, during periods of stratification result in removal of hypolimnial water and a subsequent reduction in the nutrient store of the reservoir. The basin will receive large quantities of sediment both from bank retreat and from the upper Pembina watershed. This will result in a shallower basin and a covering of the productive bottom sediments. According to presently formulated management plans, the Pembina reservoir would sustain only marginal fish populations and as a result would have a limited fishery potential.

b.) Magnolia Reservoir:

1.) Losses to Inundation:

Unlike the Pembina Reservoir, inundation losses at the Magnolia site will be negligible due to the deteriorated, intermittent status of the upper Sturgeon River. Net benefits of the fishery then would involve only the fishery potential of the proposed Magnolia Reservoir balanced against benefits or disbenefits of injecting diverted water into the lower Sturgeon system and losses to the Pembina River system due to removal of water.

2.) Pertinent Data for Proposed Magnolia Reservoir:

Predictions of total productivity and fishery potential in the proposed Magnolia reservoir are based on a reservoir constructed to the following specifications and primary management objectives.

The dam will be an earth filled type which will create a reservoir capable of flooding a total of 7900 acres (at 2550 feet above MSL) and storing approximately 430,000 acre feet at FSL. The maximum depth at FSL will be approximately 125 feet. The potential minimum pool elevation of 2465 feet will flood an area of 300 acres and store 30,000 acre feet of water. At 2536 feet, the probable minimum pool elevation, approximately 6800 acres will be flooded and 330,000 acre feet of water can be stored. The latter minimum pool allows a live storage of 100,000 acre feet, however, a potential live storage of 400,000 acre feet is available.

The amount of storage available in the Magnolia reservoir will depend on the amount and constancy of diversion water supplied by the Pembina reservoir. Apparently a diversion flow of 200 cfs can be provided at a 99.64% frequency when the Pembina reservoir is providing 100,000 acre feet of live storage. This is in addition to providing a riparian flow of 100 cfs in the Pembina River. Other alternatives involve the diversion of up to 500 cfs but are not considered due to the exceedingly large drawdowns which would be imposed on the Pembina reservoir.

The priority objectives appear to be flood control on the Pembina River and augmentation of low flow in the Sturgeon River. Development of a fishery in the Magnolia Reservoir cannot be considered a valid objective due to the variability of the inflow. It is assumed in this regard that diversion to the Magnolia Reservoir, above 200 cfs (or any other set diversion flow) will occur only if floods occur which cannot be handled adequately by the Pembina Reservoir. In a low flow year for the Pembina Reservoir it can be expected that the minimum pool will approach a storage volume of 30,000 acre feet. The degree of water level fluctuation from year to year will be severe enough to preclude any substantial fishery.

Annual water level fluctuations will also be severe and as effective in precluding development of a substantial fishery. Major injections of water can be expected periodically following spring runoff and summer floods. Preceding the injections the reservoir level will be at a minimum pool level. To benefit downstream users (lake stabilization, etc.) it will be necessary to maintain a substantial outflow. In spring, the Magnolia Reservoir would be at an extremely low elevation. It will be necessary to maintain maximum water levels throughout the summer months, while allowing sufficient live storage to provide flood control.

3.) Factors Limiting Reservoir Productivity:

Fluctuations in water level, on a yearly basis, and on a seasonal basis will preclude littoral development. A drop in elevation at FSL (2550 feet above MSL) to 2536 feet, to achieve 100,000 acre feet of storage, will result in a 25% reduction in volume and 14% reduction in flooded acreage. In a low flow year, the exposed area would be considerably greater. A drop in elevation to 2465 feet, the minimum pool elevation, will result in 95% volume reduction which will flood an area of only 300 acres.

The Magnolia Reservoir will be characterized by a low level outlet (at approximately 110 feet). In addition, the establishment of a fishery will be prevented by other inherent features of the reservoir and its management. However, these factors can be considered of minor importance since the variation in storage volume will alone preclude the existence of a substantial fishery. The Magnolia Reservoir, as proposed, should not be considered since the establishment of a substantial fishery will not occur and removal of Pembina basin water could be detrimental to that drainage system.

4.) Summary:

Inundation losses to the upper Sturgeon River fishery will be negligible as a result of the Magnolia Reservoir. Water is not available in the upper Pembina River drainage to maintain the Magnolia Reservoir in a state capable of supporting a significant fishery. Any attempts at increasing environmental quality will be at the expense of the Pembina Reservoir and the Pembina River downstream. The existence of the Magnolia Reservoir can be rationalized from a fishery viewpoint only if flow augmentation in the Sturgeon River accrues benefits to that fishery to an extent that losses in the Pembina system are justified.

2.) Possible Downstream Effects:

a.) Pembina River:

The effects of a reservoir on downstream habitat quality should be considered the most critical aspect of the proposed water management project. Due to the reservoir's upstream placement in the drainage area and the entry of major tributaries downstream,the downstream effects will be subject to modification. For example, any sediment removal benefits by the reservoir could be reduced by the injection of turbid Paddle River water. Since the Paddle River has severe flood problem this will likely occur frequently. The Lobstick River during 1971 remained at a relatively high stage and contributed significantly to the maintenance of flow in the Pembina River. However there was a marked increase in turbidity of the Pembina River below the Lobstick River confluence. Therefore it should be clear that all downstream benefits as registered below the reservoir, will not necessarily be accrued throughout the entire lower Pembina River.

The reservoir management objectives will largely determine the extent of losses or potential gains to stream quality. Uncontrolled flooding along the Pembina River is largely an artifact of human activities in the watershed. These include extensive land clearing and agricultural use of land which is naturally subject to periodic over-bank flow. The management objectives which will be most favorable to the Pembina River fishery, and recreational capabilities in general, will be those conceived with the above fact in mind. The needs of the stream biota will be provided best by reservoir discharge patterns which attempt to simulate natural flow conditions. This will involve dampened flood discharges, but the provision of natural flood peaks, and minimum flows which are sufficient to provide suitable winter habitat conditions.

1.) Changes in Flow Regime:

The reservoir will tend to smooth out the discharge, in most instances, by retaining peak flows and augmenting low flows. Retention of the spring runoff, according to proposed management objectives, will be significant since the reservoir will have maximum live storage available. The peak discharge will be substantially reduced and will probably be delayed. The occurrence of summer floods will necessitate a rapid draw-down of the reservoir to achieve adequate live storage. In this instance the entire capacity of the low level outlet, 9000 cfs, would be utilized creating immediate bank-full conditions below the reservoir. During a low flow year it will be necessary to have a constant release of minimum discharge over most of the year in order to maintain maximum storage for diversion, and low flow augmentation.

Flood retention will result in reduced bank erosion, but will also reduce the amount of bed scour (Neel, 1963). A decrease in bank erosion will be beneficial to the fishery, since it will reduce the addition of autochthonous (river induced) sediments. Decreased sedimentation of natural substrate and an increased water clarity will result in higher stream productivity. A reduction in bed scour will occur if natural flood peaks are not provided. This will result in the severe siltation of productive substrate which will adversely affect the river fishery.

2.) Changes in Habitat Quality:

It is extremely difficult to predict changes in water quality downstream from the Pembina Reservoir. The nature and degree of change will vary according to the age of the impoundment, extent and duration of thermal stratification, frequency of density currents, level of withdrawal, extent of drawdown and refill, etc., (Neel, 1963). In addition, the downstream effects will be modified to a varying degree by the Lobstick and Paddle River discharge. Annual precipitation patterns by their effects on reservoir conditions and subsequent water storage management can cause annual variation in downstream water quality.

Some of the effects, however, have been documented for other regulated systems, and will likely apply in this situation. Reservoirs usually provide "complete or near-complete removal of inflowing silt and other suspended materials. However, the presence of muddy underflow or interflow density currents in a stratified reservoir can result in extended periods of turbid discharge, (Neel, 1963). It is more likely that water clarification will occur which when combined with shallow water could result in unusually dense growth of benthic algae. Overproduction of benthic algae could result in dissolved oxygen regimes which are detrimental to gamefish. Dissolved oxygen deficiencies would be expected after photosynthetic production has been terminated either by high discharge of turbid water or during winter. In such cases the abundant organic matter contributes to the oxygen demand of the stream.

The low level outlet will result in withdrawal of water from the hypolimnion. Since hypolimnion water remains cooler throughout the summer changes in temperature regime of the Pembina River below the reservoir can be expected. A delayed temperature rise in spring and a delayed decline in autumn in addition to lower water temperatures throughout the summer can be expected. Another potential result is postponed ice formation and spring breakup (Neel, 1963). Altering the temperature regime might have significant impacts on the fish populations. The lowered summer temperature should not adversely affect gamefish populations directly since the present maximum summer temperatures may approach upper limits, particularly for cold water species. However the tendency of the reservoir to delay temperature trends may be of greater significance. Water temperature is a primary determinant of walleye spawning in the spring, therefore a delayed rise in water temperature could encourage walleye to spawn during flow conditions which do not allow successful propogation. Predictions of this nature are impossible to substantiate, but, possibilities of this nature should be considered whenever temperature regimes are altered.

Discharge from the hypolimnion could contain higher concentrations of un-utilized bicarbonates and other nutrients than would normally be present. This will further increase downstream productivity and will be most noticable in the first years of impoundment, due to the leaching of nutrients out of the impoundment basin. Decomposition in the bottom sediment layer could result in the discharge of water extremely low in dissolved oxygen, or harmful concentrations of decomposition products.

The community structure of benthic invertebrates reflects the physical, biological, and chemical condition of the environment. Spence and Hynes (1971) documented considerable changes in the benthos downstream from a flood control reservoir in Ontario. The factors which were important in effecting the changes were; (1) lowered water temperature due to low level release of water, (2) abundant development of benthic algae, and (3) addition of organic matter from the impoundment. The changes involved a decreased diversity, increased numbers of certain invertebrate species, and a replacement of other species by closely related ones. They compared the changes to those which might occur in a situation of mild organic pollution. The present structure of invertebrate communities in the upper Pembina River is characterized by a relatively high diversity of species (Volume I, 1971). It is expected then, that major environmental changes in the stream will alter this feature of the stream ecosystem.

In order to curtail the current trend of habitat deterioration in the Pembina River it will be necessary to modify present discharge patterns. The Pembina Reservoir, as envisaged by planners, will be effective in smoothing out violent flood discharges, and will result in partial flood control. The downstream discharge pattern however will in no way simulate natural conditions. This will be particularly true if the Magnolia Reservoir is included in the scheme, due to the constant low discharge which is necessary in order to develop the maximum benefits of diversion.

The best interests of the stream biota will coincide with a regulated system with management objectives vastly different from the current proposal. Diversion of the Pembina River should not be considered unless water is available in excess of the amount required to restore natural flow conditions. Reservoir discharge patterns should provide for peak discharges, though not destructive flood stages, and a guaranteed minimum flow which will not restrict gamefish populations during the low flow periods of mid-summer and winter. To determine the actual discharge required to simulate natural peaks would involve a further study and perhaps some experimentation. It would depend, to a degree, on the flow contribution of the Lobstick and Paddle rivers. It appears that insufficient water is available in the Pembina River to allow diversion to the Sturgeon River system. This would preclude the construction of the Magnolia Reservoir.

The Pembina Reservoir, if constructed, should be maintained solely for flood control and stabilizing flows in the Pembina River. The degree to which the reservoir will function successfully will depend on the live storage capacity. The maximum storage capacity will allow a higher riparian flow but will also involve a much greater drawdown. On the other hand, attempts at stabilizing the reservoir level will have deleterious effects downstream. It then becomes a matter of priority, whether to manage for a reservoir or for the benefit of the river. It is felt that even with sound management the fishery potential of the reservoir itself will be minimal, therefore the primary consideration should be to improve upon present condition in the Pembina River.

It is difficult to isolate the critical discharge which will enhance the stream biota. However, on the basis of the 1971 ecological survey it is clear that a constant riparian flow of 100 cfs will not substantially improve the present condition of the river. To effect a marked improvement, guaranteed minimum flows in the order of 300 cfs would be required. However, the provision of maximum feasible riparian flows should be a primary objective, and the importance of natural peak discharges should not be ignored.

3.) Summary:

Partial retention of flood waters will result in reduced bank erosion, and subsequently reduced substrate sedimentation and turbidity. These can be considered benefits to the system. Full retention on the other hand, will preclude occurrence of natural sized peak flows which are important in preventing accumulation of silt in the channel. Removal of destructive floods, higher water clarity, and increased nutrient inflow will probably result in an increased stream productivity. However, sustained discharge of riparian flow throughout the year will result in an overproduction of benthic algae which could be detrimental to the fishery. Increased downstream productivity will be beneficial to the system if the regulated flow regime assures provision of suitable habitat on a yearly basis. A flow regime which resembles the natural pattern and provides the maximum feasible riparian flow will best suit the stream biota. Diversion of water, at the expense of the Pembina River riparian flow or which precludes any provision of natural flood peaks would be undesirable from an ecological standpoint. Low flow is presently limiting the distribution and success of gamefish in many instances. A guaranteed flow of 100 cfs will not substantially increase present stream quality. Riparian flows in the order of 300 cfs would effect a marked improvement. Any downstream effects will be modified by inputs from the Lobstick and Paddle rivers. The influence of these flows are most significant when Pembina River discharge is low and tributary flow high.

b.) Sturgeon River:

Adding diversion water to the Sturgeon will increase present stream quality by providing higher riparian flows. Other limiting factors in the Sturgeon watershed and along the stream banks, however, will probably preclude any substantial benefits to the stream fishery. Existing limiting factors include extensive land clearing, high sediment input, nutrient enrichment, inadequate bank cover, cattle grazing, etc.

The addition of water will necessitate canalization in certain sections of the Sturgeon River. Altered sections have a low suitability to gamefish, due to the existence of a non-sinuous channel, low habitat diversity, poor bank cover and the lack of numerous other natural stream features. Elser, (1968) showed a substantial decrease in standing crop of fish in altered sections of a Montana stream. Through the use of deflectors he was able to simulate natural conditions by providing riffles and deeply scoured pools. Any attempt at recreating natural conditions in canalized sections of the Sturgeon River would impede flow and would not be consistent with the proposal objectives. A stream study in the United States by the North Carolina Wildlife Resources Commission, 1971, has found that canalized sections "have 400% fewer gamefish than natural streams" and have a lower diversity (Ecolert, 1971). Canalization below Matchayaw Lake and Lac Ste. Anne will result in a loss of important spawning and rearing habitat for northern pike and yellow perch. The section below Matchayaw Lake was utilized to a substantial degree in 1971 for spawning and rearing by both species.

Additional study is required to determine the actual value of the proposed canalized sections, as spawning and rearing habitat, to the Sturgeon basin lakes. A secondary objective would be to determine the feasibility, design and best location of artificial spawning marshes for northern pike and spawning areas (or channels) with a gravel substrate for walleye.

Stabilization of Water Level in Lakes of the Sturgeon River System:

Reducing the present degree of fluctuation in the lake levels will be beneficial to their respective fisheries.

However, the existence of outlet structures will necessitate providing passage channels to allow fish movements between the lakes and the Sturgeon River, particularly to provide access to potential spawning and rearing areas.

D. Ecological Impact of Proposed Pembina-Sturgeon Developments in a Provincial Context.

The foregoing report and discussion has been largely confined to the ecological impact of proposed changes within the specific river basins involved. Changes will, in many cases, significantly alter the ecosystems involved, their flora and fauna. Since river systems are involved it is worthwhile to priorize the significance of these changes both in terms of the actual developments as well as in a broader regional and provincial scope.

Invariably, the simplest measures of significance which can be applied are economic values. Unfortunately, in the consideration of ecological changes and aesthetics pertaining to wildlife and the natural environment, no suitable criteria for directly assigning dollar values have been developed in current economic methodology. Indirect measures of expenditures related to outdoor recreation or consumptive activities such as hunting, fishing, etc., are often applied in cost-benefit analysis for management decisions in resource development. However, at best these provide a deficient representation of a multiplicity of variables involved in ecological disturbances, particularly aesthetic factors and long term ecological values for which there are few economic yardsticks. Expressions of public opinion and projections of requirements for outdoor oriented recreational activities are the primary measures of importance, and these also vary according to a variety of factors.

An economic appraisal is not within the purview of the study conducted, and as mentioned few relevant data exist to conduct such an analysis. Objective measures of impacts are piecemeal at best. Thus we can compare the market value of furbearing animals and losses or gains which would occur as a result of development. Similar data are more difficult to apply to unpriced commodities, and thus the analysis is immediately deficient or data are not relevant. For example, a recent exhaustive study of the value of waterfowl concludes that waterfowl production creates greater economic benefits than the use of some lands for farming. The study showed that the value of a duck bagged in North America in 1968 was between $3.70 and $7.60 and that acquisition of wetlands could be justified for waterfowl production alone, not to mention alternative recreational uses or benefits. Thus, in a North American context the value of duck production lost or gained as a result of water developments could be measured for the Sturgeon-Pembina systems on the basis of data obtained in this study. While such a statistic is useful, it is not readily adaptable to regional or provincial economic circumstances. The economic benefits resulting from waterfowl production do not necessarily accrue to the producer of the resource in this case and may, in fact, constitute a disbenefit (e.g.; duck damage to grain crops of prairie farmers).

Viewed from the standpoint of wildlife production alone, the areas of both river systems where losses or ecological disturbances will be sustained are not significant in a provincial context. In all species studied, the disruption of habitat and wildlife populations represents a fraction of a percent of provincial wildlife and habitat resources. None of the species are unique to the area, or rare or endangered. All have generally widespread distribution within the province.

The foregoing, however, is not meant to minimize the impact within the basins or regionally. Several factors must be reconciled in the assessment of ecological impact and the above comments are designed, as the section heading implies, to present various perspectives of the significance of the proposed developments.

Two factors pertaining to the assessment of impact have considerable importance in the present situation. One is the proximity of the basins to the largest urban population in the province, second is the cumulative aspect of habitat losses. These are sufficiently important to receive separate consideration.

1.) Cumulative Habitat Losses in Alberta:

As a result of land clearing, marsh drainage, urban and industrial expansion and increase in population, the natural environment of Alberta is being constantly and progressively altered. In the aspen parkland region of the province, wildlife habitat and natural areas are particularly subject to extensive losses as a result of the foregoing factors. Land clearing and drainage of wetlands for increased agricultural production constitute two of the more significant wildlife habitat losses. Pollution, both industrial and domestic in its various forms has altered and continues to alter ecosystems to the detriment of a wide variety of ecological relationships. Not only are the above factors operating directly to modify ecological balances, but secondary impacts exert a substantial influence. A case in point exists in the Pembina - Sturgeon basins where extensive clearing has altered watersheds sufficiently to create rapid runoff, extreme fluctuations in the water regime and subsequent problems of flooding which adversely affect both human populations as well as the natural environment. The impact of severe water level fluctuation has been discussed at various points in this report. Combined with the above, cultural practices in agriculture have further altered the watershed of the Sturgeon River by creating a trend toward eutrophication of the watershed. As a result, an assessment of the significance of water management developments must recognize that the ecosystem has already been altered from its pristine condition to such an extent that suitable management may in fact contribute towards developing conditions more closely resembling the pre-development era. The manipulation of water levels on lakes is a case in point.

Those factors resulting in ecosystem changes, and more specifically, habitat losses have been occurring over a long period of time and at an accelerated rate as technology improves and human demands increase. The key point is that these activities are cumulative and occur concurrently across the province. Habitat losses are, by and large, permanent and losses exceed gains (such as occur in abandoned land or management or rivers to increase fish production). Thus, while any one development viewed alone, appears relatively innocuous, and may be a relatively insignificant portion of the provincial total, or of the total provincial resource, developments combined often result in highly significant or even critical impacts.

The point at which an additional loss becomes critical is impossible to ascertain. It depends in part on public values and in part on the requirements of a species for survival. Thus, whether we have production of bighorn sheep in national parks in perpetuity, and extinction or maintenance of the species in other areas, is but a matter of public priorities. The biological requirements for the species are more readily ascertained but the same principles apply, i.e.; the maintenance of widespread populations for various forms of public utilization and benefit versus the maintenance of a few individuals in managed circumstances. The motivation for present wildlife management is to maintain populations of wildlife and their habitat for a wide range of public use. These range from viewing in a natural setting and the aesthetic value of the natural habitat itself, to sustaining a harvestable surplus of wildlife for consumptive activities such as trapping, hunting and fishing.

Returning to present proposals for the Pembina - Sturgeon basins, we find that although the development would not significantly affect the status of any species involved in a provincial context that the changes which would accrue represent additional losses to those occurring simultaneously in several other areas and in many other ways. As mentioned, the point at which such changes achieve critical status is difficult to ascertain since public values are involved. These change frequently, particularly in response to scarcity. Thus the proposed developments will not significantly alter the status of waterfowl, muskrat or fish in Alberta. Changes will be localized in nature, and at that level, are of greater significance. It is at that level that the study and this report have been predicated.

2.) Proximity to Urban Populations:

The second factor which most governs the significance of proposals from the human - wildlife standpoint is the proximity of the river basins to the large urban population of greater Edmonton and the recreational opportunities provided by these river systems. Both river systems occur within "day trip" travelling distance of Edmonton and provide diverse recreational opportunities and potential opportunities, many of which are related to wildlife, water, or the natural landscape. The proximity and usability of existing resources place a much greater value on the available features provided by these systems than would otherwise be the case. Thus, although pike are not a highly prized sport fish in most areas of the province, their presence within a close distance provides a significant fishing attraction, particularly for short term family outings. The presence alone of a natural watercourse has its own attraction. Similar parallels could be drawn for other attributes of the systems; locations for picnicking, potentials for hunting; boating, etc. For these reasons it is perhaps most useful to consider that the most significant aspects of development as they pertain to the basin ecosystems are within the local or regional context. For example, Big Lake has been cited as a very important waterfowl production area in Alberta from the biological standpoint. Apart from this fact, the potential for recreational utilization based upon its wildlife and natural features has been the subject of various development proposals.

While specific and objective parameters for measurement of ecological benefits and disbenefits cannot be presented for reasons discussed above, the foregoing serves to create a framework for assessing the relative significance in social terms of the impact of proposed developments. Biological significance has been dealt with in detail in the various segments of this report. However, to summarize those facets of benefits and disbenefits discussed, a subjective tabular representation has been prepared. It is emphasized that the following must be viewed with the foregoing discussions in mind. The following has been summarized according to various components of the development proposals and is intended to briefly portray the main impacts to be expected, their relative importance, and mitigating features. The recommendations which conclude this report provide details of remedial measures which would minimize adverse impacts and management programs which would create additional benefits, and perhaps improve productivity of the ecosystems for specific species or groups of species.

E. Tabular Summary of Impacts:

Stabilized Lake Levels

	Impacts Adverse	Impacts Beneficial	Management Req'd for Benefits
Waterfowl		Potentially beneficial	*
Fur-Bearer		"	*
Big Game	Negligible		
Upland Birds	Negligible		
Sport Fish		Potentially Beneficial	*

Magnolia Reservoir

Waterfowl	Moderate
Fur-Bearer	Moderate
Big Game	Severe
Upland Birds	Severe
Sport Fish	Negligible

Increased Flows and Canalization on the Sturgeon River

Waterfowl	Severe
Fur-Bearer	Severe
Big Game	Moderate
Upland Birds	Moderate
Sport Fish	Moderate

Pembina Reservoir

	Impacts Adverse	Impacts Beneficial	Management Req'd for Benefits
Waterfowl	Negligible		
Fur-Bearer	Moderate		
Big Game	Severe		
Upland Birds	Severe		
Sport Fish	Moderate		

Pembina Reservoir Effects on Downstream Conditions

	Adverse	Beneficial	Management Req'd for Benefits
Waterfowl	Moderate		
Fur-Bearers	Negligible		
Big Game		Negligible	
Upland Birds		Negligible	
Sport Fish		Moderate	*

The most important impacts according to species and their habitat will be on waterfowl, upland bird game, and fur-bearers in the Sturgeon Basin and sport fish and upland bird game in the Pembina system.

F. Recommendations:

On the basis of an evaluation of the expected ecological impacts of proposed water resource developments, several recommendations have been synthesized. In the case of developments which provide net ecological benefits, management programs which will increase benefits are suggested. In the case where losses will occur, remedial measures which will minimize adverse impacts are proposed.

1.) Re: Lake Level Stabilization:

Water level stabilization in the Sturgeon basin lakes is recommended to maintain lake levels and reduce flooding. Implementation of the following management criteria for lakes are recommended.

Proposed water level control on Isle Lake (between 2,393' and 2,395') and Lac Ste. Anne (between 2,372.5' and 2,374.5') is potentially beneficial to waterfowl, muskrats, and fish. Allowance should be made for a drawdown of at least two feet every four or five years to restore vigorous littoral development.

Water levels should be stable during spring and early summer, with the drawdown commencing in July and being completed by the first week in August. The exposed zone should be gradually reflooded in mid-September.

Water level on Big Lake should be controlled so that at the minimum lake level a maximum percentage of the Sturgeon River and Atim Creek deltas is exposed. The maximum level should be approximately three feet higher than the minimum level and should flood a maximum area of the deltas. In order to achieve the foregoing, the minimum lake level should be approximately 2,137 feet and the maximum should be approximately 2,140 feet. A complete three-foot drawdown should be allowed every four or five years. Timing of the drawdown should be similar to that recommended for Isle Lake and Lac Ste. Anne.

The effects of all water-level manipulation should be properly monitored so that unforeseen problems may be dealt with.

2.) Re: Canalization:

Canalization will result in substantial losses to both fish and wildlife. If canalization is undertaken, in order to minimize losses to fish and wildlife, the following practices are recommended:

a.) Channel capacity should be increased by dredging rather than meander cutoffs where possible,

b.) canalization should involve minimum removal of forest cover,

c.) stream bed margins in canalized sections should be gradually sloped to facilitate establishment of littoral vegetation, d.) revegetation programs should be developed to stabilize exposed banks,

e.) extent of spawning and rearing habitat losses should be evaluated followed by examination of possible compensatory measure, if losses are severe.

3.) Re: Water Diversion:

Diversion of flood water from the Pembina River should be considered only if reservoir discharge patterns resemble the natural flow regime and if adequate riparian flows are provided. The proposed riparian flow of 100 cfs will not substantially benefit the river fishery. On the other hand, a riparian flow in the order of 300 cfs and provision for natural sized peak flows will significantly increase stream quality. Present data indicate that insufficient flows are available in the Pembina River to maintain the foregoing condition if waters are diverted to the Sturgeon basin.

Potential benefits of a managed flow regime on the Pembina River exceed benefits expected to accrue to the Sturgeon River fishery following diversion. Thus, intra-basin management is recommended over inter-basin management.

4.) Re: Pembina Reservoir:

The reservoir as presently proposed will be of little value to fish and wildlife. Stabilization of water levels in the Pembina reservoir is inconsistent with flood control objectives, and will be detrimental to the river fishery. It is therefore recommended that if the Pembina reservoir is constructed, augmentation of low flows and a regulated release of flood waters to simulate a natural flow regime be a secondary objective. This would be done at the expense of any potential recreational or faunal benefits of the Pembina Reservoir.

Potential gains to the Pembina River fishery resulting from simulation of a natural flow regime would override losses to the fishery due to inundation of the original stream channel in the region of the reservoir. However, since tributaries, particularly the Paddle River, which also exhibit unnatural flow regimes, will continue to degrade stream condition in the Pembina River, the net benefits of the proposed scheme will not be great.

When irreversible losses of wildlife (grouse, big game, fur bearers), fish and the aesthetic value of the Pembina River canyon (the result of inundation) are balanced against potential gains to the fishery due to flow regulation, the result is a net loss from a strictly ecological viewpoint.

As a result of disbenefits exceeding benefits, from the point of view of ecological considerations, construction of the Pembina reservoir is not recommended. Implementation of foregoing measures on flow management is recommended to minimize ecological disbenefits and maximize benefits to the ecosystem if a dam is constructed.

Before a reservoir is included in the Pembina River system, it is essential that a thorough study of land use practices, both present and expected, be undertaken in the Pembina watershed. The validity of establishing a reservoir in a corrective role is questionable if land use practices which contribute to the original problem continue. A reservoir which adequately fills present needs will become inadequate in the face of uncontrolled watershed abuse. Deterioration of the watershed will continue despite intensive programs of water regulation and management if efforts to correct causative factors are not made.

Programs which might be used to correct causative factors include the following:

a.) aquisition of stream side land on which natural succession would be allowed to establish a buffer zone against cleared land,

b.) enforcement of limited access to the river by livestock,

c.) enforcement of the use of fire guards between land on which stubble is burned and the vegetated zone along the river.

5.) <u>Recommendations for Further Studies</u>:

a.) Intensive studies of waterfowl production on lakes of the Sturgeon River basin are recommended to accurately determine the magnitude of benefits which might be contributed through water level control.

b.) A complete investigation of land use in both the Pembina and Sturgeon River basins should be carried out. The objectives would be 1.) to determine the type and extent of land use practices, 2.) to determine future trends of land use, and 3.) to make specific suggestions regarding implementation of corrective measures, and their probable effect on fish and wildlife populations.

c.) An investigation regarding the feasibility of restoring natural physical features of the stream channel through the use of instream devices and restoration of natural bank cover, should be carried out. This type of program would require partial control over the present erratic flow regime, but if handled correctly could substantially benefit the Sturgeon River fishery.

LITERATURE CITED:

Alberta Water Resources Division. 1970.
Preliminary engineering report on the investigation and design of Magnolia Dam. Prepared for Saskatchewan-Nelson Basin Board.

Bellrose, F.C., and L.G. Brown. 1941.
The effect of fluctuating water levels on the muskrat populations of the Illinois River valley. J. Wildl. Mgmt. 5(2):206-212.

Donohoe, R.W. 1966.
Muskrat reproduction in areas of controlled and uncontrolled water-level units. J. Wildl. Mgmt. 30:320-326.

Ducks Unlimited (Canada) 1963.
Manitoba wetland inventory. Ducks Unlimited (Canada).

Ecolert, 1971
Stream channelization damages fishing in U.S., Vol. I, No. 24, E0924, Orba Information Limited, 418 St. Sulpice Street, Montreal, Canada, cited from Wall Street Journal, October, 1971.

Edwards, D. 1969.
Some effects of siltation upon macrophytic vegetation in rivers. Hydrobiologia 34:29-37.

Ellis, M.M. 1936.
Erosion silt as a factor in aquatic environments. Ecology 17:29-42.

Elser, A.A. 1968.
Fish populations in relation to major habitat zones and channel alterations. Trans. Amer. Fish. Soc. 97:(14) 389-397.

Fillion, D.B. 1967.
The abundance and distribution of benthic fauna of three mountain reservoirs on the Kananaskis River in Alberta. J. Appl. Ecol. 4:1-11.

Fuller, W.A. and G.H. La Roi. 1971.
Historical review of biological resources of the Peace-Athabasca Delta. Presented at the Peace-Athabasca Delta Symposium, January, 1971.

Grinstead, B.G.
"Reproduction and some aspects of the early life history of walleye, *Stizostedion vitreum* (Mitchill) in Canton Reservoir, Oklahoma." in Reservoir Fisheries and Limnology. Edited by G.E. Hall (Washington D.C., American Fishery Society, spec. pub. No. 8.)

Gullion, G.W. and W.H. Marshall. 1968.
Survival of ruffed grouse in a boreal forest. Living Bird 7:117-167.

Gunter, G. 1957. Wildlife and flood control in the Mississippi Valley. Trans. 22nd North American Wildlife Conference pp. 180-195.

Harris, S.W. and W.H. Marshall, 1963.
Ecology of water-level manipulations on a northern marsh. Ecology 44: 331-344.

Hassler, T. J., 1970.
Environmental influences on early development and year-class strength of northern pike in lakes Oahe and Sharpe, South Dakota., Trans. Amer. Fish. Soc. 99:(2) 369-376.

Johnsgard, P.A. 1956.
Effects of water fluctuations and vegetation change on bird populations, particularly waterfowl. Ecology 37: 689-701.

Kimsey, J.B. 1958.
Fishery problems in impounded waters in California and the lower Colorado River. Trans. Amer. Fish. Soc. 87. 319-332.

Leopold, L.B. 1962.
Rivers. American Scientist: pp. 511-537.

McLeod, J.A. 1949.
Some aspects of muskrat management in Manitoba. Presented at the annual meeting , International Association of Game, Fish and Conservation Commissioners. Winnipeg, Manitoba.

McLeod, J.A., G.R. Bondar, and A. Diduch. 1951.
An interim report on a biological investigation of the muskrat in Manitoba, 1950 and 1951. Natural Resources Branch, Dept. of Mines and Natural Resources, Winnipeg, Manitoba.

Murphy, G.H. 1962.
Effect of mixing depth and turbidity on the productivity of fresh water impoundments. Trans. Amer. Fish. Soc. 91: pg. 69-76.

Neel, J.K. 1963.
Impacts of reservoirs. Limnology in North America. (Ed. D.G. Frey) Madison, Wisconsin, pp. 575-593.

Robel, R.J. 1962.
Changes in submersed vegetation following a change in water level. J. Wildl. Mgmt. 26: 221-224.

Rogers, J.P. 1964.
Effect of drought on reproduction of the lesser scaup. J. Wildl. Mgmt. 28(2): 213-222.

Rusch, D.H. and L.B. Keith. 1971.
Ruffed grouse - vegetation relationships in central Alberta. 35: 417-429.

Ruttner, F. 1963.
Fundamentals of Limnology. Transl. D.G. Frey and F.E.J. Fry. University of Toronto Press.

Snipe, J.H. 1970.
The ecological and economic impact of water resources development in southern Alberta: the case of fish and wildlife. M. Sc. thesis, University of Alberta, Edmonton.

Spartan and R.M. Hardy and Associates. 1967.
Pembina flood control project, engineering report.

Spence, J.A. and H.B. N. Hynes. 1971
Differences in benthos upstream and downstream of an impoundment. J. Fish. Res. Bd. Canada 28(1) 35-43.

Sverdrup, H.A. 1953.
On conditions for the vernal blooming of phytoplankton. Jour. du Conseil, 18:287-295 (in) Murphy, G. J. 1962. Effect of mixing depth and turbidity on the productivity of fresh-water impoundments. Trans. Amer. Fish Soc. 91 : 69-76.

Townsend, G.H. 1966.
A study of waterfowl nesting on the Saskatchewan River delta. Canadian Field Naturalist. 80: 74-88.

Townsend, G.H. 1969.
Proposed water regulation of Lake Winnipeg--its effects on waterfowl resources. Ducks Unlimited.

U.S. Department of the Interior. 1964.
A report on fish and wildlife resources affected by Rampart Canyon Dam and Reservoir Project--Yukon River, Alaska. U.S. Dept. of the Interior, Fish and Wildlife Service, Juneau, Alaska. April 1964.

U.S. Department of the Interior.
A detailed report on fish and wildlife resources affected by Libby dam and reservoir project, Kootenai River, Montana, U.S. Dept. of the Interior - Fish and Wildlife Service. Portland, Oregon, February, 1965.

Van der Valk, A.G. 1970.
Hydrarch succession and primary production of oxbow lakes in central Alberta. M. Sc. Thesis in Botany, University of Alberta. 116 pp.

An ecological study of the wildlife and fisheries in the Pembina and Sturgeon River Basins.