REVIEW AND ANNOTATED BIBLIOGRAPHY OF STREAM DIVERSION AND STREAM RESTORATION TECHNIQUES AND ASSOCIATED EFFECTS ON AQUATIC BIOTA

by

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PREPARED FOR

ALBERTA OIL SANDS
ENVIRONMENTAL RESEARCH PROGRAM

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The Hon. D.J. Russell
Minister of the Environment
222 Legislative Building
Edmonton, Alberta

and

The Hon. L. Marchand
Minister of State for the Environment
Fisheries and Environment Canada
Ottawa, Ontario

Sirs:

Enclosed is the report "Review and Annotated Bibliography of Stream Diversion and Stream Restoration Techniques and Associated Effects on Aquatic Biota".

This report was prepared for the Alberta Oil Sands Environmental Research Program, through its Aquatic Fauna Technical Research Committee (now part of the Water System) under the Canada-Alberta Agreement of February 1975 (amended September 1977).

Respectfully,

W. Solodzuk, P.Eng.
Chairman, Steering Committee, AOSERP
Deputy Minister, Alberta Environment

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REVIEW AND ANNOTATED BIBLIOGRAPHY OF STREAM DIVERSION AND STREAM RESTORATION TECHNIQUES AND ASSOCIATED EFFECTS ON AQUATIC BIOTA

DESCRIPTIVE SUMMARY

ABSTRACT

Stream diversion projects in the Alberta Oil Sands Environmental Research Program study area that have been or will be required in the course of oil sands development are outlined. The effects of stream diversions on aquatic life, natural recovery of stream ecosystems from the effects of diversion, effectiveness of habitat restoration or enhancement techniques, and potential applications of biomonitoring techniques for studying the effects of diversions are reviewed with special reference to the AOSERP study area. Scientific references pertaining to these topics are compiled in an annotated bibliography. Information "gaps" and research needs pertinent to the AOSERP study area are briefly outlined. The primary research need recommended at the present time is to collect as much information as possible about the effects of the Beaver Creek diversion to aid in planning future diversion projects and related programs of environmental research in the AOSERP study area.

BACKGROUND

Core activities in the Water System sector of AOSERP have been defined as "baseline states", "applied research", "monitoring techniques", and "restoration". The majority of effort so far has been in defining the "baseline states"; however, it is planned that activities will wind down in favour of the other core activities in the later years of the program.

This study was designed to identify research needs in these other core activities, notably "restoration", that warrant AOSERP support. The specific objective of this study was to review the published literature on the effects of permanent and temporary stream diversion and successful stream restoration techniques on aquatic biota, and to produce an annotated bibliography on the subject having specific reference to the AOSERP study area.

ASSESSMENT

The report has been reviewed by different people in Alberta Environment, the University of Alberta, and Program Management of AOSERP. One reviewer noted that the Bibliography missed covering a pertinent work, "Stream Channelization Hearings before a Sub-Committee of the Committee on Government Operations, House of Representative 93rd Congress", March 20, 1973, library number TC 530 U58C Pt5. The content of the report does not necessarily reflect the views of Alberta Environment, Fisheries and Environment Canada, or AOSERP.

The Alberta Oil Sands Environmental Research Program accepts the report "Review and Annotated Bibliography of Stream Diversion and Stream Restoration Techniques and Associated Effects on Aquatic Biota" as a document that will be very useful in planning future research and thanks the authors for their efforts. It is recommended that the report be distributed to the public via selected Canadian libraries.

S.B. Smith
Program Director

R.T. Seidner
Research Manager
Water System

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ACKNOWLEDGEMENTS

This research project AF 4.9.2 was funded by the Alberta Oil Sands Environmental Research Program, a joint Alberta-Canada research program established to fund, direct, and co-ordinate environmental research in the Athabasca Oil Sands area of north-eastern Alberta.

1. INTRODUCTION

The Alberta Oil Sands Environmental Research Program (AOSERP) requested Envirocon Limited to review the published literature on the effects of permanent and temporary stream diversion and successful stream restoration techniques on aquatic biota and to prepare an annotated bibliography on the subject having particular reference to the AOSERP study area (Figure 1). The review and bibliography was also to deal with the ability of stream ecosystems to recover naturally from the effects of diversion, and with biomonitoring techniques, including remote sensing, that may be used to study changes in these ecosystems resulting from diversion projects in the AOSERP study area.

The need for this study arises chiefly because oil sands development may require stream diversions wherever streams flow through projected mining areas. Present development plans in the AOSERP study area call for the diversion of two streams: Hartley Creek, and the Muskeg River (Jantzie 1977). However, the possibility that by the late 1990's there may be as many as 20 plants in the area (Yurko 1974, cited in Laycock 1974), indicates that more stream diversions may be necessary.

A diversion project that has already been completed is the diversion of Beaver Creek, which used to flow through the Syncrude Lease area. The stream above Syncrude has been diverted through Ruth Lake into Poplar Creek by two dams and a canal (Syncrude Canada Ltd. 1973a, 1975a). Four tributaries that previously flowed into Beaver Creek within the Syncrude Lease area are now diverted by means of a drainage ditch along the western edge of the Syncrude mining area into the lower reaches of Beaver Creek. Another diversion project that has been completed is the cut-off channel on the Athabasca River in the Peace-Athabasca Delta. This project was not related to oil sands mining--it was intended to prevent the impending breakthrough of a meander loop of the Athabasca River into the nearby Embarras River with consequent drastic changes in the entire Peace-Athabasca Delta complex (Fisheries and Environment Canada 1976). At present there is no indication that other similar erosion-control projects will be necessary in the AOSERP study area.

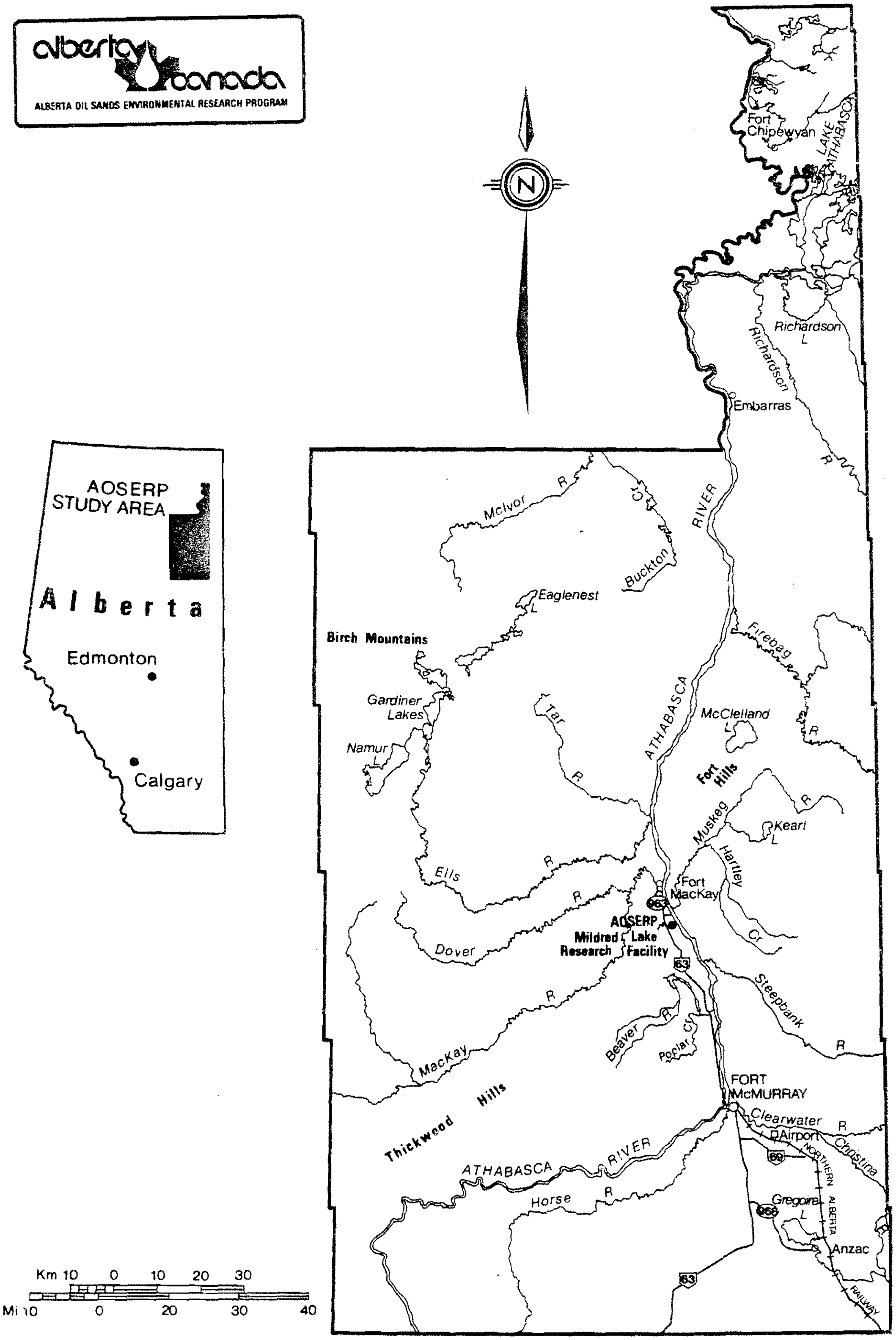

Figure 1. The Alberta Oil Sands Environmental Research Program study area.

Stream diversion can impose gross changes on physical elements of the environment with immediate consequences for the floral and faunal elements. The most obvious avenues of physical change are raised water levels in some areas and lowered water levels in others, but numerous other possible effects must be considered as well. These include increased sedimentation arising from construction activities, changes in the water temperature regime, alterations in channel form and streamside soil and vegetation characteristics, destabilization of channel equilibrium, regulation of streamflow, and changes in runoff and erosion characteristics in the drainage basin as a whole.

The best technique for evaluating the potential effects of a particular diversion project and for planning means by which the undesirable environmental effects can be minimized or eliminated is to study the consequences of a similar project in a nearby area. Unfortunately, no such information is presently available for the diversion projects that have already been completed in the AOSERP study area, although some information may be available by May 1978 (Letter dated 16 February 1978 from S. Elliot, Syncrude Canada Ltd. Environmental Coordinator, Special Projects). In addition, relatively little is known about the ability of aquatic ecosystems in the area to withstand or recover from the types of environmental change that can result from stream diversion.

Baseline studies of environmental conditions in the Beaver Creek and Poplar Creek drainage basins before implementation of the Beaver Creek diversion project have been prepared by McCart et al. (1977), Penner (1976), Renewable Resources Consulting Services Ltd. (RRCS 1973, 1977) and Syncrude Canada Ltd. (1973b,c,d, 1975a,b). Some baseline environmental studies have also been prepared for the Muskeg River and Hartley Creek basins (RRCS 1974; Shell Canada Ltd. 1975; T. W. Beak Consultants Ltd. 1973), where diversions are planned for the year 2002 (Shell Canada Ltd. 1975).

This study is an attempt to supplement the existing knowledge of those areas in the AOSERP study area that have been or will be affected by diversions, with relevant published information from studies in other areas. To this end, we utilized computer-assisted searches for recent publications indexed in data bases by Lockheed and QL Information Systems as well as tape services by the Systems Development Corporation. We then reviewed the Alberta Oil Sands Index, and the indexes of key wildlife, fisheries, and aquatic science journals to obtain other titles relevant to the AOSERP study area. These references were reviewed and the pertinent data were abstracted for presentation under four main headings:

1. Effects of stream diversion;
2. Natural recovery of stream ecosystems;
3. Habitat restoration and enhancement techniques; and
4. Biomonitoring and remote sensing.

With the information at hand we then identified information gaps and outlined research needs.

2. EFFECTS OF STREAM DIVERSIONS

Stream diversion affects aquatic life by imposing certain types of physical changes on the environment. These initial changes can cause secondary physical effects, from which tertiary effects can result, and so on. Aquatic life can be affected by changes occurring at any level of the causal chain. It is beyond the scope of this review to provide a detailed discussion of this hierarchical structure of physical changes, which leads into the complex subject of river dynamics. However, physical changes are discussed briefly below. Effects of diversions on aquatic life are discussed under the headings of channelization and impoundment, the two main methods that may be used to divert stream flow. The effects of channelization are presented in many sources including symposia edited by Corning et al. (1975) and Schneberger and Funk (1971), and a report by A. D. Little Inc. (1973). The effects of impoundment are usually discussed in the context of hydroelectric development, flood control, or irrigation (for example, Geen 1974; Neel 1963).

2.1 PHYSICAL CHANGES

Stream diversion always leads to changes in water level, and it may also result in changes in water temperature. Temperature change affects aquatic organisms directly and is discussed as appropriate in the sections following. Water level change has consequences both in the water bodies directly involved in a diversion project, and in the wetlands associated with them. In wetland areas water level change has direct effects on resident organisms which are discussed in subsequent sections; in stream environments it leads to secondary physical changes which are outlined below.

It is well known that such variables as stream discharge, gradient, sediment load, bed roughness, channel sinuosity, and channel geometry are inter-related. When the equilibrium of a stream is disrupted by augmenting or decreasing the discharge, adjustment within the variables occurs until a new equilibrium is reached. Discussions of this type of process are given by Apmann and Otis (1965), Blench (1972), and Keller (1975). The mechanics of the adjustment vary considerably from one situation to another, and it is sufficient to note that while equilibrium is being restored there will be destabilization of the aquatic habitat rendering it less suitable for aquatic life. Destabilization means that there will be erosion of the stream bed or banks, increased suspended sediment concentrations, and channel sedimentation in different areas. It is also possible that the new equilibrium conditions, when they are reached, will involve a permanent degradation or loss of aquatic habitat.

In terms of aquatic life, the habitat provided in artificial channels is important because it is normally the only compensation for aquatic habitat which is lost in the stream from which water has been diverted. Unfortunately, channel instability is usually a severe problem in man-made watercourses, because they normally do not even closely approximate an equilibrium gradient or geometry. Channelization normally involves straightening of a watercourse; if the channelized stream originally followed a very sinuous course, as do many of the streams in the AOSERP study area, there will be a great increase in gradient. Unless the channel is made of concrete, the inevitable result will be erosion and sedimentation as the stream seeks its original gradient. Both lateral and vertical adjustments may occur, unless the banks are not erodible. In that case the adjustment will take the form of bed scour in the upstream portions of the channel and sedimentation in the lower portions (Blench 1972), and secondary adjustments in any tributaries to the channel will also occur. Daniels (1960) provides a particularly graphic example of this type of channel adjustment: over a period of 38 years, the upstream end of a drainage ditch in Iowa entrenched itself to a depth of 9.5 m below its original level, and the original channel width increased from about 9 m to about 35 m.

2.2 AQUATIC FLORA

Aquatic plants are those that are found growing or living in or upon water. Representative species of algae, fungi, liverworts, mosses, and vascular plants may all be found living in freshwater environments. The major effects of stream diversion on these species are caused by changes in water levels, and to a lesser degree by changing temperatures, currents, and turbidities.

2.2.1 Channelization

We found few studies dealing with the direct effects of channelization on aquatic vegetation. Patrick (1959) found that algae and fungi were quick to colonize a new channel (see section 3.1) and that high organic matter content in the substrate could be responsible, but colonization by macrophytes was very irregular and sporadic after six months study. A two year comparison of channelized and unchannelized river reaches in Mississippi indicated that the number of plankton organisms was higher in two channelized stream segments (Arner et al. 1975). The unchannelized stream segment showed a greater species diversity than channelized stream segments. However, the authors believed that one of the channelized stream segments was influenced by nutrients from a nearby sewage lagoon.

The effects of changes in current velocity on macrophyte vegetation are illustrated by Bilby (1977). The current speed distribution in a small pool was altered by the diversion of flow away from the pool. This caused a corresponding change in the distribution of two plant species within the pool.

The effects of sediment on aquatic plants have been reviewed by Cordone and Kelley (1961). Increased suspended sediment concentrations are believed responsible for reducing photosynthesis in aquatic plants by direct abrasion, by reducing the amount of light available for photosynthesis, and by covering the bottom of the stream with silt. Cordone and Pennoyer (1960) described the destruction of algal communities by increased suspended sediment loads in the Truckee River, and Edwards (1969) found that increased sediment loads in rivers caused a general decline in aquatic vegetation.

An indirect but common effect of channelization projects is the lowering of water levels in wetland habitats drained by the altered channels (Barstow 1971; Choate 1972; A. D. Little Inc. 1973). Small drainage channels in the AOSERP study area are likely to lower the water levels in associated marshlands. The effects of drainage can be severe as illustrated by the results of the Peace-Athabasca Delta Project (PADP 1973a). There is a drying out process which initiates a shift in species as succession moves from an aquatic enviroment to a drier one. The trends in vegetation succession under such conditions have been clearly described by Dirschl (1971, 1972, 1973) and Dirschl et al. (1974).

2.2.2 Impoundment

A common effect of impoundment is the leaching of soils and organic materials during the flooding of a reservoir (Kimsey 1957; Rawson 1958; Sylvester and Seabloom 1966). The initially high nutrient levels encourage the development of a brief period of high primary productivity. This gradually falls as the rate of nutrient leaching declines and nutrient out-flow (flushing) occurs. Thus the basic productivity of new impoundments is first high and then low (Rawson 1958). Diversion impoundments are characterized by low level dams and small size. Water passes through such reservoirs very rapidly and the basic fertility of the basin may be leached out more quickly than in larger reservoirs. Chamberlain (1972, cited in McCart and Jones 1975), found that high initial values for primary productivity (C^{14} method) in a new reservoir were attributable to flooding of organic material. The high values were transitory and subsequent patterns of primary productivity were similar to those in an older reservoir used as a control.

The initial increased productivity of an impoundment may also lead to the development of greater downstream growths of attached algae than found in the stream before damming (Neel 1963). The "flushing" of the increased nutrient loads downstream results in a corresponding temporary increase in primary productivity, especially if water temperatures are increased during the growing season. This is likely to occur if summer discharges are reduced (Gordon 1965) or if the source of the discharge is from the epilimnion (Johnson and Berst 1965). A hypolimnial release would have the effect of lowering temperatures during the summer; however, diversion impoundments are not likely to be deep enough to become stratified and water released is likely to be epilimnial. This could result in a slight warming of downstream waters during the summer for a distance downstream that depends on the rate of flow. During the winter hypolimnial releases of warmer water may cause a slight warming trend downstream from the impoundment. Epilimnial releases at these times are not likely to cause any significant change in the temperature regime. Small temperature changes at these times are unlikely to affect plant growth greatly.

The creation of a diversion impoundment raises water levels and may mitigate wetland loss due to channelization in some diversion projects. There is also the opportunity to manipulate water levels and manage aquatic resources.

Raised or lowered water levels have been shown to cause drastic changes in vegetation patterns (PADP 1973b; McDonald 1955; Anderson and Glover 1967; Harris and Marshall 1963; Jeglum 1975; Robel 1962; Kadlec 1962; Stübe 1958). Higher water levels generally retard the reproduction of mud-flat and shoreline annuals (Harris and Marshall 1963; McDonald 1955), but may cause a corresponding increase in submerged vegetation. Robel (1962) found that the effects of raised water levels on submerged vegetation were variable; in deeper areas vegetation production decreased but in shallower areas it increased. Apparently the amount of submerged vegetation produced by changing the water levels depended upon the extent of the deep and shallow areas. Lowered water levels have been shown to initiate a series of successional trends towards less productive and reduced habitat for aquatic plant life (PADP 1973b; Harris and Marshall 1963; Jeglum 1975; Kadlec 1962). In general, stable water levels are best for the production of submerged aquatic vegetation (Bellrose and Brown 1941). The production of emergent vegetation on the other hand tends to decrease as long as water levels are stable. However, by controlled drawdowns and flooding it has been shown that productivity can be increased or maintained. Harris and Marshall (1963) found that 1-2 year drawdowns every 5 to 10 years maintained emergent vegetation. Furthermore the timing of drawdowns within the year was shown to affect the rate of plant of succession (Meeks 1969). The reasons for improved primary productivity caused by fluctuating water levels are that periodic flooding destroys older sections of the floodplain and allows space for sediment to be laid down; then when drawdown occurs a new successional unit can develop. Many aquatic plants have adapted for survival in response to regular fluctuations in water level. They may even require such fluctuations for continued seed production and survival (Harris and Marshall 1963).

2.3 AQUATIC FAUNA

2.3.1 Macroinvertebrates

Aquatic macroinvertebrates are those small animals including insects, crustaceans, molluscs, worms, etc. that inhabit lakes, reservoirs, and streams. The effects of channelization and impoundment on bottom dwelling (benthic) macroinvertebrates are well documented in the literature; the effects on zooplankters are largely unknown. The physical causes of these effects usually involve changes in flow and temperature regimes, and sedimentation.

2.3.1.1 Channelization. Some effects of channelization on stream invertebrates are documented in symposia by Corning et al. (1975), Schneberger and Funk (1971), and a report by A. D. Little Inc. (1973). Arner et al. (1975) and Moyle (1976) found that the species diversity of macroinvertebrates was much greater in unchannelized stream segments than channelized segments. Hansen (1971) reported that the composition of bottom fauna remained similar in channelized and unchannelized segments of a river but that drift rates were higher in the channelized section, thus suggesting that there was a lack of suitable attachment areas there. Ellis (1936) noted that changes in invertebrate species composition and abundance can occur when there are changes in turbidity, or temperature, or in the amounts of organic detritus entering the water body.

Pearson and Franklin (1967) cited increased turbidity as a cause of increased drift rates of some organisms. Physical abrasion by suspended sediment particles may damage benthic organisms and cause them to release from the substrate. The light scattering properties of suspended sediment could also increase drift rates because many macroinvertebrates have a positive activity response to decreases in light intensity. Sedimentation is destructive to aquatic habitat because sand, silt, and clay particles are easily transported and represent a poor substrate for most macroinvertebrates to colonize. Luedtke and Brusven (1976) found that many common riffle insects could not move upstream against low current velocities over a sand substrate. In a study of six streams in Pennsylvania, Duvel et al. (1976) concluded that channelization did not alter the overall composition or density of benthic communities because suitable substrates were present in both natural and channelized stream reaches. Morris et al. (1968) obtained similar results in Nebraska. However, they calculated that the total amount of habitat available to benthic organisms had been reduced 67 percent by channelization. Taking this into account it was found that the average standing crop of drift was only 57 mg/m^3 in channelized segments compared to 483 mg/m^3 in unaltered river habitat.

Channelization frequently involves the removal of streamside vegetation (Schneberger and Funk 1971; A. D. Little Inc. 1973). Minshall (1967) has shown that canopy removal on a small stream can reduce the amount of allochthonous detritus that serves as an important food source for aquatic invertebrates. He found a significant decrease in the amounts of this material in cleared stream sections.

The removal of streamside vegetation has also been shown to cause significant changes in water temperature regimes in some channelized streams (Stoeckeler and Voskuil 1959; Hansen 1971). In the former study, reduced stream temperatures were obtained by diverting a small stream through high willows, while in the latter study the removal of streambank vegetation was found to result in an increase in water temperatures. Increases in stream temperatures caused by removal of streamside vegetation are well documented by Gray and Edington (1969), Burton and Likens (1973), Brown and Krygier (1970), and Swift and Messer (1971).

2.3.1.2 Impoundment. The creation of small impoundments provides new habitat for macroinvertebrates. The colonization of new areas by macroinvertebrate fauna has been described by Nursall (1952) and Kimsey (1957). The typical pattern of colonization as described by McCart and Jones (1975) is:

1. During the very early stages of initial flooding, terrestrial insects and earthworms constitute a large proportion of the total invertebrate biomass (by weight);
2. Zooplankton populations, particularly Cladocerans, increase rapidly, then decline to lower but still substantial levels;

3. Benthic invertebrate populations increase substantially during the initial flooding as many groups of stream-dwelling invertebrates (oligochaetes, nematodes, oribatoid mites and chironomids) colonize the new habitat;
4. The terrestrial and stream derived invertebrate fauna is largely replaced within a few months by a truly limnophilic (lake-dwelling) fauna which invades the reservoir during the summer temperature rise;
5. During the winter, many species are eliminated by freezing and ice scour as lake levels decline; the groups that suffer most are the larger crustaceans (the amphipods such as *Gammarus*, an important fish food), the larvae and nymphs of large insects, and the molluscs; among the Chironomidae, the tribe Chironomini disappear in favour of the Tanytarsini; and
6. With respect to species composition, it is likely that the invertebrate fauna is essentially complete by the end of the first summer of the reservoir's existence, though it may be several years before the fauna is stabilized in terms of relative abundance.

The overall pattern is one of greater invertebrate abundance early in the life of the reservoir and lower, more stable levels as the reservoir ages.

2.3.1.3 Downstream. Impoundments can alter downstream invertebrate populations. Spence and Hynes (1971a) found pronounced differences in the macroinvertebrate fauna upstream and downstream of a flood control impoundment. Downstream differences were comparable with those resulting from mild organic enrichment. There was a reduction in the total number of species, an increase in numbers of some species, and the replacement of some species by other closely related ones.

These changes were the result of hypolimnion release from the dam. Three primary factors were considered to be important:

1. Alteration of the temperature regime so that water temperatures were lower in the summer;
2. Increased abundance of attached filamentous algae as a result of lower summer temperatures, stabilized water levels, and altered substrate surfaces; and

3. Flushing of organic matter, particularly zooplankton and phytoplankton, from the impoundment.

Briggs (1948), Hilsenhoff (1971), Lehmkuhl (1972), and Ward (1974) have made similar studies and drawn similar conclusions. Temperature regime is generally considered to be of extreme importance because many stream insects have strict thermal requirements which affect their reproductive success. These studies show that as aquatic communities below dams become stressed, there is an increase in total standing crop but a decrease in diversity. Such communities are unstable and susceptible to minor biotic or abiotic changes which could produce great changes in community structure.

2.3.2 Fish

2.3.2.1 Channelization. Channelization practices have varying effects on fish life but in general the effects are detrimental. Numerous papers are available on the subject and many of these are adequately reviewed in reports by A. D. Little Inc. (1973), Hooton and Reid (1975), and White (1973).

The most obvious effect is that productive fish habitat (pools and riffles) is lost by channel straightening and shortening. Estimates of habitat loss due to some channelization projects in the United States range from 54 percent to 90 percent (Hansen 1971; Barstow 1971). Habitat is further reduced by the removal of obstructions that create areas used by fish for protection, feeding and breeding.

Increased sediment load is the major pollutant resulting from channelization projects; consequent detrimental effects have been documented in reports by Apmann and Otis (1965), Cordone and Kelley (1961), Peters (1967), and Phillips (1971). Increased sediment loads in diversion channels may result from poor channel design, as outlined in section 2.1, or from a disruption of surface drainage patterns which may cause faster runoff, higher peak flows, and increased surface erosion. Increased turbidity and siltation can reduce fish populations by reducing light penetration, by blanketing fish spawning areas, and by covering aquatic insects used by fish for food. A reduction in biomass and diversity of trophic levels inevitably results from siltation (Hooton and Reid 1975).

Channelization generally involves the removal of streamside vegetation and natural stream obstructions. Stream cover has been shown to be very important in shading water from the sun (Stoeckeler and Voskuil 1959), and in providing protection cover for fish from predators (Hooton and Reid 1975; White 1973). The value of stream bank vegetation to trout has been shown by Boussu (1954) and Lewis (1969). The removal of this cover and its insulating effect may cause an increase in water temperatures in the daytime and lowered water temperatures at night. Thus a greater diurnal variation in temperature can occur in a channelized stream (United States Environmental Protection Agency -- U.S. EPA 1973). Increased water temperatures caused by the removal of bank vegetation are reported by Brown and Krygier (1970), Burton and Likens (1973), Gray and Edington (1969), and Swift and Messer (1971). Higher temperatures in a channelized section of a river in Iowa have been recorded by Hansen (1971). Temperature changes can have detrimental effects on fish through water quality changes, and biological responses to them. Indeed many warm water fish species have been shown to have preferences for certain water temperatures which affect their local distribution patterns (Stauffer et al. 1976). Hence the effect of increased solar radiation may be to indirectly change the stream fishery.

2.3.2.2 <u>Impoundment.</u> Any diversion impoundment that is built in the AOSERP study area is likely to be small and shallow. Such impoundments will provide new habitat for fish, but perhaps not for the species that originally inhabited the stream or lake.

In general, impoundment during the first few years tends to produce good growth and survival of most fish species. This period is followed by a sharp decrease, then a gradual rise to a fishery near half the magnitude of the initial phase (Kimsey 1957; Runnström 1955; Stube 1958). These changes are generally ascribed to the high initial productivity of the impoundment and the gradual decrease in productivity as the rate of leaching decreases and nutrient outflow continues.

Changes in growth rates of fish species may also occur. Runnström (1955) found that the size and growth rates of Arctic char increased dramatically immediately after impoundment but that eventually there was a significant decrease in both numbers and growth. He also noted that a similar pattern had been observed in whitefish populations of other Swedish lakes.

Gradual changes in the relative abundance of various fish species are likely to occur as the biological community adapts from a moving water stream system to a lake environment. Species well adapted to the new environment increase in abundance while ill-adapted species decline.

Machniak (1975a,b,c) has reviewed the effects that impoundment for hydroelectric development can have on the reproduction and population dynamics of three fish species common in the AOSERP study area: lake whitefish *(Coregonus clupeaformis)*, northern pike *(Esox lucius)*, and yellow walleye *(Stizostedion vitreum vitreum)*. The prime factors determining their success in impoundments are accessibility to spawning grounds, availability of food, water temperature, siltation, water level, and flow. Impoundment is considered to be detrimental to lake whitefish spawning. However, it is pointed out that whitefish can adapt to new spawning areas and this may compensate for an initial decrease in spawning success. If water level fluctuations in impoundments are small then sizeable whitefish populations can develop in impoundments. The reproduction of northern pike is favoured initially during the filling of impoundments but afterwards pike reproduction is inconsistent. Pike populations decline, as impoundments age, because forage fish species decrease in abundance and spawning success deteriorates. Walleye are more consistent spawners than near-shore spawners such as northern pike. Growth rates and population size of yellow walleye are dependent upon the availability of forage species and spawning success. Generally as a reservoir ages yellow walleye populations increase.

Data about the responses to impoundment of other fish species found in the AOSERP study area are scanty. Nelson (1965) described the changes in fish populations of the Kananaskis River reservoirs in Alberta. Complex interactions among fish species caused definite changes in species abundance and distribution. Some of these fish species (longnose sucker, white sucker, mountain whitefish, lake chub, brook stickleback, and longnose dace) are found in the AOSERP study area. Miller and Paetz (1959) described the fisheries potentials of several Alberta irrigation and diversion reservoirs. The largest impoundments contributed substantially to pike and whitefish production in the province, while the smaller tributary impoundments or diversion impoundments became well populated by northern pike. In some cases short term opportunities for trout fisheries were found. Burbot, suckers, sticklebacks and various minnow species usually became well established in impoundments.

There appears to be no other available information which is directly applicable to the type of tributary impoundments expected to be constructed in the AOSERP study area. Most important, little is known about the effects that impoundment will have on Arctic grayling populations in the Athabasca Oil Sands area.

2.3.2.3 Upstream and downstream. The effects of impoundment are not confined to the reservoir itself. Prior to impoundment conditions in a small stream are contiguous and probably similar throughout its length. Dam building divides a stream into upstream and downstream areas where definite fish population changes can occur.

The presence of the impoundment itself may cause changes in the relative abundance and distribution of fish species upstream. The major effects are caused by the blockage of fish movements upstream and the possible elimination of migratory fish populations. A good example of how grayling populations were reduced by migration barriers in small streams in Montana is given by Nelson (1954). Other upstream effects can result when large populations of fish develop in a reservoir and move into tributary streams to avoid population pressures. Ruhr (1957) and Erman (1973) have described drastic changes in fish populations, above impoundments, that might be undesirable.

The downstream effects of impoundment are related to habitat changes caused by alteration of flow, temperature, and nutrient regimes. It is likely that such changes could cause changes in the relative abundance and distribution of fish species below an impoundment. There appears to be only one clearly documented case of such changes: Spence and Hynes (1971b) found that four species of cyprinid fishes found upstream of an impoundment were absent downstream. It was concluded that lowered water temperatures below the dam were mainly responsible for the absence of these minnows downstream.

2.3.3 Birds

Effects of diversions on birds are related to the amount of habitat lost directly by channel alteration and indirectly by the drainage of wetlands. Impoundment of water for diversions may create additional habitat for birds, providing that the reservoirs are properly managed. Water level fluctuations resulting from diversion can have serious consequences for birds if they occur during the breeding period.

2.3.3.1 Channelization. The effects of large scale channelization projects on birds in the United States are reviewed by A. D. Little Inc. (1973), and Corning et al. (1975). The removal of riparian vegetation may dramatically change species composition and total avian productivity depending on the severity of the vegetational loss (Carothers and Johnson 1975). There are numerous studies reviewed by Carothers and Johnson (1975) which describe the importance of riparian vegetation to birds.

A large number of birds are almost entirely dependent on riparian habitat, especially during the breeding season. Avian productivity in riparian habitat is usually much greater than that found in adjacent habitat types.

Numerous examples of wetland loss due to channelization are reviewed by A. D. Little Inc. (1973). In general the loss of habitat is severe. Choate (1972) found a 54 percent areal decrease in marshlands following channelization, and Barstow (1971) demonstrated that a proposed channelization project could reduce basic biological productivity by nearly 50 percent.

Drainage caused by channelization can cause a shift in birdlife from waterfowl to upland game. In one case, channelization of the Kissimmee River in Florida, migratory waterfowl almost totally disappeared (A. D. Little Inc. 1973). The changes were attributed to a change in vegetation associated with changes in water level in the swamps near the river and its floodplain. The detrimental effects, other than total habitat loss that changes of water level can have on waterfowl are described by Kadlec (1962), Rogers (1964), Smith (1970), Swanson and Meyer (1977), and Wolf (1955). They include a reduction of food availability, displacement of breeding pairs, failure to reproduce, and increased predation.

2.3.3.2 Impoundment. Flooding of impoundments, when it occurs outside of the breeding period, has been shown to improve waterfowl production (Kadlec 1962; Munro 1966?; Anderson and Glover 1967; McKnight and Low 1969; Schroeder et al. 1976; Burgess 1969). However, flooding does not necessarily lead to an increase in the amount of productive waterfowl habitat (Bonnema and Zschomler 1974). When flooding occurs during the breeding period it is likely to have a disruptive effect on waterfowl.

In the AOSERP study area, waterfowl habitat losses due to channelization will likely be mitigated in part by habitat improvement due to impoundments. The degree of habitat improvement will depend on the magnitude and timing of water level changes, and the types of habitats affected.

2.3.4 Mammals

The environmental changes associated with stream diversion that have been described earlier in this review may also, of course, have adverse affects on semiaquatic mammals. The report of A. D. Little Inc. (1973) discusses a number of cases from the United States where channelization has led to loss of habitat and declining populations, and Arner et al. (1975) found that beavers and muskrats were far less abundant on channelized than on unchannelized reaches of a river in Mississippi. However, there seems to be little quantitative documentation of semiaquatic mammal population changes resulting from diversion projects.

2.3.4.1 Muskrat. There are a number of good ecological studies which can be used to predict the effects of diversion projects on muskrat populations. Basically, fluctuating or declining water levels generally have an adverse effect on populations (Bellrose 1950; Bellrose and Brown 1941; Bellrose and Low 1943; Errington 1939; Gill 1973), while recovery of low water levels can be expected to have a beneficial effect. Sudden flooding may also have a detrimental effect (Bellrose and Low 1943). There is little information on the effects of raised water levels, but in one study Bonnema and Zschomler (1974) found that muskrat habitat actually decreased after water levels were raised by an impoundment. Presumably, the effects of increasing water level depend heavily on the type of habitat being flooded. Muskrats seek an optimum water depth for lodge construction (Bellrose 1950; Bellrose and Brown 1941; Gill 1973) so that an increase in water level does not necessarily mean an increase in muskrat habitat in areas where they are already established. Flooding of previously unproductive areas would be more likely to have beneficial effects for muskrats.

The effects of drought on muskrat populations are discussed by Errington (1939) and Bellrose and Low (1943). Errington (1939) suggested that because of their attachment to home territory, muskrats may be fatally slow in adjusting to altered conditions even when superior habitat is available nearby, and that individuals that left the home range were generally unable to find safety. Bellrose and Low (1943) found that drought-evicted muskrats had fair success in moving to other areas during summer, but that lowered water levels had much more severe consequences in winter -- ponds froze to the bottom and muskrats were forced to forage for food, becoming vulnerable to predation. In the Peace-Athabasca Delta, Ambrock and Allison (1973) found increased predation of muskrats in areas where bottom freezing had occurred. The effects of lowered water levels are well documented in the Wood Buffalo Park portion of the Peace-Athabasca Delta where the harvest of muskrats fell from 144,000 during the winter of 1965-66 to less than 2,000 during the winter of 1971-72. Many of the marshes supporting the muskrats either dried up or froze to the bottom as a result of the lowered Delta water levels (Fisheries and Environment Canada 1976).

Raised water levels cause an initial disruption in muskrat populations because lodges disintegrate and burrows are flooded. Eviction ensues, with increased mortality due to predation (Ambrock and Allison 1973; Bellrose and Low 1943) and in some cases, intraspecific strife (Bellrose and Low 1943). Relatively quick adaptation to the new water levels was noted in both studies.

2.3.4.2 Beaver. Beavers occupy a somewhat different type of aquatic habitat than do muskrats, and are less dependent on aquatic vegetation for food. Aspen is the preferred food, although willow, alder and red osier dogwood may also be heavily used (Gill 1973; Townsend 1953). When supplies of these plants run out, the beavers are forced to move (Leege 1968).

Although beavers are well known as mammals that sometimes alter their environment by raising or lowering water levels, man will have the ultimate control over water levels in streams and lakes diverted for the purpose of oil sands development.

Decreasing water levels can cause direct habitat loss for beavers if the decline is great enough to make the aquatic habitat unsuitable for their activities. Leege (1968) has indicated that some beaver migrations are probably directly related to declining water levels. A drop in water level during winter would have very severe consequences if bottom freezing occurred and the beavers were unable to use their underwater food supplies. Over a longer period of time, declining water levels can cause an indirect loss of habitat by accelerating the succession of aspen and shrub stands towards the climax spruce forest, which is useless to beavers. On the other hand, succession towards aspen and shrubs could in certain circumstances occur on sites which had previously been too wet to support those species.

Rising water levels could cause temporary disruption for beavers by flooding lodges and burrows, but would not necessarily lead to migration to other areas. Leege (1968), however, has suggested flooding as a probable cause of some beaver migrations. A rise in water level during winter could be disastrous as it could cause beaver mortality through drowning or eviction. Over the long term, rising water levels could lead to the creation of additional beaver habitat and an eventual rise in beaver populations in areas where the lack of suitable aquatic habitat was originally a limiting factor, rather than the lack of appropriate food sources. Usually, however, an increased water level cannot be expected to create additional beaver habitat.

2.3.4.3 Other semiaquatic mammals. Otter and mink are usually also considered to be semiaquatic mammals, and are known to occur in various parts of the AOSERP study area. Mink are probably quite common, and in the Syncrude Lease Penner (1976) found them to be more abundant than any other mustelid except the ermine. Otters are uncommon throughout their range (Soper 1964), and Penner (1976) made only one observation of otter tracks during his wildlife study. We found no published studies of mink or otter directly related to any section of this review. For that reason, discussion of mink and otter is limited to the brief oulines of their habitat preferences that follow.

Soper (1964) characterizes the mink as a semiaquatic mammal which prefers aquatic habitat types although it takes readily to dry ground. The preference for aquatic enviroments was also noted by Penner (1976). Dens are of various forms, but are always near water. Food consists of any fish, animal or bird the mink can catch, either in water or on land (Soper 1964).

Otters are more thoroughly aquatic in habit than mink. Otter dens are most commonly bank burrows, and the entrance is usually underwater. Fish, frogs, waterfowl, muskrats and young beavers are commonly preyed on when available. Otters will also hunt on land for birds and rodents but never stray far from water (Soper 1964).

Probably the only inference that can safely be drawn from this information is that declining water levels would lead to habitat loss for both mink and otters.

3. NATURAL RECOVERY OF STREAM ECOSYSTEMS

As yet there appears to be no published information on recovery of stream ecosystems within the AOSERP study area. Most of the published studies are from areas in the United States and eastern Canada, and most discuss only fish or invertebrates.

3.1 AQUATIC FLORA

With few exceptions, we were unable to find any published information directly related to the natural recovery of aquatic vegetation following the types of environmental change that could result from stream diversion projects. Patrick (1959) found that algae were able to become established in a new stream within ten days. Other available studies on aquatic macrophytes seem to indicate that any significant increase or decrease in water level, if it is sustained, will lead to plant succession and a permanent change in community structure. Significant vegetation changes following a water level rise of only 7.5 cm were noted by Robel (1962). Change from a stable to a fluctuating water regime may also lead to vegetation change (Bellrose and Brown 1941).

Recovery of macrophytic vegetation following permanent changes in water level or water regime, then, will not occur in the sense of a return to original conditions. Rather, the zones in which a particular community type is found will move (Bilby 1977; Robel 1962), or the community will be eliminated in favour of another which is better adapted to the altered environmental conditions.

3.2 AQUATIC FAUNA

3.2.1 Invertebrates

Recovery of stream invertebrate populations following denudation is well documented in the literature, although there have been no such recovery studies located in the AOSERP study area. Colonization or repopulation often occurs by means of downstream drift from unaffected areas (Crisp and Gledhill 1970; Kennedy 1955; Nilson and Larimore 1973; Townsend and Hildrew 1976; Waters 1964; Williams 1977; Williams and Hynes 1976b, 1977). In two quantitative studies where various means of colonization were possible, drift was found to be the principal method (Townsend and Hildrew 1976; Williams and Hynes 1976b). Williams (1977) found drift to be the most important colonization method in a permanent stream; in intermittent streams, he found that migration from within the substrate was most important. In these and other studies, invertebrate colonization by upstream migration (Bishop and Hynes 1969; Hultin 1971; Hultin et al. 1969; Minckley 1964; Roos 1957; Williams 1977; Williams and Hynes 1976b, 1977), migration from within the substrate (Nilson and Larimore 1973; Williams 1977; Williams et al. 1974; Williams and Hynes 1976a,b,c, 1977), and aerial colonization (Williams 1977; Williams and Hynes 1976a,b, 1977) has been documented. Studies exist for altered, unaltered, and new habitat.

3.2.1.1 Unaltered habitat. In streams where the habitat has remained essentially unaltered, rapid recovery of invertebrate populations on denuded portions of natural substrate, or colonization of artificially planted substrates, has been documented by Larimore et al. (1959), Waters (1964), Nilson and Larimore (1973), and Townsend and Hildrew (1976). Townsend and Hildrew (1976) estimated that the average benthic density for all taxa would be regained in about 38 days, while Waters (1964) reported that populations of some individual species could recover within one day at certain times of the year. Successful adaptation to yearly drought by invertebrate populations is documented by Larimore et al. (1959), Williams (1977), Williams et al. (1974), and Williams and Hynes (1976c). In a single case of abnormal drought, many of the common invertebrate species failed to reappear after the resumption of normal flow, presumably because they were not adapted to survive the adverse conditions (Hynes 1958, cited in Williams and Hynes 1976c).

3.2.1.2 Altered habitat. There is little available information regarding recovery of invertebrates in natural streams after habitat change. Invertebrate repopulation of a severely disrupted stream habitat in England was investigated by Crisp and Gledhill (1970). The stream was drained, dredged, and then rewatered. According to the authors, recovery of the benthic population "was fairly complete about one year after dredging". Elwood and Waters (1969) studied a stream in which invertebrate populations were severely damaged by floods, during which productive pool and riffle areas were covered by sand. Recovery in six months following the last flood was reported. Neither of these studies discussed recovery on a species-by-species basis.

In channelized streams, recovery of invertebrate populations depends upon the type of habitat that is available. Population densities are usually able to return to normal within a year, provided that substrate materials are suitable and temperature regimes are not altered. This recovery, when it does occur, does not, however, compensate for loss of total habitat caused by channel straightening, nor does it guarantee that species composition and relative abundance of invertebrates will remain the same. Changes in invertebrate populations resulting from channelization are discussed in section 2.2.1.

3.2.1.3 New habitat. Rapid colonization by certain invertebrates of previously uninhabited stream habitat is documented by Kennedy (1955), and Williams and Hynes (1976a, 1977). Patrick (1959) found that protozoa, bacteria and algae were the first life forms to colonize a new stream, becoming established within ten days. Macroinvertebrate colonization was sporadic: after six months some species from the parent stream had become established but others had not. Patrick (1959) suggested that time of year may be an important variable in recovery rates, as certain organisms may be able to colonize new habitat only during certain periods of their life cycle. In support of this hypothesis, Hultin et al. (1969) found that upstream migration of insects was restricted to a limited part of the year, and Pearson and Franklin (1967) found a late-summer peak in drift rates corresponding to the seasonal increase in insect populations.

In a new reservoir in Ontario, Paterson and Fernando (1969) found that colonization of the marginal zone by macroinvertebrates approached completion, with respect to the prevailing conditions, during the first open-water period of the reservoir's existence. Sixty-two percent of the colonizing species were known to have occurred in the impounded stream prior to the filling of the reservoir. In the deeper zones of the reservoir, the macroinvertebrate benthic fauna was judged to be essentially complete, with respect to species composition, by the end of the first summer. Organisms from nearby lentic habitats were more numerous than those previously present in the impounded creek (Paterson and Fernando 1970). Nursall (1952) studied the development of the bottom fauna of Barrier Lake, Alberta, for the first two years following impoundment. He found that bottom organisms originating in the impounded Kananaskis River were unable to survive in the new lentic environment. Other invertebrates were able to become established and a population peak was reached within a year of impoundment. During the second year, siltation of the bottom occurred and there was decline in benthic populations along with a major change in species composition.

3.2.1.4 Discussion. The available literature points out the ability of invertebrate populations in streams to successfully recover from a wide variety of adverse environmental circumstances. Recovery rates seem to vary from a few days in the case of simple denudation without habitat alteration, to about a year in cases of severe habitat disruption. The ability of certain invertebrates to colonize new stream habitats is also shown.

Recovery in terms of total invertebrate populations is not complete when there is habitat loss or degradation, and certain species may not be able to recover after some kinds of severe disruption. Changes in species composition and relative abundance may be involved when recovery does occur.

Rate of recovery and eventual species composition of invertebrate populations appear to depend on various factors, which vary in relative importance from one recovery situation to another. These factors may include the severity, duration, and time of year of the disturbance; the species of organisms available for recolonization and the methods by which they are able to enter the affected area; and the physical characteristics and stability of the habitat being colonized. The trends are for colonization to be very rapid at first after which it decreases steadily with time.

3.2.2 Fish

Documented cases of the recovery of fish populations following natural or artificial disasters are of limited application to the AOSERP study area because they deal either with warm water species or with trout. Further, most of the literature discusses cases in which the physical habitat and flow characteristics of the stream remained unaltered.

3.2.2.1 Unaltered habitat. Gunning and Berra (1968, 1969) and Berra and Gunning (1970) studied repopulation of short sections of warm-water streams after electroshock decimation of the fish populations. Complete repopulation, on a weight basis, was effected by certain species within a year in each experimental section except one. Other species required a longer period for repopulation. Olmsted and Cloutman (1974) studied the repopulation of a section of a warm-water stream in which a pesticide fish kill had occurred. Repopulation began almost immediately and after a year most species had become re-established, although some had not. In addition, four new species were found in the year following the fish kill. In each of these studies, unaffected fish populations remained both upstream and downstream of the decimated stream section.

Larimore et al. (1959) studied repopulation of a warm-water stream decimated by drought. Within two weeks of the resumption of full flow, 21 of 29 species had re-entered the stream and after a year, 25 species were present. After four years, two of the original species were still not present. Repopulation was by upstream migration. Boccardy and Cooper (1961) studied repopulation of a coldwater stream decimated by rotenone. Repopulation by all species originally present occurred within a year, relative abundance remaining essentially unchanged although a few individuals of some new species were collected. Repopulation was by survival and downstream migration. Phinney (1975) studied repopulation by downstream migration of brook trout in a stream section treated with rotenone. Complete repopulation was judged to have occurred after a year.

3.2.2.2 Altered habitat. There seems to be very little concrete information on the recovery of fish populations in natural streams where the habitat has been altered. Hanson and Waters (1974) studied a Minnesota stream in which severe flooding virutally eliminated two year classes of brook trout. Habitat reduction occurred as a result of sedimentation. Recovery of the population occurred over a period of four to five years, during which time rainbow trout were able to become established by upstream migration.

In streams which have been altered by channelization, rapid initial colonization by trout has been noted by Kennedy (1955). However, the losses in total habitat available and in habitat quality that are inevitably associated with channelization (if rehabilitation techniques are not employed) invariably lead to sharply decreased fish populations and usually also to decreased species diversity in the affected section of stream. Documented cases of such decreases are numerous, and are cited in section 2.2.2.

3.2.2.3 Discussion. The published literature indicates that recovery of fish populations after decimation occurs within a year or so, provided that the physical habitat is not altered and that fish in unaffected areas have access to the depopulated area. These findings have little application in the AOSERP study area, where stream diversion projects will likely cause changes in physical habitat, alter streamflow characteristics, or introduce new stream habitat. However, it is important to note that even when the habitat is not altered, minor changes in fish species diversity often occur during repopulation. Presumably, this effect can be traced to inter-specific differences in ability to repopulate a given habitat.

In channelized sections of stream, the literature clearly demonstrates that fish populations will not recover in terms of numbers or biomass, and that recovery of the original species diversity may not occur. Recovery following other forms of habitat alteration is insufficiently documented to warrant detailed discussion, but appears to depend on severity of disruption, length of stream affected, and fish species available for repopulation.

3.2.3 Birds

Since waterfowl are so highly mobile, population losses in a particular area may simply mean that the birds have gone elsewhere. Recovery, then, would consist of their returning to that area -- either because lost habitats had been restored or new habitat had been created. Waterfowl are easily able to adjust to new habitats if they are suitable, as can be inferred from the well-known success of waterfowl impoundments all over Northern America in attracting ducks and geese. Similarly, once the water level is restored in habitat temporarily rendered useless by draining or drought, the waterfowl will likely return. Such a case is documented in Manitoba for pintails by Hochbaum and Bossenmaier (1972). Of course, if the habitat remains dry for a long period, plant succession will render it less suitable even after water levels are restored.

As indicated in the introduction to section 3, there is virtually no published information directly related to the natural recovery of waterfowl populations following the types of habitat disturbance that may result from stream diversion projects. However, it seems reasonable to suppose that complete recovery of temporarily disrupted seasonal waterfowl populations will occur, provided that there is no long-term net loss in suitable habitat. In the AOSERP study area, habitat losses due to diversion of water away from some areas will be at least qualitatively compensated for by habitat creation through impoundments and rising water levels elsewhere.

3.2.4 Mammals

There is little published information regarding recovery of semiaquatic mammal populations from diversion-related habitat disturbances. However, much can be inferred from ecological studies of the habitat requirements and behaviour of semiaquatic mammals. In general, recovery of semiaquatic mammal populations requires that there be no net loss in suitable habitat, assuming that all such habitat is being exploited at the time of disruption.

3.2.4.1 Muskrat. Errington (1939) found that because of their attachment to a home territory, muskrats did not successfully adapt to a summer drought by migration, even though apparently suitable habitat was available nearby. Bellrose and Low (1943) documented fairly successful migration in a similar situation, also in summer, although the new habitat was underpopulated with respect to muskrats at the time. Heavy mortality among muskrats affected by declining water levels during winter has been noted by Bellrose and Low (1943) and Ambrock and Allison (1973). The same authors also found increased mortality in muskrats following eviction by flooding.

The conclusion to be drawn from these studies seems to be that muskrat population levels are likely to drop, perhaps quite drastically, following diversion-related environmental changes. Even if complete mortality of the local population does occur, however, muskrat populations should eventually recover to predisturbance levels if there are undisturbed refugia from which immigration can occur.

3.2.4.2 Beaver. Beavers are highly successful in exploiting new habitat, as the common eviction of the young, usually when they are about two years old, ensures a constant "floating" population of transient animals (Aleksiuk 1968; Leege 1968; Rutherford 1964). These transients will utilize new habitat or reoccupy previously vacated habitats (Slough and Sadleir 1977), but they will not trespass in occupied territory (Aleksiuk 1968). Migration of adult males is also quite common (Hibbard 1958; Leege 1968; Townsend 1953), and adult females or even entire colonies will move when necessary (Townsend 1953). Migrations of over 100 km have been recorded (Hibbard 1958), and movements of about 10 km are common (Hibbard 1958; Leege 1968).

This relatively free mobility of beavers indicates that they would likely be able to quickly exploit new habitat after diversion-related environmental disruptions. In certain cases beavers might also be able to counteract small declines in water level by dam-building. Recovery of beaver populations after diversion projects, then, might be quite rapid, provided of course that there is not an overall loss of either suitable aquatic habitat or food supplies.

4. HABITAT RESTORATION AND ENHANCEMENT TECHNIQUES

Most of the published material on aquatic habitat enhancement concerns techniques for restoring fisheries values in different areas of the United States. There is comparatively little information on vegetation restoration or enhancement of aquatic wildlife habitat following damage due to diversion, and almost none for stream invertebrate populations.

Habitat enhancement following diversions in the AOSERP study area may be desirable both in the affected streams and in associated wetlands. Enhancement will be particularly important in artificial channels which, in addition to being unstable, normally provide poor fish habitat if they are not rehabilitated.

4.1 AQUATIC FLORA

Restoration of vegetation following stream diversion could be of concern in four main habitat types: the affected water bodies themselves, their associated wetlands, the banks of affected streams, and the banks of man-made channels.

In aquatic habitats changes in plant distribution and abundance can follow from changes in water level, or increases in turbidity or suspended sediment concentration (section 2.1). Restoration of the original floral assemblage at a given site requires that these conditions be returned to normal (section 3.1). Similar considerations with regard to water levels apply to wetland vegetation types. Enhancement of wetland habitat for waterfowl and mammals is discussed in sections 4.2.3 and 4.2.4.

Streamside vegetation can also be affected by changes in water level. In some cases restoration is unnecessary, as existing zones of vegetation will simply move towards or away from the stream over time, depending on whether the water level drops or rises. If the water level change is great enough, some plant species or communities could be entirely eliminated, and restoration would require a return towards the original water level.

The early establishment of vegetation along the banks of man-made channels is of particular importance, if the banks are to be stable and the channel is to provide suitable habitat for fish and invertebrates (section 4.2.2). The main considerations are to secure an initial quick growth to stabilize the banks, followed by the development of a cover type appropriate to the environment. The Wildlife Habitat Improvement Handbook, published by the United States Department of Agriculture (USDA 1969) recommends that grasses -- either native species or exotics that are adapted to the area and the intended use -- should be used for the initial stabilization. At the same time, slower-growing native shrubs which will eventually take over should be planted. Willows generally give the best results where the streamside habitat is very moist (USDA 1969). In the United States, clearing for channel construction is commonly done from one side only, to minimize the amount of revegetation work that will be required (Grizzell and Vogan 1973).

Enhancement of riparian vegetation can also be combined with the installation of stream improvement devices. Hunt (1969) and Shetter et al. (1946) describe projects in which the spaces in log and rock current deflectors were filled with gravel and soil, and then sodded. Photos in these articles indicate excellent results: in at least one case forbs and shrubs were established on a deflector within two years (Hunt 1969). In an artificial channel without existing riparian vegetation, however, this sort of result could be achieved only by planting.

4.2 AQUATIC FAUNA

4.2.1 Invertebrates

In some cases, special enhancement techniques are not necessary to the recovery of aquatic invertebrate populations, because of their ability to withstand environmental change and to rapidly colonize new stream environments (sections 2.2.1 and 3.2.1). Nevertheless, any stream improvement technique that improves habitat in regard to stability (erosion and sedimentation), substrate type, or water quality should have a beneficial effect for invertebrate populations.

There are few studies of invertebrate population response to stream improvement. Gard (1961) studied invertebrate populations before and after ponding of a California stream by small dams. He found a five-to eight-fold increase in weight per unit bottom area in the newly-formed ponds. However, ponds of this type are prone to sedimentation (Boreman 1974; Ehlers 1956; Gard 1961; USDA 1969), so it is uncertain whether these increases could have been maintained. In a similar study in Michigan, Shetter et al. (1946) found an initial decrease in invertebrate populations followed by recovery. The study was interrupted and never completed, and recovery may not have been complete at that time. At the time of interruption there was slight decrease in total number and biomass of the bottom fauna, but an increase in the numbers of organisms known to be favoured by trout for food. In a more conclusive study, Morofsky (1936) compared the benthic invertebrate populations of natural and artificially improved sections of 13 Michigan streams. In 11 of the improved sections, the total number of bottom organisms and proportion of insects were found to be significantly higher than in the unimproved sections.

4.2.2 Fish

Published studies of fish population response to stream improvement techniques deal almost exclusively with trout, particularly eastern brook trout, and most are in the U.S.A. However, since the elements of stream habitat -- food, cover, suitable physical habitat, and suitable water quality -- required by different species of coldwater fish are generally similar, these studies have some applicability to the AOSERP study area.

Reviews of stream improvement techniques, without regard to actual effects on fish populations, are found in Apmann and Otis (1965), Dillon and Marriage (1973), Ehlers (1956), Grizzell and Vogan (1973), Keller (1975), Reid (1954), USDA (1969), U.S. Environmental Protection Agency (U.S. EPA 1973), Warner and Porter (1960), and White (1973). The Wildlife Habitat Improvement Handbook (USDA 1969) is particularly useful in that it gives design drawings and placement criteria for a large number of stream improvement devices, including fishways. These studies deal with improvements of both natural and artificial channels.

Stream improvement techniques fall into four main categories: direct channel improvement with regard to channel stability or habitat quality, streamside improvement and protection, regulating dams, and watershed protection. There seems to be agreement that in-stream improvement devices such as current deflectors and rock dams, which are intended to create pools or riffles, are most effective on small streams. Of these, lowland streams (White 1973) and streams with relatively constant flow (Dillon and Marriage 1973) may be the most suitable. The need for careful planning of stream improvement structures with regard to local ecological conditions and streamflow equilibrium is repeatedly pointed out, and planning in the context of management of the entire watershed is advocated by Apmann and Otis (1965) and Greene (1950). Of individual techniques, current deflectors seem to be the most consistently satisfactory structures both in terms of beneficial alteration of the physical habitat and durability. The role of streamside vegetation in stabilizing the stream banks and preventing erosion is well known, but it is also important in anchoring stream improvement structures (Ehlers 1956), in preventing high summer water temperatures (Greene 1950; Stoeckeler and Boskuil 1959; USDA 1969) and in decreasing diurnal fluctuations in water temperature (U.S. EPA 1973). Additionally, riparian vegetation provides necessary cover for fish (Boussu 1954; Lewis 1969; USDA 1969; Warner and Porter 1960) and vegetable matter on which stream primary consumers feed (Minshall 1967). Changes in the water temperature regime resulting from impoundment can be prevented or minimized by a number of impoundment release designs and management strategies (U.S. EPA 1973). Research needs for studying the effects of stream improvement programs are outlined by Thomas (1975) and Hunt (1976).

Among the studies reviewed here of fish population response to stream improvement, all but one concern trout. Edwards et al. (1975) compared fish populations in a natural stream section in Ohio with those in an improved and an unimproved channelized reach. The results were generally inconclusive, although species diversity was highest in the natural stream section. In another inconclusive study, Elser (1968) found no significant gains in trout populations following installation of rock deflectors to create pools and riffles. However, the study took place shortly after installation and Elser suggested the possibility of subsequent population increases. More positively, Boreman (1974) found no difference in rainbow trout biomass or numbers between natural and artificial pools in a New York stream. Gard (1961, 1972) found that planted brook trout were able to become permanently established in a previously barren stream section in California after habitat improvement using small dams. In Wisconsin, Hunt (1969, 1976) documented increases in numbers, size and annual production of brook trout for six years following the addition of bank covers and current deflectors, with the greatest increases occurring during the second three years. One year after the installation of dams, deflectors and covers in a Prince Edward Island stream, Saunders and Smith (1962) reported the numbers of age one and older trout to be doubled. Over a five-year period following placement of current deflectors in a Michigan stream, brook trout total catch improved 120 percent despite a 64 percent increase in fishing pressure (Shetter et al. 1946). Warner and Porter (1960) indicate modest improvement in the brook trout population following the installation of deflectors and the digging of pools in a bulldozed stream in Maine. The use of artificially improved spawning areas for brook trout in New York lakes was studied by Webster (1962), who found that for unknown reasons, some were utilized while others were not. Additional similar studies published by various American state government agencies are cited by White (1973).

The conclusion to be drawn from these studies is that damaged stream physical habitats can be beneficially altered by stream improvement techniques. Trout populations can be significantly increased, provided that the improvement structures are carefully planned on a site-specific basis as well as in the context of the stream system as a whole. Long-term studies seem to show that only well-designed and carefully constructed stream improvement structures can be expected to remain functional for long periods without maintenance (Ehlers 1956; Gard 1972). However, many of the small streams in the AOSERP study area are slow-moving and there seems to be no reason to suppose that existing stream improvement techniques cannot be modified to suit them and the fish species they support.

Another important stream rehabilitation consideration is the provision of passage facilities (fishways) for fish species whose spawning migration routes have been blocked by the construction of diversion dams. A comprehensive discussion of fishway planning and design is presented by Clay (1961), and a summary of the most important factors to be considered is provided by USDA (1969). The available literature concentrates on fishways designed for salmonids on large rivers. However, extensive usage of such facilities by two common species of the AOSERP study area -- the Arctic grayling and the long-nosed sucker -- is known to occur (Clay 1961; Gordon et al. 1960). We found no definite evidence regarding the use or avoidance of fishways by other fish species of the AOSERP study area.

In the AOSERP study area to date, aquatic habitat rehabilitation has apparently been restricted to the Peace-Athabasca Delta, to correct the well-known adverse ecological effects attendant upon the lowered water levels caused by the Bennet Dam. As a temporary measure, the Quatre Fourches weir was constructed in 1971 to impound water from the Birch River basin. The water levels of Lakes Claire and Mamawi and their adjacent wetlands were raised and 1972 water levels in Lake Athabasca and the Delta approached the desired objectives. As a more permanent, long-term solution it was subsequently decided to construct a weir at the Little Rapids site on the Rivière des Rochers in conjunction with a cut-off dam on the Revillon Coupé to prevent flow from passing through that channel. These structures were completed in 1976 and the Quatre Fourches weir was removed (Fisheries and Environment Canada 1976).

4.2.3 Birds

Loss of waterfowl habitat in the Athabasca Oil Sands area could occur as a result of diversion projects (section 2.2.3), and direct rehabilitation would presumably not be possible in most instances -- a new diversion to restore water levels would be necessary, leading to further habitat loss elsewhere, and so on. Increased duck production following seasonal water application before the spring migration has been documented by Anderson and Glover (1967) and

Schroeder et al. (1976), but this is a costly technique restricted to managed areas.

Creation of new habitat for waterfowl by the use of impoundments is a well-known and often successful technique with obvious applications in the AOSERP study area where impoundments and locally raised water levels will be associated with diversion projects. However, some impoundments are unsuccessful and some may have adverse side effects. Bonnema and Zschomler (1974) studied attempts to mitigate wetland habitat loss following channelization projects. In one, the wetland habitat was increased only at the expense of an equal amount of productive upland habitat; in another, only marginal improvement occurred; while in a third, an impoundment designed to increase waterfowl habitat actually decreased it by 15 percent.

Creation of new wetland habitat for waterfowl is clearly a technique which requires careful planning. In many cases, at least a minimum level of continued management may also be desirable. Waterfowl impoundments tend to slowly lose their attractiveness to ducks after an initial peak in use, and productivity can apparently only be restored by periodic drawdowns (Burgess 1969; Kadlec 1962; Keith 1961).

In the Athabasca Oil Sands area, enhancement of wetland habitat could perhaps center on waste lands, or on habitat types which are presently unproductive. Some quite successful work on the utilization of waste land and water to provide waterfowl habitat in Maryland is described by Uhler (1956).

4.2.4 Mammals

Muskrats and waterfowl utilize similar sorts of habitat, so that rehabilitation considerations in each case are much the same. Ambrock and Allison (1973) suggested that in the Peace-Athabasca Delta, muskrat production could be maximized by a management scheme in which adequate water levels are maintained in muskrat habitat for a period of five to ten years, followed by a year of drawdown for regeneration of emergent vegetation.

For beavers, the situation is somewhat different because the provision of new aquatic habitats is unlikely to lead, by itself, to an increase in food availability. Slough and Sadleir (1977) suggest that for beavers, the best method of maintaining or enhancing suitable habitat is the preservation of existing stands of aspen, their preferred food source.

5. BIOMONITORING AND REMOTE SENSING

A biomonitoring system is a system of organized observations, over time, of changes in the environment as evidenced by certain indicators defined in a program (Fedorov 1975). For maximum effectiveness, the program should allow for the simultaneous study of the different agents of environmental change and the various elements of the biosphere that are affected by them. The program should also, of course, provide for comparison of data with baseline conditions. There seems to be very little published literature on biomonitoring in a general sense, perhaps because the study needs for specific areas vary so much according to the types of changes that are occurring and the types of environments they affect.

Remote sensing is an invaluable tool in the monitoring of environmental change, as it has major advantages over conventional ground-based studies: it provides an overall view which is not available from the ground; it can provide a permanent time record for large areas; and it can expand the limits of the human eye to provide data that would otherwise not be available at all (Scherz 1971). In addition, it makes possible the simultaneous collection of data on different environmental factors. In practical terms, these advantages can lead to increased speed of data acquisition, increased accuracy and usefulness of data, and decreased expense. Where remedial measures are being planned, the time factor in data acquisition may be particularly important (Cairns et al. 1973). Remote sensing is not the cheapest surveillance system in every monitoring situation (Ward 1974); but in the AOSERP study area, much of which is relatively inaccessible by ground transportation, its advantages are obvious. The relevance of remote sensing to the AOSERP study area is discussed in Syncrude (1974), and specific remote sensing studies in the area are discussed later in this section.

A wide variety of different remote sensing systems are now available for environmental studies. A comprehensive review of basic remote sensing principles, instrumentation, data analysis including digital processing, ground truth requirements, and applications and limitations of remote sensing systems may be found in Lintz and Simonett (1976). Some of the more sophisticated systems, while they offer advantages in the collection of certain types of data, suffer from the drawback of being very expensive. A case in point is multispectral scanning, which also requires sophisticated data analysis. Lent and Thorley (1969) present an overview of multispectral remote sensing techniques and some guidelines concerning their suitability for different types of wildland resource studies. One relatively inexpensive application of multispectral remote sensing in the AOSERP study area might be the monitoring of long-term changes in the turbidity or trophic state of large water bodies using ERTS-1 satellite data. Other remote sensing systems that may be of use in the AOSERP study area are mentioned later in this section as appropriate.

The current state of the art in remote sensing is such that many changes in floral assemblages and in certain parameters of water quality can be monitored directly, while changes in populations of aquatic invertebrates, fish, waterfowl, and small mammals can not. Changes in faunal populations must either be monitored on the ground by conventional methods, or inferred from remotely-obtained data on habitat change coupled with information on the relationships of particular organisms with specific habitat factors.

5.1 AQUATIC FLORA

In monitoring post-diversion changes in aquatic flora, the principal subjects of investigation are changes in abundance or distribution of individual plant species or of plant communities, as related to pre-diversion conditions. Many of these changes, particularly those involving entire plant communities, can now conveniently be monitored by remote sensing, although at least a minimum of ground truth data is always necessary. When data at the level of individual species are required, as in a study of changes in relative abundance within a particular community, a much higher proportion of ground-based work may be required.

5.1.1 Periphyton

Mapping of algal concentrations over large areas using remotely sensed data has been described by Lawrence and Graham (1975) and Polcyn and Lyzenga (1973), and mapping of chlorophyll *a* (which may reflect the presence of macrophytic vegetation as well as algae) by Bukata and Bruton (1974), Bukata et al. (1974), and Wezernak (1974). The technique uses multispectral data from aircraft or satellite to detect changes in reflectance in certain spectral bands, and relative algal concentrations can be distinguished by density analysis of the data. Changes in chlorophyll *a* concentration can be discriminated from changes in turbidity because of differential corresponding changes in certain spectral bands (Bukata and Bruton 1974). Remote sensing at present, then, appears to be useful only in detecting changes in distribution or density of algal masses detectable from the air.

Detailed monitoring of periphyton communities requires repeated sampling for species identification. Density changes can be detected by drying and weighing samples to determine unit biomass. Conventional techniques for sampling and analysis of periphyton communities, as adapted for studies in the Athabasca River near the Syncrude lease, are discussed by McCart et al. (1977). Techniques used in Ruth Lake and Poplar Creek, on the Syncrude lease, are discussed in RRCS (1977) and Syncrude (1975a).

5.1.2 Macrophytes

Aquatic vegetation can be readily discriminated on certain types of film if it is near the surface, and it can also be detected by remote sensing when it is submerged, provided that the water is clear (Long and Link 1977). Species identification is apparently possible in some, but not all cases, and would obviously depend on the amount of ground truth information available. Dirschl et al. (1974) mention mapping of aquatic vegetation in the Peace-Athabasca Delta using colour and colour infra-red photography in conjunction with transect studies. In Ontario, Wile (1973) found colour negative film to be superior to colour infra-red film in mapping aquatic vegetation, while

Nielson (1972) used colour and colour infra-red film in Wabamun Lake, Alberta. Wile felt that remote sensing provides a more rapid, more accurate, and less expensive method of mapping aquatic vegetation than do conventional mapping techniques. Gustafson and Adams (1973) discriminated stem density and biomass classes for two species of aquatic plants in a Wisconsin Lake, using microdensitometric analysis of colour infra-red film in conjunction with sample harvesting. Gustafson and Adams (1973) found this technique to give more reliable results than conventional procedures in a much shorter time. Conventional techniques involve the collection, drying and weighing of macrophyte samples to determine species composition and biomass (Robel 1962). In the Syncrude lease area, RRCS (1977) and Syncrude (1975a) used transect sampling to determine species composition of macrophytic communities.

The technique described by Gustafson and Adams (1973) has obvious promise in the monitoring of aquatic vegetation change, although it might be restricted to water bodies where seasonal turbidities are relatively constant from year to year. Gross changes in aquatic plant distribution can, of course, easily be detected by standard visual photo-interpretation.

5.1.3 Other Wetland Vegetation

It is well known that wetland vegetation communities are very susceptible to change in response to relatively minor variations in water level (section 2.1), with direct consequences for waterfowl and semiaquatic mammals. Wetland vegetation mapping and monitoring of wetland vegetation change using remotely sensed data are not new techniques, and there are many relevant articles. Quite subtle discriminations among community types are possible using colour and colour infra-red images in conjunction with ground studies, so that remote sensing is definitely an indispensable tool in wetland vegetation studies. Moisture stress resulting either from moisture deficiency or surplus is detectable on infra-red colour film, allowing early detection of changes in moisture regime (Bajzak 1975; Myers 1970; Syncrude 1974).

Wetland vegetation of the Syncrude lease area has been studied using colour infra-red photography (Syncrude 1974); and the Peace-

Athabasca Delta has been mapped and changes resulting from decreased water levels have been studied using colour and colour infra-red imagery in conjunction with transect studies (Dabbs 1971; Dirschl and Dabbs 1972; Dirschl et al. 1974). Seher and Tueller (1973) present some observations on attempts to determine the optimum film type, scale, time of day, and time of year for best results in wetland photography. Kolipinski et al. (1969) discuss automated monitoring of wetland vegetation change using multispectral scanning and computer processing of data, and the possibility of applying this technique to the AOSERP study area is mentioned in Syncrude (1974).

Vegetation change can also be studied by the establishment and sequential examination of numerous sample plots, but with the advent of remote sensing techniques this method has been outmoded for all but the most detailed ecological studies. Modern studies of wetland vegetation may require only limited plot sampling in order to correlate ground vegetation structure with photographic image characteristics. Dabbs (1971) and Dirschl et al. (1974) discuss the balance between air and ground data acquisition in the Peace-Athabasca Delta studies. An AOSERP project currently in progress will present a vegetation classification system designed specifically for remote sensing in the AOSERP study area. It will also present findings concerning the time of day, time of year, and emulsion type most suitable for different remote sensing purposes in the area.

5.2 AQUATIC FAUNA

As mentioned above, direct remote sensing of aquatic fauna appears to be impossible using existing techniques. Remote sensing can, however, be used to monitor other elements of the environment that have a direct effect on the aquatic fauna. In many cases remote sensing appears to be the most efficient monitoring technique, obvious examples being wetland vegetation change (section 5.1.3), erosion processes and stream channel change, and the detection of point sources of sediment and pollutants in streams. Less obvious applications involve the monitoring of water temperature and turbidity.

Different types of diversion could raise or lower water temperatures, with harmful effects for fish and aquatic invertebrates. Surface water temperature can be remotely sensed using thermal infra-red photography or thermal scanning devices; the monitoring possibilities are obvious. Temperature mapping by thermal infra-red imagery seems to have been applied mostly to lake studies, although its use in a river study in Montana is described by Ruff et al. (1974). Another application of thermal remote sensing techniques is the detection of groundwater seeps through temperature differences (Souto-Maior 1973). Very accurate temperature mapping can be achieved using thermal scanners. Temperature differences of considerably less than 1°C can be discriminated (Polcyn and Lyzenga 1973), and many scanners are now designed to give absolute temperature readings without the need of ground truth observations (Scherz 1971).

Monitoring of changes in turbidity or sediment concentrations may also be required in the AOSERP study area. The use of ERTS-1 data for long-term monitoring of water quality in larger lakes is suggested by Munday (1974), and Bukata et al. (1974) mapped turbidity zones in Lake Huron using satellite data. At a local level, Ruff et al. (1974) mapped relative sediment concentrations by using visual interpretation of colour and colour infra-red photography in conjunction with sediment sampling. Scherz (1971) suggested that detailed data on sediment mixing patterns could be obtained by combining micro-densitometric analysis of photographs with ground truth data, and Rosgen (1976) successfully used this technique in a Montana River. Related applications are monitoring the dispersal patterns of pollutants, and studying flow patterns by dye tracing (McCoy and Lackie 1973).

Remote detection of changes in water levels is also possible in some cases. This can be achieved by measurement of change in width of water bodies on sequential photos, or water depth can be measured directly using certain spectral frequencies (Nelson et al. 1970; Polcyn and Lyzenga 1973). The latter technique, however, is limited to use in clear water and is effective to depths of only about 5 m.

5.2.1 Invertebrates

Monitoring of changes in invertebrate populations following diversion-related environmental change requires successive sampling of both attached and drifting organisms at selected sites throughout the affected area. Pre-diversion baseline data should be available for these sites. Changes in abundance and distribution of individual species must be monitored in order to detect changes in total invertebrate population or community structure. It is also important to find out if new species are entering the habitat, and if previously established species are disappearing.

A wide variety of invertebrate sampling techniques and devices are available for use in different habitat types. The variance in results among different techniques for the same environment is pointed out by Hughes (1975), and it is beyond the scope of this review to provide a detailed discussion of the relative merits of different techniques for sampling invertebrate populations. Invertebrate sampling methods used in the area of the Syncrude lease are described in McCart et al. (1977), RRCS (1977), and Syncrude (1973d, 1975a). A brief overview of invertebrate sampling considerations for the AOSERP study area is given by Jantzie (1977).

5.2.2 Fish

Changes in stream fish populations must also be monitored by successive sampling techniques. General monitoring considerations are much the same as for invertebrates, except that it is often desirable to monitor fish movements as well as populations.

Various methods of fish censusing can be used in different situations, including visual identification, angling, various kinds of trapping and netting, electrofishing, rotenone, explosives, and echo sounding. Of these, netting and electrofishing with subsequent return of captured fish are the methods most commonly used. In the Peace-Athabasca Delta, Kooyman (1973) used gillnets in his study of goldeye, as did Bidgood (1973) in his study of walleye. McCart et al. (1977) used seining, gillnetting, and electrofishing in their Athabasca

River fish study. Similar methods were used by RRCS (1977) and Syncrude (1975a) in their studies of fish in Beaver and Poplar creeks and Ruth Lake, and by Shell (1975) in studies of lakes and streams in the Shell lease area. In earlier studies of Beaver Creek, RRCS (1973) used trapping, netting and explosives, and Syncrude (1973d) used explosives. Jantzie (1977) presents a short overview of fish sampling considerations for the AOSERP study area.

The standard techniques of monitoring fish movements are tagging and fin clipping. Tagging was used by Bidgood (1973) and Syncrude (1973d). An interesting recent development is the use of radio tracking devices adapted for underwater use to study walleye movements in a Minnesota Lake (Holt et al. 1977). There are also ongoing studies by H. A. Baldwin and D. B. Bidgood to study fish movements in the AOSERP study area by means of surgically implanted radio tracking devices in goldeye, walleye, lake whitefish, and pike (AOSERP 1977?).

5.2.3 Birds

Waterfowl populations may be affected by various types of events at any point along their migration route, so that year-to-year censusing of populations does not necessarily reflect waterfowl response to environmental changes in a specific locality. For that reason, monitoring of wetland habitat changes per se appears to be a necessary part of waterfowl studies. Methods of estimating waterfowl populations, breeding success, and production are well known and need not be reviewed here. Censusing techniques used in a waterfowl study of the Syncrude lease are discussed by Syncrude (1975b), and techniques used in a waterfowl study in the Peace-Athabasca Delta are presented by Hennan (1973).

Remote sensing is an ideal tool for monitoring wetland vegetation change (section 5.1.3). Remote sensing techniques for studying wetland vegetation specifically as waterfowl habitat are discussed by Kirby (1976), Nelson et al. (1970), Pakulak et al. (1974), and Seher and Tueller (1973).

5.2.4 Mammals

Monitoring of diversion-related changes in semiaquatic mammal populations would require successive censuses of the animals. Monitoring of movements might also be desirable.

In small areas, beaver and muskrat populations can be accurately censused by live-trapping. Marking of captured animals before release prevents the possibility of counting an individual more than once. Live-trapping is a time-consuming technique and is not practical for large areas, which require aerial surveys. In population surveys covering large areas, live-trapping or field observation is first used to relate numbers of animals to numbers of structures built by the animals in several areas. Numbers of beaver lodges and caches, and numbers of muskrat lodges and pushups, can then be used as indices of population density in subsequent aerial surveys. Penner (1976) used aerial observation in a systematic search pattern in conjunction with ground checks in a study of beaver and muskrat on the Syncrude lease. On the Peace-Athabasca Delta, Ambrock and Allison (1973) used trapping, and aerial and ground reconnaissance in their study of muskrat populations; and Surrendi and Jorgensen (1971) used intensive field observations in their study of muskrat winter ecology.

Successful studies of beaver movements have used live-trapping, marking, and release, followed later by recapture (Leege 1968; Townsend 1953). The same technique could no doubt be used in monitoring muskrat movements.

Remote sensing, apart from aerial observation, can be used to monitor changes in beaver and muskrat habitat. Aerial photography as it relates specifically to beaver habitat is discussed by Dickinson (1971) and Kirby (1976).

6. RESEARCH NEEDS

An evaluation of the effects of stream diversion and related restoration or enhancement techniques on aquatic biota in the AOSERP study area requires:

1. Knowledge of environmental conditions existing before disturbance (baseline information); and
2. Practical knowledge of the effects of diversion and stream restoration or enhancement techniques on similar ecosystems.

Baseline information on the aquatic biota of the AOSERP study area is quite extensive: Syncrude Canada Ltd. has supported reasonably thorough studies for their oil sands development project (Syncrude Canada Ltd. 1973b, 1973c, 1973d, 1975a, 1975b; RRCS 1973, 1977; McCart et al. 1977; and Penner 1976) and Shell Canada Ltd. and Home Oil Co. Ltd. have supported baseline research for their proposed developments (T. W. Beak Consultants Ltd. 1973; RRCS 1974; Shell Canada Ltd. 1975). AOSERP has also sponsored a wide range of baseline research projects (AOSERP 1976?, 1977?), many of which are as yet unpublished. These include: projects TF 1.1.4, Baseline inventory of furbearers; TF 2.1, Avifauna baseline studies; TF 5.1, Amphibians and Reptiles; VE 2, Landscape classification and mapping; VE 2.3, Habitat mapping of the AOSERP study area; AF 2.0, Ecological studies of benthic invertebrates of rivers in the AOSERP study area; AF 2.5.1, Ecology and life cycles of aquatic invertebrates in Hartley Creek; and AF 4.5.1, Intensive study of fish fauna of the Muskeg River watershed. In addition, the Canadian Wildlife Service and the Alberta government have supported studies of waterfowl (Schick and Ambrock 1974), and fish (Griffiths 1973) in the Athabasca Oil Sands area.

These studies will help provide the means of detecting ecological changes that are caused by diversion projects in the AOSERP study area. It is important to study all the environmental components that might be affected by diversion projects because they are so interrelated that changes in one element may cause changes in others. Needed baseline study projects required to fulfil the first basic research needs are:

1. Develop and evaluate baseline biomonitoring techniques, including remote sensing, that are best suited for use with the aquatic biota of the AOSERP study area.
2. Using these techniques, determine natural variations in population characteristics of aquatic biota in water systems of the AOSERP study area -- especially those which may be affected by future development. Diversion-related changes can then be differentiated from natural ones.
3. Accurate inventory maps of wetland areas (apart from streams and lakes) above and below possible diversion sites are necessary. Aquatic macrophytes including emergent, submerged, and floating-leaved species in wetland communities should be classified and mapped at a suitable scale by using remote sensing techniques. This information would be used to identify successional trends in relation to diversion projects as compared to the successional trends that occur naturally.
4. A continuous monitoring study of water temperatures in streams and lakes that may be affected by diversion projects because stream diversion can alter stream temperature regimes. The objectives should be to obtain background data on temperature regimes before, during, and after development. The direct effects of diversions on water temperatures could then be assessed and related to their effects on aquatic biota. These results could be extrapolated to other areas.
5. Initiate further baseline environmental studies in aquatic ecosystems that could be affected by proposed diversion projects.

The second basic research need is to document the effects of diversion projects, and restoration or enhancement techniques. As yet there is no published information on the effects of these activities in the AOSERP study area; thus a major information "gap" exists. However, environmental studies of the Syncrude Canada Ltd. diversion project are in progress and may be available for review in May 1978 (Letter dated February 16, 1978 from S. Elliot, Syncrude Canada Ltd., Environmental Coordinator, Special Projects). The results of this diversion

(Beaver Creek) are being regarded as an example from which much can be learned by future oil sands developers. Shell Canada Ltd., for instance, will apparently delay detailed planning of their Muskeg River-Hartley Creek diversion until the results of the Beaver Creek diversion are known (Shell 1975). This then is a primary research need: to determine as much as possible about the effects of the Beaver Creek diversion on aquatic life.

The following suggestions for research should be considered as a means of gaining practical knowledge about the effects of diversions, and restoration or enhancement techniques in the AOSERP study area:

1. Biomonitoring techniques used in baseline studies should be used during and after diversions to detect diversion-related changes in aquatic biota. Particular attention should be given to long-term trends.
2. Review the reproduction and population dynamics of Arctic grayling, burbot, perch, suckers, and forage fish species found in the AOSERP study area. Using this information, the probable effects of diversion and impoundment on these fish species could be summarized.
3. Monitor the distribution, abundance, and composition of fish and macroinvertebrate populations above and below the Beaver Creek diversion and in impoundments created by the diversion. Results could be used to detect population shifts caused by diversion projects.
4. Experimentally test the effectiveness of various stream restoration techniques in the Beaver Creek diversion. To the best of our knowledge there are no rehabilitation studies which are directly applicable to the AOSERP study area. The diversion of Beaver Creek provides the first opportunity to design experiments to test the effectiveness of stream restoration or enhancement techniques in the AOSERP study area. The small streams and diversion channels involved seem very suitable for the installation of various stream improvement devices such as current deflectors, and rock or log dams. Experiments could also be designed to revegetate altered stream

banks. Biomonitoring of vegetation, invertebrates, fish, birds, and mammals would indicate the efficacy of these techniques.

5. Study the colonization or recolonization by aquatic biota of areas altered by diversion-related activities.
6. Determine the effects that diversion dams and channels have on fish movements in the Beaver Creek-Poplar Creek drainage. Some aspects to consider are the timing and size of fish spawning migrations. If diversion channels or dams restrict fish movements then devices could be designed to allow fish passage past such barriers. Necessary research may involve a determination of fish swimming capabilities and rheotatic responses.
7. Diversions in the AOSERP study area will provide opportunities for wetland management by control of water levels. A review of water level management techniques should be conducted and experiments begun to determine the best strategies for production of aquatic life. Aspects to consider are the extent and timing of flooding or drawdowns.
8. Conduct a literature review of the physical and chemical changes that could occur in water bodies of the AOSERP study area as a result of channelization and impoundment.

Monitoring and inventory studies should be carried out before, during, and after the period of disturbance. They should continue until the ecosystems affected complete their adjustment to the altered environmental conditions. The period of time that may be required for this stabilization to occur will vary with the particular circumstances of each diverion project and can only be determined by practical experience in the field. After detailed information is collected on the effects of the Beaver Creek diversion project, and the effectiveness of restoration or enhancement techniques are assessed, then it will be possible to determine the areas of study that will require more detailed research for future diversion projects in the AOSERP study area.

7. BIBLIOGRAPHIES

Articles and documents reviewed in the main body of this report are listed below in the annotated bibliography. Each reference is accompanied by a listing of:

1. The geographic location of the study area, where applicable;
2. The main and secondary subjects of the article; and
3. Critical and explanatory notes.

All the annotations were adapted from the original papers unless otherwise noted. Most of these references are publicly available in university libraries, the Alberta Environment Library, or from the various government agencies responsible for the publication of the articles.

Publications that we requested from various sources, but did not receive in time for annotation, are listed in a separate section of additional references.

We do not claim that this bibliography is a complete compilation of all the references that could have some bearing on diversion-related problems in the AOSERP study area. Rather, it is a selected list of such references designed to illustrate and/or document the various points that should be considered in studying the environmental effects of diversion.

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and other plant species that provided
waterfowl.

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AOSERP study area
oil sands research

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Construction activities, including stream improvement, particularly those which encroach directly on a stream channel, must be based on a knowledge of stream behavior and sedimentation if unanticipated, detrimental changes in the shape and location of the channel are to be avoided. Valuable guidance regarding the effect of stream improvement designs may be derived from studying existing installations and correlating the circumstances involved with those in situations under consideration.

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Mississippi
effects, channelization, plankton, macroinvertebrates, fish, mammals.

Biological data were collected for two years from an old channelized segment, an unchannelized segment, and a newly channelized segment of the Luxapalila River. Six permanent stations were sampled for plankton, benthos, and water quality. Three areas were established for fish and furbearer investigations. Species diversity of plankton, macroinvertebrates and fish was greater in the unchannelized segment. Muskrat and beaver were more numerous in the unchannelized segment than in either the old or new channelized segments.

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effects, channelization, wetlands

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North Carolina
effects, channelization, fish

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effects, channelization, fish

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muskrat, aquatic vegetation

The habitat requirements of muskrats in terms of food sources and water level are discussed.

Bellrose, F. C., and L. G. Brown. 1941. The effect of fluctuating water levels on the muskrat population of the Illinois River Valley. J. Wildl. Manage. 5: 206-212.

Illinois River
effects, water levels, muskrat, aquatic vegetation

Higher densities of muskrat houses were found in lakes with stable water levels than in lakes with fluctuating water levels. Stable and semi-stable water levels directly favored those species of plants that supported the highest population of muskrats.

Bellrose, F. C., Jr., and J. B. Low. 1943. The influence of flood and low water levels on the survival of muskrats. J. Mammal. 24: 173-188.

Illinois
effects, water levels, muskrat

The effects of floods and droughts on the survival of muskrats in lakes along the Illinois River valley are described. Adaptation to drought was found to be more successful in summer than in winter.

Berra, T. M., and G. E. Gunning. 1970. Repopulation of experimentally decimated sections of streams by longear sunfish *Lepomis megalotis megalotis* (Rafinesque). Trans. Amer. Fish. Soc. 99: 776-781.

Louisiana
recovery, fish

The recovery of fish populations in an artificially decimated section of stream is described.

Bianchi, D. R., and R. Marcoux. 1975. The physical and biological effects of physical alteration of Montana trout streams and their political implications. Pages 50-59 in Corning et al., Eds. Symposium on stream channel modifications: proceedings. Harrisonburg, Virginia. 15-17 August, 1975.

Montana
effects, channelization, fish

In 1973, 160 miles of six streams were surveyed and it was determined that 24 miles of channel and 44 miles of streambank were altered. Also, trout populations were determined in three adjacent sections of the Ruby River with different amounts and types of alterations. There were approximately three times as many brown trout in a natural section as compared to a bulldozed section and two times as many as compared to a riprapped section.

Bidgood, B. F. 1973. Walleyes and water levels in Lake Athabasca. In Section E, Vol. 2. The Peace-Athabasca Delta Project, Technical Appendices. 20 p.

Peace-Athabasca Delta
effects, water levels, diversion, walleye

A hydroelectric dam on the Peace River caused lowered water levels in the Peace-Athabasca Delta. The course of the Maybelle River was diverted and a spawning run of walleye was prevented from moving into the river to spawn. When water levels were raised, the course of the Maybelle River was restored.

Bilby, R. 1977. Effects of a spate on the macrophyte vegetation of a stream pool. Hydrobiologia 56: 109-112.

New York State
effects, water levels, aquatic vegetation

Flooding of a small pool caused a change in current velocities within the pool. This in turn caused a redistribution of two plant species: *Elodea canadensis* and *Potamogeton crispus*. The average plant cover per m^2 was also reduced after the spate.

Bishop, J. E. and H. B. N. Hynes. 1969. Upstream movements of the benthic invertebrates in the Speed River, Ontario. J. Fish. Res. Board Can. 26: 279-298.

Ontario
colonization, macroinvertebrates

Investigation of the benthic fauna of the Speed River, Ontario, revealed upstream movement of substantial numbers of invertebrates. The upstream movements were of sufficient quantity and species diversity to account for recolonization of dried-out or erosion-denuded areas.

Blench, T. 1972. Morphometric changes. Pages 287-308 in R. T. Oglesby, C. A. Carlson, and J. A. McCann, Eds. River Ecology and Man. Academic Press, New York.

effects, diversion, channelization, impoundments, environment

A non-technical presentation of the quantitative study of river regimes through morphometrics. The effects of interfering with river regimes -- on themselves and on the environment -- are discussed. A case history of the Peace-Athabasca Delta is presented.

Boccardy, J. A., and E. L. Cooper. 1961. Resilience of a fish population in a stream in Pennsylvania. Prog. Fish Cult. 23: 26-29.

Pennsylvania
recovery, fish

After decimation of the fish population by rotenone, a stream was quickly repopulated by all the species originally present. The species composition remained essentially the same; only minor changes in the abundance of certain species were noted.

Bonnema, K. W., and M. S. Zschomler. 1974. Drainage, mitigation, and land treatment in a PL 83-566 watershed. Wildlife Society Bulletin 2: 185-190.

Minnesota
effects, rehabilitation, waterfowl, muskrat

The effects of a channelization and flood control project on wetland wildlife habitat are discussed. The effectiveness of attempts to mitigate wildlife habitat loss by means of water level control structures, diking, level ditching, nesting islands, and dugouts are reviewed. These mitigation attempts resulted in the creation of 309 acres of lakes and wetlands but 3,360 acres of wetlands were drained during project construction.

Boreman, J. 1974. Effects of stream improvement on juvenile rainbow trout in Cayuga Inlet, New York. Trans. Amer. Fish. Soc. 103: 637-641.

New York State.
rehabilitation, fish

The standing crops of juvenile rainbow trout in improved areas of Cayuga Inlet, New York, were compared with those in natural areas. There was no difference in biomass, average weight, or number of trout between altered and natural areas.

Boussu, M. F. 1954. Relationship between trout populations and cover on a small stream.. J. Wildl. Manage. 18: 229-239.

Montana
rehabilitation, fish

Trout populations were censused before and after alterations were made to improve trout habitat. Fish populations increased after alterations were made and decreased when the stream alterations were removed.

Briggs, J. C. 1948. The quantitative effects of a dam upon the bottom fauna of a small California stream. Trans. Amer. Fish. Soc. 78: 70-81.

California
effects, impoundment, macroinvertebrates

The damming of a small stream resulted in marked changes below the dam. It was concluded that the dam had a beneficial effect in increasing the production of stream-bottom fauna.

Brown, G. W., and J. T. Krygier. 1970. Effects of clear-cutting on stream temperature. Water Resources Research 6: 1133-1139.

Oregon
vegetation, stream temperature effects, vegetation removal

The amount of sunlight reaching the stream may be increased after clear-cut logging. Average monthly maximum temperatures increased by 14°F and annual maximum temperatures increased from 57° to 85°F one year after clear-cut logging on a small watershed in Oregon's coast range. In a nearby watershed where strips of brush and trees separated logging units from the stream, no changes in temperature were observed that could be attributed to clear-cutting.

Bukata, R. P. and J. E. Bruton. 1974. ERTS-1 digital classifications of the water regimes comprising Lake Ontario. Proc. Can. Symp. on Remote Sensing. 2: 628-631. Univ. of Guelph.

Ontario
remote sensing

The use of ERTS-1 data in mapping chlorophyll *a* concentration and surface turbidity in Lake Ontario is discussed.

Bukata, R. P., W. S. Haras, and J. E. Bruton. 1974. Space observations of lake coastal processes in Lake Huron and Lake St. Claire. Proc. Can. Symp. on Remote Sensing. 2: 532-551. Univ. of Guelph.

Ontario
remote sensing, sediment sources

Distinct turbidity zones in Lake Huron were delineated using ERTS-1 data in conjunction with low level aerial photography.

Bukata, R. P., G. P. Harris, and J. E. Bruton. 1974. The detection of suspended solids and chlorophyll *a* utilizing digital multispectral ERTS-1 data. Proc. Can. Symp. on Remote Sensing. 2: 552-555. Univ. of Guelph.

Ontario
remote sensing

The use of multispectral ERTS-1 data in studies of turbidity and chlorophyll *a* distribution in lakes is discussed.

Burgess, H. H. 1969. Habitat management on a mid-continent waterfowl refuge. J. Wildl. Manage. 33: 843-847.

Missouri
enhancement, waterfowl

Management techniques involving seasonal drawdowns to increase waterfowl production in a managed waterfowl area are discussed.

Burton, T. M., and G. E. Likens. 1973. The effect of strip-cutting on stream temperatures in the Hubbard Brook Experimental Forest, New Hampshire. Bioscience 23: 433-435.

New Hampshire
effects, temperature, aquatic vegetation

The effects of strip-cutting on temperatures in a small stream were studied. A 10 m strip of trees left on each side of the main stream was effective in buffering stream temperature fluctuations.

Carothers, S. W. and R. R. Johnson. 1975. The effects of stream channel modification on birds in the southwestern United States. Pages 60-76 in R. V. Corning et al., Eds. Symposium on stream channel modifications: proceedings. Harrisonburg, Virginia.

Southwestern U.S.A.
effects, channelization, vegetation, birds

The effects of channelization and phreatophyte control in riparian habitats are evaluated. The importance of riparian habitat to breeding avifauna in the southwestern United States is discussed. Environmental factors which influence bird species diversity and population density are outlined and discussed from a managerial point of view.

Cairns, J. Jr., K. L. Dickson, and E. E. Herricks, eds. 1977. Recovery and restoration of damaged ecosystems. Univerity Press of Virginia, Charlottesville. 531 p.

United States, England, Sweden, Costa Rica
recovery, rehabilitation, ecology

This book explores the prospects of recovery in an ecosystem if damage has already occurred. International scientists contribute case histories, present theories, and raise questions related to restoration and recovery of damaged ecosystems. The book focuses on three major topics: (1) the nature of recovery processes for various ecosystems; (2) identification of elements common to the recovery process for all ecosystems as well as unique attributes of various kinds of ecosystems; and (3) propects for accelerated recovery and restoration by human intervention and management.

Choate, J. S. 1972. Effects of stream channeling on wetlands in a Minnesota watershed. J. Wildl. Manage. 36: 940-944.

Minnesota
effects, channelization, wetlands

Over 60 miles of stream were channeled in the lower three quarters of the Hawk Creek watershed, west-central Minnesota. Streams straightened and deepened caused drainage of adjacent wetlands valuable to wildlife in two ways: (1) directly by the channeling operation which encouraged a more rapid removal of flood waters; and (2) indirectly when auxiliary drainage systems were established to take advantage of more efficient drainage. Only a small portion of the wetland loss was direct; most was indirect. On a percentage basis, wetland acreage loss in the unchanneled area was 6% and in the channeled area it was 54% after 13 years.

Clay, C. H. 1961. Design of fishways and other fish facilities. Dep. Fish. Ottawa. 301 p.

rehabilitation, fish

A comprehensive discussion of fishways and related structures, with emphasis on the problems faced at hydroelectric dams on large rivers.

Congdon, J. C. 1971. Fish populations of channelized and unchannelized sections of the Chariton River, Missouri. Pages 52-62 <u>in</u> E. Schneberger and J. L. Funk, Eds. Stream Channelization: a Symposium, N. Cent. Div. Amer. Soc. Spec. Pub. 2.

Missouri
effects, recovery, channelization, fish

Fisheries losses resulting from channelization of over 200 miles of the Chariton River, Missouri are described. The results show that channelization caused an 87% reduction of the fish population 30 years after channelization. Channel straightening reduced the stream's length by 55.2%.

Cordone, A. J., and D. W. Kelley. 1961. The influence of inorganic sediment on the aquatic life of streams. Calif. Fish and Game 47: 189-228.

California
effects, sediment, aquatic life

Investigations of the effects of inorganic sediment on the aquatic life of streams are reviewed and discussed.

Corning, R. V., R. F. Raleigh, G. D. Schuder Sr., and A. Wood, eds. 1975. Symposium on stream channel modification: proceedings. Harrisonburg, Virginia. August 15-17, 1975. 125 p.

United States
effects, channelization, aquatic life

Twelve lectures are presented by legislators, scientists, and engineers. The following topics are discussed: (1) policies and objectives of agencies that modify stream channels, (2) biological considerations of stream channel modification, and (3) stream modification alternatives and methods of mitigation or enhancement. The proceedings of panel discussions and a citizens' forum on stream channel modification are also given.

Crisp, D. T., and T. Gledhill. 1970. A quantitative description of the recovery of the bottom fauna in a muddy reach of a mill stream in southern England after draining and dredging. Arch. Hydrobiol. 67: 502-541.

England
recovery, macroinvertebrates

Describes the recovery of the benthos in a stream for two years after it had been drained and dredged. Observations suggested that recovery was fairly complete about one year after dredging.

Cullen, A., and A. Ducharme. (1977?). Techniques for determination of maintenance flows for protection of fish habitat. Environment Canada, Fisheries and Marine Serv. Unpublished manuscript.

Eastern Canada
effects, flow regime, macroinvertebrates, fish

The results of a literature review of studies in a variety of streams, show that below 30% of the mean annual flow and 25% of the average daily flow causes significant reductions in fish cover, food, and spawning areas. Stream velocity is considered as a strong habitat limiting factor for many benthic organisms.

Dabbs, D. L. 1971. Landscape classification of the Peace-Athabasca Delta using air photo techniques. Unpublished M.Sc. thesis, Univ. of Saskatchewan. 169 p.

Peace-Athabasca Delta
remote sensing, vegetation

Discusses the successful adaptation of known air photo techniques to studies and mapping of vegetation in the Peace-Athabasca Delta.

Daniels, R. B. 1960. Entrenchment of the Willow Drainage Ditch, Harrison County, Iowa. American Journal of Science 258: 161-176.

Iowa
effects, channelization, erosion

Rapid changes in river morphology, caused by the construction of drainage ditches, are described.

Dickinson, N. R. 1971. Aerial photographs as an aid in beaver management. N.Y. Fish and Game J. 18: 57-61.

New York
remote sensing, beaver

The use of aerial photographs in recognizing potential beaver colony sites is discussed.

Dillon, O. W. and L. D. Marriage. 1973. Fish and wildlife habitat improvement in watershed projects. Pages 43-48 in Soil Conservation Society of America. Wildlife and Water Management: Striking and Balance.

U.S.A.
rehabilitation

Techniques for improving trout habitat have been successful in streams having a relatively constant flow and show promise for use in controlled-flow streams. For widely fluctuating streams, however, stream improvement structures show less promise.

Dirschl, H. J. 1971. Ecological effects of recent low water levels in the Peace-Athabasca Delta. Pages 174-186 in Proceedings of the Peace-Athabasca Delta Symposium: Univ. of Alberta, Edmonton.

Peace-Athabasca Delta
effects, water levels, environment

The environmental effects of an altered water regime in the Peace-Athabasca Delta are discussed.

Dirschl, H. J. 1972. Water levels in the Peace-Athabasca Delta. Canadian Wildlife Service Occasional Paper No. 13. 27 p.

Peace-Athabasca Delta
effects, water levels, vegetation

This study is a preliminary account of plant succession on exposed silt surfaces in the Peace-Athabasca Delta. It discusses techniques used to: (1) classify and map the delta's landscape according to homogeneous units and (2) examine the distribution of those landscape units in relation to topography and moisture regimes.

Dirschl, H. J., and D. L. Dabbs. 1972. The role of remote sensing in wildland ecology and environmental impact studies. Canadian Symposium on Remote Sensing. 1: 337-344.

Peace-Athabasca Delta
remote sensing, vegetation

Sequential aerial photography in the Peace-Athabasca Delta has facilitated an understanding of the complex deltaic processes and the study of plant succession and wildife habitat changes resulting from a recently modified river regime.

Dirschl, H. J., D. L. Dabbs, and G. C. Gentle. 1974. Landscape classification and plant successional trends: Peace-Athabasca Delta. Canadian Wildlife Service Report Series Number 30, Environment Canada, 1974.

Peace-Athabasca Delta
remote sensing, vegetation

Plant successional changes resulting from lowered water levels in the delta are discussed. The role of remote sensing in mapping vegetation types and in monitoring vegetation change is also discussed. Several vegetation maps are included.

Donald, D. B., and A. H. Kooyman. 1977. Food, feeding habits, and growth of goldeye, *Hiodon alosoides* (Rafinesque), in waters of the Peace-Athabasca Delta. Can. J. Zool. 55: 1038-1047.

Peace-Athabasca Delta
goldeye

The feeding habits of goldeye were determined by examining the food items found in 1785 stomachs collected from the Peace-Athabasca Delta, Alberta, in 1971, 1972, and 1973.

Dunst, R. S., S. M. Born, P. D. Ultomark, S. A. Smith, S. A. Nichols, J. V. Peterson, D. R. Knauer, S. L. Serns, D. R. Winter, and T. L. Wirth. 1974. Survey of lake rehabilitation techniques and experiences. Tech. Bull. No. 75. Dept. of Nat. Res., Madison, Wisconsin. 179 p.

world
rehabilitation

This comprehensive review delineates the accomplishments of lake restoration-related activities worldwide. The various techniques are identified, described and evaluated; and almost 600 accounts of lake rehabilitation experiences are inventoried. More than 800 literature references are listed.

Duvel, W. A. Jr., R. D. Volkmar, W. L. Specht, and F. W. Johnson. 1976. Environmental impact of stream channelization. Water Resources Bulletin 12: 799-812.

Pennsylvania
effects, channelization, ecology

Investigations of six Pennsylvania coldwater streams were undertaken to determine the impact of channel modifications instituted before and after Hurricane Agnes. The focus of the study was on the ecological changes brought about by stream channelization. No long-term deleterious effects on water quality, attached algae, benthic fauna, or forage fish populations were found. Trout, however, were found to be greater in numbers and weight in natural than in channelized stream reaches. Lack of suitable physical habitat appeared to be the primary cause of reduced trout populations in stream reaches which had been channelized.

Edwards, C. J., B. L. Griswold, and G. C. White. 1975. An evaluation of stream modification in the Olentangy River, Ohio. Pages 34-49 in R. V. Corning, R. F. Raleigh, G. D. Schuder, Sr., and A. Woods, eds. Symposium on stream channel modifications: proceedings. Harrisonburg, Virginia.

Ohio
rehabilitation, effects, fish

Compares fish populations in a natural section of stream, a section modified conventionally by channelization, and an altered section modified by the construction of artificial pool and riffle structures.

Edwards, D. 1969. Some effects of siltation upon aquatic macrophyte vegetation in rivers. Hydrobiologia 34: 29-36.

South Africa
effects, sedimentation, aquatic vegetation

Despite high silt loads in South African rivers there appears to be no intensive direct effect upon aquatic macrophytes. Data indicate a general decline in the aquatic vegetation as a result of the changed aquatic environments.

Ehlers, R. 1956. An evaluation of stream improvement devices constructed eighteen years ago. Calif. Fish and Game 42: 203-217.

California
rehabilitation

Reviews the effectiveness of various types of stream improvement structures 18 years after placement. Well-anchored log dams and deflectors were found to be the most effective -- most of the other structures had been washed out by endcutting or undercutting.

Elser, A. A. 1968. Fish populations of a trout stream in relation to major habitat zones and channel alterations. Trans. Amer. Fish. Soc. 97: 389-397.

Montana
effects, rehabilitation, channelization, fish, vegetation

The relationship of fish populations to major habitat zones and channel alterations was studied in a small creek for two summers. Trout were 78% more abundant in unaltered sections than in the altered sections. Amount of cover per acre of stream was about 80% greater in the unaltered sections than in the altered sections. Rock deflectors in the altered stream sections rendered the physical characteristics nearly comparable to those of the unaltered sections.

Elwood, J. W., and T. F. Waters. 1969. Effects of floods on food consumption and production rates of a stream brook trout population. Trans. Amer. Fish. Soc. 98: 253-262.

Minnesota
effects, recovery fish, macroinvertebrates

Four severe floods in two years nearly eliminated two year classes of brook trout. Invertebrate populations were also severely damaged. The stream's carrying capacity was reduced after sand and debris carried into the stream by flood waters filled pools and blanketed riffle areas.

Emerson, J. W. 1971. Channelization: a case study. Science 173: 325-326.

Missouri
effects, channelization, erosion, sedimentation

Channelization of the Blackwater River in Johnson County, Missouri, nearly doubled the gradient, which caused an increase in the rate of erosion for the river and its tributaries. Since the channel was much wider and deeper than it was when newly dredged, bridge repairs were necessary and farmland was lost. Downstream reduction in channel capacity due to termination of dredging caused channel sedimentation and increased flooding.

Erman, D. C. 1973. Upstream changes in fish populations following impoundment of Sagehen Creek, California. Trans. Amer. Fish. Soc. 102: 626-629.

California
impoundment, fish, population changes

Fish populations were compared before (1952-1961) and after (1970-1972) construction of Stampede Reservoir in a mile of Sagehen Creek above the reservoir. Relative abundance and species composition were quite different after reservoir construction. Suckers (*Catostomus platyrhynchus* and *C. tahoensis*) became abundant (79% of all fish); whereas, formerly they made up 18% (by numbers) of the fish composition. Rainbow trout increased, but brown trout and whitefish decreased; and brook trout disappeared. Reservoir construction was the only major change in the Sagehen Creek watershed.

Errington, P. L. 1939. Reactions of muskrat populations to drought. Ecology 20: 168-186.

Iowa
effects, muskrat

The generally unsuccessful responses of a muskrat population to drought conditions are described.

Eschner, A. R.,and J. Larmoyeux. 1963. Logging and trout: four experimental practices and their effect on water quality. Prog. Fish Cult. 25: 59-67.

West Virginia
effects, recovery, logging, water quality, fish

Studies were made to determine how four different timber harvesting practices affected turbidity, temperature, pH, alkalinity, specific conductance, and stream flow. The effects as they relate to fish are discussed.

Etnier, D. A. 1972. The effect of annual rechanneling on a stream fish population. Trans. Amer. Fish. Soc. 101: 372-375.

Tennessee
effects, channelization, fish, macroinvertebrates

Studies were made of a stream before and after channelization. After channelization the diversity of the invertebrate population declined and the fish population structure changed. One species of darter disappeared rapidly after channelization, and other species became more abundant.

Fedorov, V. D. 1975. Biological monitoring: justification and organizational experience. Hydrobiol. J. 11: 1-5.

biomonitoring

A general discussion of biomonitoring, with a case study of a Russian reservoir.

Fisheries and Environment Canada. 1976. Canada Water Year Book 1976. Supply and Services Canada, En 36-425. 104 p.

Peace-Athabasca Delta
effects, rehabilitation, ecology

Summarizes the ecological effects of lowered water levels in the Peace-Athabasca Delta following construction of the Bennett Dam.

Flannagan, J. F. 1977. Life cycles of some common aquatic insects of the Athabasca River, Alberta. Prep. for the Alberta Oil Sands Environmental Research Program by Fisheries and Environment Canada, Freshwater Institute. AOSERP Report 11. 20 p.

AOSERP study area
benthic macroinvertebrates

Macroinvertebrates were collected by means of 20 artificial substrate samples taken during the open water period. Estimates of life cycle lengths and emergence times were made for several species of plecopterans, ephemeropterans, and trichopterans.

Fraser, F. J., and T. G. Halsey. 1969. The application of an air-percolation system for water temperature reduction in Robertson Creek. Can. Fish Cult. 40: 41-49.

Vancouver Island, British Columbia
rehabilitation, fish

Two air percolation systems were used to reduce water temperatures in the headwaters of a small creek. Concomitantly, water temperatures downstream were reduced. Results show that temperature regimes can be easily altered.

Fraser, J. C. 1972. Regulated discharge and the stream environment. Pages 263-285 in R. T. Oglesby, C. A. Carlson, and J. A. McCann, eds. River Ecology and Man, Academic Press, New York, 1972.

effects, discharge, sedimentation, fish, vegetation

Reviews some of the findings on the effects of controlled discharges on river environments with emphasis on fisheries resources.

Funk, J. R. and C. E. Ruhr. 1971. Stream channelization in the midwest. Pages 5-11 in E. Schneberger, and J. L. Funk, eds. Stream Channelization: a Symposium, N. Cent. Div. Amer. Fish. Soc. Spec. Pub. 2.

Midwest U.S.A.
effects, channelization, recovery, fish, birds, mammals

Channelization was investigated in the mid-western United States. The problems of management and the effects on the aquatic environment are discussed.

Gallup, D. N., P. Van Der Giessen, and H. Boerger. 1973. A survey of the plankton and bottom invertebrates of the Peace-Athabasca Delta Region. in Section H, Vol. 2, the Peace-Athabasca Delta Project, Technical Appendices. 35 p.

Peace-Athabasca Delta
effects, water levels, plankton, macroinvertebrates

Background information of the plankton and bottom fauna found in the Delta was obtained. Invertebrate faunas in different regions of the Delta were compared with respect to available food for fish. The effects of lowered water levels on aquatic life in shallow lakes and streams were considered.

Gard, R. 1961. Creation of trout habitat by constructing small dams. J. Wildl. Manage. 52: 384-390.

California
rehabilitation, fish

Small dams 1 to 2 feet high were built across Sagehen Creek in an attempt to create trout habitat in a previously unpopulated headwater reach. Trout were introduced and spawned successfully, and a resident population of trout became established.

Gard, R. 1972. Persistence of headwater check dams in a trout stream. J. Wildl. Manage. 36: 1363-1367.

California
rehabilitation, fish

Discusses the condition of small dams in the headwaters of Sagehen Creek 12 years after placement. Trout planted in the previously barren stream section were able to become established and their standing crop was comparable with a lower reach of the same stream.

Geen, G. H. 1974. Effects of hydroelectric development in Western Canada on aquatic ecosystems. J. Fish. Res. Board Can. 31: 913-927.

Western Canada
effects, impoundment, aquatic life

The effects of hydroelectric development on the lakes and rivers of western Canada are reviewed. Within the impoundment littoral production is usually low, plankton production and water chemistry are little affected, growth rates of fish are frequently reduced, and the relative abundance of fish and their food organisms is frequently altered. The lack of information on the downstream effects of impoundments is discussed.

Gill, D. 1973. Modification of northern alluvial habitats by river development. Canadian Geographer 17: 138-153.

Northwest Territories, Peace-Athabasca Delta
effects, impoundment, diversion, aquatic life, vegetation

The environmental effects of large water storage projects in northern rivers are discussed.

Gordon, R. N., R. A. Crouter, and J. S. Nelson. 1960. The fish facilities at the Whitehorse Rapids Power Development, Yukon Territory. Can. Fish Cult. 27: 43-56.

rehabilitation, fish

The fish passage facilities at the Whitehorse Rapids power development are described. Observations showed that the fishway was used frequently by salmon and Arctic grayling.

Gorski, R. V. 1973. The 1971 congressional hearings on stream channelization - an aid to environmental impact analysis. in L. Ortolano, Ed. Analyzing the environmental impacts of water projects. NTIS AD - 766-286.

U.S.A.
effects, channelization

Summarizes the main environmental impacts of channelization projects in the United States as presented in testimony before congressional hearings in 1971.

Gray, J. R. A., and J. M. Edington. 1969. Effect of woodland clearance on stream temperature. J. Fish. Res. Board Can. 26: 399-403.

England
effects, vegetation removal

A study was made of the temperature characteristics of a stream which flowed first through open fields and then through woodland. When the woodland was felled, that section of the stream showed a marked rise in summer temperature. It was argued that the presence or absence of tree shading can be the decisive factor in determining the temperature of small streams.

Greene, G. E. 1950. Land use and trout streams. J. Soil and Water Conserv. 5: 125-126.

North Carolina, Tennessee
fish, rehabilitation

Careful manipulation of riparian vegetation can be a means of maintaining optimum temperatures for trout and the aquatic organisms on which they feed.

Grimas, Ulf. 1965. The short-term effect of artificial water level fluctuations upon the littoral fauna of Lake Kultsjon, Northern Sweden. Rep. Inst. Freshwater Res., Drottningholm 46: 5-22.

Sweden
macroinvertebrates, water levels

The results of investigations, carried out before and after an artificially induced fluctuation of water levels in a northern lake, are presented.

Grizzell, R. A., and R. G. Vogan. 1973. Characteristics of channels: managing rights-of-way for wildlife and aesthetics. Pages 27-30 in Soil Conservation Society of America, Wildlife and Water Management: Striking a Balance.

rehabilitation, wetlands, aquatic life

Several techniques for mitigation of the adverse effects of channelization on fish and wildlife are reviewed. These include preservation of channel loops, clearing from one side only, using weirs to impound water and preserve wetland vegetation, and installation of current deflectors.

Gunning, G. E., and T. M. Berra. 1968. Repopulation of a decimated stream segment by the sharpfin chubsucker. Prog. Fish Cult. 30: 92-95.

Louisiana
recovery, fish

Sharpfin chubsuckers repopulated an experimentally decimated section of stream within a year. Other fish species required a much longer period for repopulation.

Gunning, G. E., and T. M. Berra. 1969. Fish repopulation of experimentally decimated segments in the headwaters of two streams. Trans. Amer. Fish. Soc. 98: 305-308.

Louisiana
recovery, fish

Discusses fish repopulation of experimentally decimated sections of two warm water streams studied over two years.

Gustafson, T. D., and M. S. Adams. 1973. Remote sensing of *Myriophyllum spicatum* L. in a shallow, eutrophic lake. Pages 387-391 in K. P. B. Thomson, R. K. Lane, and S. C. Csallany, eds. Remote Sensing and Water Resources Management. American Water Resources Ass., Urbana, Illinois.

Wisconsin
remote sensing, aquatic vegetation

An aerial 35 mm system was used for the acquisition of vertical colour and colour infrared imagery of the submergent aquatic macrophytes of Lake Wingra, Wisconsin. A method of photographic interpretation of stem density classes is tested for its ability to make standing crop biomass estimates of *Myriophyllum spicatum*. The results of film image density analysis are significantly correlated with stem densities and standing crop biomass of *Myriophyllum* and with the biomass of *Oedogonium* mats. Photographic methods are contrasted with conventional harvest procedures for efficiency and accuracy.

Hansen, D. R. 1971. Stream channelization effects on fishes and bottom fauna in the Little Sioux River, Iowa. Pages 29-51 in E. Schneberger and J.L. Funk, eds. Stream Channelization: a Symposium, N. Cent. Div. Amer. Fish. Soc. Pub. 2.

Iowa
effects, channelization, fish, macroinvertebrates

Differences in water velocities, temperatures, and turbidity; and bottom fauna and fish populations were evaluated in channelized and unchannelized portions of a river over a two year period.

Hanson, D. L., and T. F. Waters. 1974. Recovery of standing crop and production rate of a brook trout population in a flood-damaged stream. Trans. Amer. Fish. Soc. 103: 431-439.

Minnesota
recovery, fish

Brook trout populations and productivity recovered in four to five years after severe flood damage. Food sources recovered within one year. Rainbow trout migrated from downstream and were able to become established after brook trout populations were lowered.

Harris, S. W., and W. H. Marshall. 1963. Ecology of water-level manipulations on a northern marsh. Ecology 44: 331-343.

Minnesota
effects, water levels, aquatic vegetation

A program of water level manipulations was conducted to establish emergent vegetation in a wildlife refuge.

Henegar, D. L., and K. W. Harmon. 1971. A review of references to channelization and its environmental impact. Pages 79-83 in E. Schneberger and J.L. Funk, eds. Stream Channelization: a Symposium, N. Cent. Div. Amer. Fish. Soc. Spec. Pub. 2.

U.S.A.
effects, recovery, channelization

The available literature on the subject is reviewed and discussed in the following topics: downstream flooding, drainage outlets, sediment damage, groundwater recharge, fishery losses, and wildlife losses.

Hennan, E. 1973. Status of waterfowl on the Peace-Athabasca Delta. In Section K, Vol. 2. The Peace-Athabasca Delta Project, Technical Appendices. 105 p.

Peace-Athabasca Delta
monitoring, waterfowl

Presents census techniques and baseline information for a Delta waterfowl study.

Hibbard, E. A. 1958. Movements of beaver transplanted in North Dakota. J. Wildl. Manage. 22: 205-211.

North Dakota
recovery, mammals

A brief study of beaver movements after transplantation. One individual travelled over 100 km in seven months although movements of about 10 km were more typical.

Hilsenhoff, W. L. 1971. Changes in the downstream insect and amphipod fauna caused by an impoundment with a hypolimnion drain. Ann. Entomol. Soc. Amer. 64: 743-746.

Wisconsin
effects, impoundment, macroinvertebrates

Impoundment had a pronounced effect on the insect and amphipod fauna below a dam. There was a reduction in the number of species and a shift in population structure.

Hochbaum, G. S., and E. F. Bossenmaier. 1972. Response of pintails to improved breeding habitat in southern Manitoba. Can. Field - Naturalist 86: 79-81.

Manitoba
recovery, waterfowl

The elastic response of pintails to improved habitat conditions following drought is documented.

Holt, C. S., G. D. S. Grant, G. P. Oberstar, C. C. Oakes, and D. W. Bradt. 1977. Movement of walleye, *Stizostedion vitreum*, in Lake Bemidji, Minnesota, as determined by radio-biotelemetry. Trans. Amer. Fish. Soc. 106: 163-169.

Minnesota
biomonitoring, fish

Authors studied walleye movement by attaching radio-tracking devices designed for underwater operation.

Hooton, R. S., and D. S. Reid. 1975. Impact of stream channelization on fish and wildlife. Habitat Protection Section, Fish and Wildlife Branch, Department of Recreation and Conservation, Victoria, B.C. 14 p.

effects, channelization, fish, wildlife

The direct and indirect effects of stream channelization upon fish, wildlife, stream hydrology, and recreation are discussed. Fish losses caused by channelization are documented.

Hubbs, C. 1972. Some thermal consequences of environmental manipulations of water. Biological Conservation 4: 185-188.

effects, impoundment

Many of the thermal impacts of "development" projects are discussed. Environmental manipulations can alter thermal regimes, upset the delicate adaptations of natural populations, and have detrimental effects on aquatic biota.

Hughes, B. D. 1975. A comparison of four samplers for benthic macroinvertebrates inhabiting coarse river deposits. Water Research 9: 61-69.

biomonitoring, macroinvertebrates

Four different sampling techniques were found to give substantially different results in qualitative and quantitative composition of macroinvertebrate catches. Explanations are discussed.

Hultin, L. 1971. Upstream movement of *Gammarus pulex pulex* (Amphipoda) in a south Swedish stream. Oikos 22: 329-347.

Sweden
colonization, macroinvertebrates

Upstream movements in the amphipod *Gammarus pulex pulex* were studied in a Swedish stream. Upstream movements appeared to fluctuate seasonally in response to temperature and water level.

Hultin, L., B. Svensson, and S. Ulfstrand. 1969. Upstream movements of insects in a south Swedish small stream. Oikos 20: 553-557.

Sweden
colonization, macroinvertebrates

Documents upstream movements of insects in both juvenile and adult stages. The upstream movements of each species were restricted to a limited time of the year.

Hunt, R. L. 1969. Effects of habitat alteration on production, standing crops and yield of brook trout in Lawrence Creek, Wisconsin. Pages 281-312 in T. G. Northcote, ed. Proc. Symp. on Salmon and Trout in Streams, UBC, Vancouver.

Wisconsin
rehabilitation, fish

Improvements in stream habitat and brook trout populations following stream alterations are described.

Hunt, R. L. 1976. A long-term evaluation of trout habitat development and its relation to improving management-related research. Trans. Amer. Fish. Soc. 105: 361-363.

Wisconsin
rehabilitation, fish

Changes in brook trout populations for five years following the installation of stream improvement devices are described.

Hynes, H. B. N. 1958. The effect of drought on the fauna of a small mountain stream in Wales. Vern. Internat. Verein. Limnol. 13: 826-833.

U.K.
recovery, macroinvertebrates

A number of common macroinvertebrates failed to reappear in a stream after a severe drought, presumably because they had no adaptive mechanism to survive the severe conditions.

Isom, B. G. 1971. Effects of storage and mainstream reservoirs on benthic macroinvertebrates in the Tennessee Valley. Pages 179-191 in G. Hall, ed. Reservoir Fisheries and Limnology. Amer. Fish. Soc. Spec. Pub. No. 8.

Tennessee
effects, impoundments, macroinvertebrates

Studies of benthic macroinvertebrates show that they may be limited by siltation, alteration of currents, water level fluctuations, increased hydrostatic pressure, light, and dissolved oxygen. Declines in number of species of mussels (Unionidae) are associated with impoundment. Significant numbers of Anodontinae and Lampsilinae were able to colonize the shallows of some impoundments. Snail populations declined as a result of impoundment.

Jacobs, M. L. 1972. Salinity and sedimentation study - Cooper River re-diversion, Charleston, South Carolina. Water Resources Bulletin 8: 87-92.

South Carolina
effects, diversion, sedimentation

The effects of a fresh water diversion on a salt marsh are evaluated.

Jantzie, T. D. 1977. A synopsis of the physical and biological limnology and fishery programs within the Alberta oil sands area. Prep. for the Alberta Oil Sands Environmental Research Program by Renewable Resources Consulting Services Ltd. AOSERP Report 7. 73 p.

AOSERP study area
oil sands research, limnology

A background reference document on the limnology of the AOSERP study area in northeastern Alberta. An extensive bibliography of the pertinent literature for the area is included.

Jeglum, J. K. 1973. Boreal forest wetlands, near Candle Lake, Central Saskatchewan. Musk-Ox 12: 32-48.

Central Saskatchewan
effects, water levels, wetlands

Vegetational variation in the Candle Lake wetlands was related to major environmental gradients. The major vegetational patterns in the landscape were described. The effects of moisture, nutrients, and disturbance regimes on vegetational patterns were analyzed.

Jeglum, J. K. 1975. Vegetation - habitat changes caused by damming a peatland drainageway in Northern Ontario. Can. Field-Naturalist 89: 400-412.

Northern Ontario
effects, water levels, wetlands

The effects of a road-dam on wetland vegetation are described. Implications of the changes caused by the road-dam for other road-building and damming activities in northern Canada are discussed.

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

Washington
effects, impoundment, waterfowl

Studies were conducted over a two year period to determine the effects of water fluctuations on aquatic biota. A reservoir was built which flooded many potholes and raised the water levels of others. These changes caused a redistribution of bird populations and reduced waterfowl habitat.

Kadlec, J. A. 1962. The effects of a drawdown on a waterfowl impoundment. Ecology 43: 267-281.

Michigan
effects, impoundment, waterfowl, macroinvertebrates, vegetation

This report evaluates a pilot drawdown on the Backus Lake flooding project and its effect on vegetation, waterfowl, soil, water, and bottom fauna.

Keith, L. B. 1961. A study of waterfowl ecology on small impoundments in southeastern Alberta. Wildl. Mono. No. 6.

Southeastern Alberta
enhancement, waterfowl

A five year study of duck ecology on Alberta impoundments. A discussion of duck response to water level changes is included.

Keller, E. A. 1975. Channelization: a search for a better way. Geology 3: 246-248.

rehabilitation

An optimal spacing of pools and riffles, averaging about six times the channel width, will improve a modified stream by providing a channel morphology that is relatively stable and biologically productive.

Kennedy, H. D. 1955. Colonization of a previously barren stream section by aquatic invertebrates and trout. Prog. Fish Cult. 17: 119-122.

California
colonization, fish, macroinvertebrates

Macroinvertebrates and trout were found to have colonized a new stream, apparently by downstream drifting, although it carried water for only three months.

Kimsey, J. B. 1957. Fisheries problems in impounded waters of California and the lower Colorado River. Trans. Amer. Fish. Soc. 87: 319-332.

California
effects, impoundment, diversion, fish

This report discusses warm water fishery problems resulting from impoundments and diversions in California and the lower Colorado River.

Kirby, R. E. 1976. Mapping wetlands on beaver flowages with 35 mm photography. Can. Field-Naturalist 90: 423-431.

Minnesota
remote sensing, wetland vegetation

Wetlands were mapped by using low-altitude colour slide photography rather than field observations.

Kolipinski, M. C., A. L. Higer, N. S. Thomson, and F. J. Thomson. 1969. Inventory of hydrobiological features using automatically processed multispectral data. Proc. Int. Symp. on Remote Sensing of Environment 6: 79-95. Ann Arbor, Michigan.

Florida
remote sensing, wetland vegetation

Multispectral data were used to automatically map eight different landscape site units in a portion of Everglades National Park in south Florida. Data in this form, collected periodically, will be used to determine the direction and extent of successional changes of vegetation in the park and should provide a better basis for water management practices. The success of this study indicates that the multispectral scanning techniques employed in the Everglades have transfer value to other hydrologic situations.

Kooyman, A. H. 1973. Status of goldeye, *Hiodon alosoides*, populations in the Peace-Athabasca Delta. in Section F, Vol. 2, The Peace-Athabasca Delta Project, Technical Appendices. 26 p.

Peace-Athabasca Delta
effects, water levels, fish

The status of goldeye populations in the Peace-Athabasca Delta is appraised and the effects on these populations of changes in water levels are considered.

Larimore, R. W., W. F. Childers, and C. Heckrotte. 1959. Destruction and re-establishment of stream fish and invertebrates affected by drought. Trans. Amer. Fish. Soc. 88: 261-265.

Illinois
recovery, fish, macroinvertebrates

A stream that had been severely affected by drought was studied. When normal flow resumed, repopulation by aquatic insects began immediately. 21 of 29 fish species repopulated the stream by upstream movement within 2 weeks, and 25 species were present after one year. Two species were still absent after four years.

Larkin, P.A., and Graduate Students. 1959. The effects on fresh water fisheries of man-made activities in British Columbia. Can. Fish Cult. 25: 27-59.

British Columbia
effects, resource development, fish

The diversified resource development in British Columbia and its effects on fisheries are described. The effects of forestry practices, agriculture, mining, hydroelectric development and industrial pollution are discussed. A useful table is presented which summarizes the types of effects on fisheries from hydroelectric projects in British Columbia.

Lawrence, G.R., and C.W. Graham. 1975. Remote sensing applied to algal problems in lakes. Canadian Symposium on Remote Sensing 3: 309-314. Edmonton, Alta.

Ontario
remote sensing, algae

Multispectral satellite data were used to map surface distribution of algae blooms. Relative algae concentrations were distinguished by electronic density analysis.

Laycock, A. H. 1974. Water problems in Alberta oil sands development. Reprinted from American Water Resources Association Proceedings. 18: 184-200.

AOSERP study area
effects, oil sands development

A general survey of the Alberta oil sands resource and the status of its development is given. Water balance patterns for the major plants are reviewed and discussed.

Leege, T. A. 1968. Natural movements of beavers in southeastern Idaho. J. Wildl. Manage. 32: 973-976.

Idaho
monitoring, effects, aquatic mammals

Movements of live-trapped beavers were studied by tagging, release, and recapture. Causes of migration included declining water levels, floods, food shortages, and human disturbance.

Lehmkuhl, D. M. 1972. Change in thermal regime as a cause of reduction of benthic fauna downstream of a reservoir. J. Fish. Res. Board Can. 29: 1329-1332.

Saskatchewan River
effects, impoundment, macroinvertebrates

The kinds and numbers of Ephemeroptera and other insects in the Saskatchewan River are greatly reduced downstream of a dam. This is attributed to changes in river temperatures caused by the reservoir. The river is warmed in winter and cooled in summer. Consequently, mayflies and other insects with strict thermal requirements cannot hatch and grow successfully. The effect is evident 70 miles downstream.

Lent, J. D., and G. A. Thorley. 1969. Some observations on the use of multiband spectral reconnaissance for the inventory of wildland resources. Remote Sensing of Environment 1: 31-45.

remote sensing

The advantages of multispectral data over conventional photography in wildland studies are outlined and information is presented which may help others to decide whether multispectral reconnaissance can be of use in their resource inventory problems.

Lewis, S. L. 1969. Physical factors influencing fish populations in pools of a trout stream. Trans. Amer. Fish. Soc. 98: 14-19.

Montana
habitat requirements, fish

The physical habitat quality of stream pools is evaluated. Surface area, volume, depth, current velocity, and cover accounted for 70% to 77% of the variation in numbers of trout over 6.9 inches total length. Most of the variation was the result of differences in current velocity and cover. Cover was the most important factor for brown trout, and current velocity for rainbow trout. The density of all trout per unit area of pool surface and cover increased significantly as current velocity became greater. Deep-slow pools with extensive cover had the most stable trout populations. The importance of cover to trout is discussed.

Lindsey, C. C. 1957. Possible effects of water diversions on fish distribution in British Columbia. J. Fish. Res. Board Can. 14: 651-665.

British Columbia
effects, diversion, fish

Proposed water diversions for hydroelectric development are discussed and their probable effects on fish distribution are listed. Some diversions could cause striking changes in fish distribution.

Lintz, J., and D. S. Simonette, eds. 1976. Remote Sensing of Environment. Addison-Wesley, Reading, Massachusetts.

remote sensing

An up-to-date textbook of remote sensing technology and applications. Included are detailed discussions of basic principles, instrumentation, data processing and analysis, ground-truth requirements, and applications and limitations of remote sensing systems.

Little, A. D., Inc. 1973. Report on channel modification. Vol. 1. Council Envir. Qual. U.S. Govt. Print. Off. Washington, D.C. 394 p.

U.S.A.
effects, channelization

Chapter 5 of this volume discusses the biological effects observed in 21 channelization projects in the U.S. Discussion includes the effects of channelization projects which cause erosion, sedimentation, and turbidity. Alternatives to channel construction that will mitigage adverse effects are also discussed.

Lombard North Group Ltd. 1974. Environmental study, Amoco Tar Sands lease, Gregoire Lake Area, Alberta. Prepared for Amoco Canada Petroleum Ltd. 158 p.

AOSERP study area
effects, rehabilitation, oil sands development

The environmental characteristics of an oil sands project study area are documented. The probable impacts of development activities are discussed.

Long, K. S., and L. E. Link. 1977. Remote sensing of aquatic plants. Proc. Int. Symp. on Remote Sensing of Environment 11: 817-823.

Southern U.S.A.
remote sensing, aquatic vegetation

Describes a study designed to test various remote sensors for their ability to detect and discriminate among aquatic macrophytes.

Lynch, J. A., E. S. Corbett, and R. Hoopes. 1977. Implications of forest management practices on the aquatic environment. Fisheries: a Bulletin of the American Fisheries Society. 2(2): 16-22.

effects, vegetation removal, macroinvertebrates

Removal of the shading overstory causes higher water temperatures and increases the amplitude of diel temperature fluctuations. Removal of riparian vegetation alters species composition of aquatic invertebrates through the loss of organic detritus, and also decreases the standing crop of terrestrial insects.

Macan, T. T. 1960. Factors that limit the range of freshwater animals. Biol. Rev. 36: 151-198.

effects, habitat suitability, aquatic life

The factors that limit a species to a certain habitat within its geographical range are discussed.

Machniak, K. 1975a. The effects of hydroelectric development on the biology of northern fishes (reproduction and population dynamics). I. Lake whitefish *Coregonus clupeaformis* (Mitchill). A literature review and bibliography. Fish. Mar. Serv. Res. Dev. Tech. Rep. 527. 67 p.

effects, impoundment, fish

The reproduction and early life history of the lake whitefish, *Coregonus clupeaformis*, is reviewed. The potential impact of reservoirs on whitefish reproductive success are outlined. The hazards to reproduction of whitefish in impoundments are: water level fluctuations, altered water quality (thermal, current, and chemical), predation, and erosion silt.

Machniak, K. 1975b. The effects of hydroelectric development on the biology of northern fishes (reproduction and population dynamics). II. Northern pike *Esox lucius* (Linnaeus). A literature review and bibliography. Fish. Mar. Serv. Res. Dev. Tech. Rep. 528. 82 p.

effects, impoundment, fish

The reproduction and population biology of the northern pike, *Esox lucius*, in relation to impoundment is reviewed. Hazards to spawning success are: fluctuating water levels, cold weather, water quality, disease, predation, cannibalism, and siltation.

Machniak, K. 1975c. The effects of hydroelectric development on the biology of northern fishes (reproduction and population dynamics). III. Yellow walleye, *Stizostedion vitreum vitreum* (Mitchill). A literature review and bibliography. Fish. Mar. Serv. Res. Dev. Tech. Rep. 529. 68 p.

effects, impoundment, fish

The reproduction and early life history of the yellow walleye, *Stizostedion vitreum vitreum*, is reviewed. The effects that water level fluctuations, water temperatures, siltation, and predation in impoundments can have on walleye reproduction are discussed.

Machniak, K. 1975d. The effects of hydroelectric development on the biology of northern fishes (reproduction and population dynamics). IV. Lake trout, *Salvelinus namaycush* (Walbaum). A literature review and bibliography. Fish. Mar. Serv. Res. Dev. Tech. Rep. 530. 52 p.

effects, impoundment, fish

The effects of impoundment on lake trout, *Salvelinus namaycush*, reproduction and population biology are discussed. Water level fluctuation and siltation are considered to be the main factors determining success in reservoirs.

McCart, P. J., and D. de Graaf. 1974. Effects of disturbance on the benthic fauna of small streams in the vicinity of Norman Wells, N.W.T. In Chapter IV, Vol. 15, Arctic Gas Biological Report Series. 31 p.

Northwest Territories
recovery, effects, erosion, macroinvertebrates

This report is a study of the effects of erosion on the benthic invertebrate fauna of streams in the vicinity of Norman Wells, N.W.T. Generally, active erosion adversely affects benthic invertebrate populations but when conditions are stabilized natural hydrological processes tend to restore the original habitat and invertebrate populations recover or in some cases even exceed the original level.

McCart, P. J., P. Tsui, W. Grant, and R. Green. 1977. Baseline studies of aquatic environments in the Athabasca River near lease 17. Syncrude Canada Ltd. Environmental Research Monograph 1977-2. 205 p.

Athabasca River, AOSERP study area
monitoring

The results of detailed studies of water quality, periphyton, benthic macroinvertebrates, and fish are given. The studies were designed to provide a basis for comparison with changing conditions in the Athabasca River as oil sands development proceeds.

McCoy, W. B. and T. H. Lackie. 1973. Water pollution surveillance using local remote sensing equipment. Pages 325-330 in K. P. B. Thomson, R. K. Lane, and S. C. Csallany, eds. Remote Sensing and Water Resources Management. American Water Resources Ass., Urbana, Illinois.

South Saskatchewan River, Saskatchewan
remote sensing

Authors describe a method of studying stream sediment concentration and pollution using supplementary aerial photography with locally-available equipment. The technique is suitable for studying mixing patterns.

McDonald, M. E. 1955. Cause and effects of a die-off of emergent vegetation. J. Wildl. Manage. 19: 24-35.

Michigan
effects, water levels, muskrat, aquatic vegetation

The causes and effects of a die-off of marsh vegetation in marshes connected with Lake Erie were investigated. The causes of the die-off were generally rising or high water levels. Immediate effects of the die-off were an increase in the amount of submerged waterfowl food plants, the break-up of large blocks of reed marsh, an increase in the amount of edge between reed marsh and water, the formation of expanses of flotage or mud banks above the water level, and a reduction in the amount of muskrat habitat. Later effects included an increase in round-stem bulrush facies of the reed marsh, an increase in *Typha glauca* in comparison with *Typha angustifolia*, and a deepening of portions of the marsh.

Meeks, R. L. 1969. The effect of drawdown date on wetland plant succession. J. Wildl. Manage. 33: 817-828.

Ohio
effects, water levels, muskrat, wetlands

The effects of reduced water levels on vegetation in a marsh were studied for seven years. Water levels were reduced in March, April or May and restored in September each year. Plant succession tended from semiaquatic species to predominantly annual weeds. Drawdowns in May produced the best plant associations for wildlife after seven seasons.

Miller, R. B. and M. J. Paetz. 1959. The effects of power, irrigation, and stock water developments on the fisheries of the South Saskatchewan River. Can. Fish Cult. 25: 1-14.

Bow River, Alberta
effects, diversion, impoundment, fish

Good sport fisheries have been provided by irrigation reservoirs on small streams but continued production is dependent on extent of drawdown. Diversion reservoirs have provided sport fishing for pike and the larger reservoirs contribute substantially to the commercial pike and whitefish production of Alberta. Stock watering dams have provided successful trout fisheries because of their small size and the absence of coarse fish species.

Minckley, W. L. 1964. Upstream movements of *Gammarus* (Amphipoda) in Doe Run, Meade County, Kentucky. Ecology 45: 195-197.

Kentucky
colonization, macroinvertebrates

Upstream movements of amphipod crustaceans in Doe Run indicate that some species may recolonize denuded upstream areas of streams by movements against the current.

Minshall, G. W. 1967. Role of allochthonous detritus in the trophic structure of a woodland springbrook community. Ecology 48: 139-149.

Kentucky
invertebrates, vegetation

The most important food source for primary consumers in a stream was found to be leaf materials derived from streamside vegetation.

Morofsky, W. F. 1936. Survey of insect fauna of some Michigan streams. J. Econ. Entomol. 29: 749-754.

Michigan
rehabilitation, macroinvertebrates

Comparative studies of improved and unimproved sections of streams showed that improved streams had a larger total number of bottom organisms, and a higher proportion of the total were insects.

Morris, L. A., R. N. Langemeier, T. R. Russell, and A. Witt,Jr. 1968. Effects of mainstem impoundments and channelization upon the limnology of the Missouri River, Nebraska. Trans. Amer. Fish. Soc. 97: 380-388.

Nebraska
effects, impoundment, channelization, fish, macroinvertebrates

Impoundment and channelization of the Missouri River has caused environmental changes in channelized and unchannelized sections of the river below main stem impoundments. A limnetic cladoceran *Leptodora kindti* contributed to the drift and the distribution of benthos was modified. The size and variety of aquatic habitat was reduced by channelization.

Moss, E. H. 1953. Marsh and bog vegetation in northwestern Alberta. Can. J. Bot. 31: 448-470.

Northwestern Alberta
wetland vegetation

Swamp, marsh, wet meadow, saline meadow, bog, and aquatic vegetation types are described, and their ecological relationships are discussed. Successional patterns are also reviewed.

Moyle, P. B. 1976. Some effects of channelization on the fishes and invertebrates of Rush Creek, Modoc County, California. Calif. Fish and Game 62: 179-186.

California
effects, channelization, fish, macroinvertebrates

Channelized and unchannelized sections of a stream were compared to determine the impact of channelization on fish populations. Channelized sections contained fewer and smaller trout and suckers, as well as a lower biomass, than the unchannelized sections. Pit sculpin *(Cottus pitensis)* were more numerous in channelized sections, but total fish biomass in channelized sections was less than 1/3 of that in unchannelized sections. Biomass of invertebrates was also less than 1/3, and species composition of the two areas was different.

Munday, J. C. 1974. Water quality of lakes of southern Ontario from ERTS-1. Proc. Can. Symp. on Remote Sensing. 2: 78-82. Univ. of Guelph.

Ontario
remote sensing

Relative water quality of water bodies in southern Ontario was investigated using ERTS-1 data. The technique, using multispectral data, may be useful in long-term monitoring of lake water quality and site selection for surface investigation.

Myers, V. I. 1970. Soil, water and plant relations. Pages 253-297 in Remote Sensing, with Special Reference to Agriculture and Forestry. National Academy of Sciences, Washington, D.C.

remote sensing, vegetation

A lengthy review of the types of information that can be gathered about vegetation, vegetation condition, and soil moisture using different remote sensing techniques.

Munro, W. T. [1966?]. Changes in waterfowl habitat with flooding on the Ottawa River.

Quebec
effects, water levels, vegetation, waterfowl

Changes in riparian vegetation and in waterfowl numbers were studied after a permanent 6 ft. rise in the water level of the Ottawa River, Quebec. The pioneering aquatic plants were river bulrush *(Scirpus fluviatilis)*, floating and large-leaved pondweeds *(Potamogeton natans, P. amplifolius)*, marsh cinquefoil *(Potentilla palustris)*, and scarlet knotweed *(Polygonum coccineum)*. After flooding, vegetation was less abundant in water less than 36 inches deep and more abundant in water 37 to 60 inches deep. Only in flooded hardwood forest was the development of vegetation after flooding influenced more by the previous vegetation type than by the depth of water. The number of breeding waterfowl increased from 1.4 to 6.5 pairs per mile.

Narver, D. W. 1972. A survey of some possible effects of logging on two eastern Vancouver Island streams. J. Fish. Res. Board Can. Technical Report No. 323. 55 p.

Vancouver Island
effects, logging, fish, macroinvertebrates

Fish populations, macroinvertebrate drift, stream temperatures, and stream channel widths were compared in recently clear cut and burned stream sections and adjacent upstream sections in standing timber.

Nebeker, A. V. 1971. Effect of high winter water temperatures on adult emergence of aquatic insects. Water Res. 5: 777-783.

effects, temperature, macroinvertebrates

Unseasonably high temperatures caused premature emergence of 10 species of aquatic insects in laboratory experiments. It is postulated that an increase of only a few degrees in a natural stream may eliminate certain species.

Nelson, J. S. 1965. Effects of fish introductions and hydroelectric development on fishes in the Kananaskis River system, Alberta. J. Fish. Res. Board Can. 22: 721-753.

Kananaskis River system, Alberta
effects, impoundment, fish

Changes in fish species abundance and distribution are described in the Kananaskis River system after fish introductions and hydroelectric development. Data from surveys from 1936 to 1961 show the probable chronology of events.

Nelson, H. K., A. T. Klett, and W. G. Burge. 1970. Monitoring migratory bird habitat by remote sensing methods. Trans. N. Amer. Wildl. Conf. 35: 73-84.

Michigan
remote sensing, wetland vegetation

Multispectral data collected by scanner were used to map waterfowl habitat.

Nielson, G. L. 1972. Thermal pollution investigation at Wabamun Lake, Alberta. Canadian Symposium on Remote Sensing 1: 201-209.

Wabamun Lake, Alberta
remote sensing, aquatic vegetation

Aquatic plant distributions were mapped using colour and colour infra-red photography, and temperature distributions were studied by thermal infra-red photography.

Nilson, H. C., and R. W. Larimore. 1973. Establishment of invertebrate communities on log substrates in the Kaskaskia River, Illinois. Ecology 54: 366-374.

Illinois
colonization, macroinvertebrates

Development of invertebrate communities on implanted log substrates was investigated in three stream habitat types. Rapid colonization occurred in all habitats. Colonization was by drift, and by organisms present in the logs.

Northwest Hydraulic Consultants Ltd. 1975. Working paper on probable hydrological impact of oil sands development. Prepared for Ekistic Design Consultants Ltd. Edmonton. 26 p.

AOSERP study area
effects, oil sands development

This paper outlines some of the recognizable hydrological reactions to certain actions (key sub-activities) associated with aspects of oil sands development. Erosion, contamination, and land use changes are highlighted as causes of hydrological changes.

Nursall, J. R. 1952. The early development of a bottom fauna in a new power reservoir in the Rocky Mountains of Alberta. Can. J. Zool. 30: 387-409.

Alberta
colonization, macroinvertebrates

The benthic colonization of a hydroelectric reservoir for two years after impoundment is described.

Olmsted, L. L., and D. G. Cloutman. 1974. Repopulation after a fish kill in Mud Creek, Washington County, Arkansas following pesticide pollution. Trans. Amer. Fish. Soc. 103: 79-87.

Arkansas
recovery, fish

100% mortality of 29 species occurred after pesticide pollution. Repopulation of some species began almost immediately, but others were not yet present after a year. Rate of repopulation appears to be related to length of stream affected, severity and duration of kill, and season of year. Rapid repopulation also requires that the habitat be unaltered.

Pakulak, A. J., W. Sawka, and R. K. Schmidt. 1974. Analysis of nesting habitat of Canada geese using remote sensing imagery. Proc. Can. Symp. on Remote Sensing 2: 366-370. Univ. of Guelph.

Manitoba
remote sensing, waterfowl

The purpose of this study was to evaluate nesting habitat of Canada geese using recent remote sensing imagery. Two types of colour infra-red photography proved to be most suitable and were used in delineating vegetation-landform (habitat) units on a study area map. These units were then compared with goose nesting data collected in spring, 1970. In general, results suggested that remote sensing imagery could be used to describe habitats in other, largely inaccessible goose breeding areas.

Paterson, C. G., and C. H. Fernando. 1969. Macroinvertebrate colonization of the marginal zone of a small impoundment in Eastern Canada. Can. J. Zool. 47: 1229-1238.

Ontario
colonization, macroinvertebrates

Colonization of the marginal zone of a reservoir was essentially complete after its first summer of existence. 62% of the macroinvertebrates were derived from the fauna of the impounded creeks.

Paterson, C. G., and C. H. Fernando. 1970. Benthic fauna colonization with particular reference to the Chironomidae. J. Fish. Res. Board Can. 27: 213-232.

Ontario
colonization, macroinvertebrates

Describes the colonization patterns of benthic macroinvertebrates over two years in a newly-formed reservoir.

Patrick, R. 1959. Aquatic life in a new stream. Water and Sewage Works 12: 531-535.

Pennsylvania
recovery, macroinvertebrates

The development of aquatic life in a newly-constructed stream channel was studied. Protozoa, bacteria and algae were established within 10 days. Establishment of macroinvertebrates was spotty with some species only being established after six months.

Peace-Athabasca Delta Project. 1973a. Technical Report. A report on low water levels in Lake Athabasca and their effect on the Peace-Athabasca Delta. Peace-Athabasca Delta Project Group. 176 p.

Peace-Athabasca Delta
effects, water levels

The setting of Lake Athabasca and the Peace-Athabasca Delta is described. Intergovernmental studies are outlined and hydrologic, ecological, socio-economic and other investigations are summarized. The effects of lowered water levels on the Delta are predicted and remedial actions are discussed. Discussions of the legal framework, government coordination, and a summary of the appendices are also included.

Peace-Athabasca Delta Project. 1973b. Technical appendices volume 2: ecological investigations. The Peace-Athabasca Delta Project Group.

Peace-Ahtabasca Delta
effects, water levels, vegetation, fish, wildlife

The results of detailed ecological studies carried out to determine the effects of low water levels in the Peace-Athabasca Delta are presented. Species lists of plants, fishes, birds, and mammals occurring in the Delta are given. The status of three fish species, waterfowl, and muskrat inhabitating the Delta and Athabasca Lake is described. Major wildlife habitats of the delta are delineated and the changes over time due to plant succession are described. A computer model is used to predict the effects that water level changes could have on habitat and populations of major wildlife species.

Pearson, W. D., and D. R. Franklin. 1967. Some factors affecting drift rates of *Baetis* and Simulidae in a large river. Ecology 44: 75-81.

Utah and Colorado: Green River
effects, habitat alteration, macroinvertebrates

Effects of eight factors on the drift rates of *Baetis* nymphs and Simulidae larvae were tested with multiple regression analyses. Illumination, population density of all other organisms, and temperature had significant influences on drift rates of both organisms. Turbidity and water-level fluctuations were related to changes in drift rates indirectly through influence upon light penetration and population density, respectively. Dissolved-oxygen concentration, calendar date, and depth of water at the sample site did not clearly affect drift rates of either organism.

Penfound, W. T., and J. D. Schneidau. 1945. The relation of land reclamation to aquatic wildlife resources in southeastern Louisiana. Trans. N. Amer. Wildl. Conf. 6: 308-313.

Louisiana
effects, rehabilitation, aquatic life

The effects of wetland drainage and flooding on aquatic life are discussed. Drainage eliminated the original aquatic environment. Many reflooded areas provided good habitat for wildlife.

Penner, D. F. 1976. Preliminary baseline investigations of furbearing and ungulate mammals using Lease No. 17. Syncrude Canada Ltd. Environmental Research Monograph 1976-3. 181 p.

Syncrude lease No. 17
baseline conditions, monitoring, mammals, vegetation

Provides baseline data on beaver and muskrat in the Syncrude lease, and describes censusing techniques.

Peters, J. C. 1967. Effects on a trout stream of sedimentation from agricultural practices. J. Wildl. Manage. 31: 805-812.

Montana
effects, sedimentation, fish

The interrelationships between sediment, flow, and water temperature as caused by habitat manipulations, and how they influence stream trout populations are considered.

Peters, J. C., and W. Alvord. 1964. Man-made channel alterations in thirteen Montana streams and rivers. Trans. N. Amer. Wildl. Conf. 29: 93-101.

Montana
effects, channelization, fish

Altered channels of thirteen streams were studied in contrast to unaltered stream sections. Altered channels did not support nearly as many fish as did natural channels. Results showed that channel manipulations caused significant adverse effects on fish populations in Montana streams.

Phinney, D. E. 1975. Repopulation of an eradicated stream section by brook trout. Trans. Amer. Fish. Soc. 104: 685-687.

Montana
recovery, fish

The rate of repopulation of a stream section treated with rotenone was studied. Brook trout from upstream had completely repopulated the area after one year. The primary repopulation was by young-of-the-year trout.

Polcyn, F. C., and D. R. Lyzenga. 1973. Multispectral sensing of water parameters. Pages 394-403 in K. P. B. Thomson, R. K. Lane and S.C. Csallaney, eds. Remote Sensing and Water Resource Management. Amer. Water Resources Ass., Urbana, Illinois.

Michigan
remote sensing, algae

With the development of the multispectral scanner, improved techniques for mapping temperature gradients, turbidity, water colour, and algae concentrations over large areas have been demonstrated. Where lake water transparency is sufficiently clear to detect light reflections from the lake floor a remote calculation of water depth is possible. Depths to 20 ft. have been measured in the nearshore zone of Lake Michigan, and maps showing relative chlorophyll concentrations have been made for a portion of the shoreline areas.

Radford, D. S., and R. Hartland-Rowe. 1971. A preliminary investigation of bottom fauna and invertebrate drift in an unregulated and a regulated stream in Alberta. J. Appl. Ecol. 8: 883-903.

Alberta
effects, water levels, macroinvertebrates

The effects of fluctuating stream flows on standing crops and drift of benthic organisms were studied in two mountain streams. Reductions in stream flow caused increases in invertebrate drift and it was suspected that reservoir releases caused increased drift rates.

Rawson, D. S. 1958. Indices to lake productivity and their significance in predicting conditions in reservoirs and lakes with disturbed water levels. Pages 27-42 in Symposium: The investigation of fish-power problems. U.B.C. press.

Alberta
effects, impoundment, water levels, aquatic life

The factors involved in lake productivity are discussed and experiences with reservoirs in the Rocky Mountains are described.

Reid, K. A. 1954. Check dams to maintain trout streams. Prog. Fish Cult. 16: 169-171.

New York
rehabilitation, fish

Check dams with pipe outlets to allow fish passage were installed, to regulate flow and prevent low summer flows and high temperatures. In the two following years, there was an appreciable increase in size and number of trout caught.

Renewable Resources Consulting Services Ltd. 1973. An investigation of spring spawning migrations in Beaver Creek, Alberta, 1973. Prepared for Syncrude Canada Ltd. 42 p.

Syncrude Lease 17
baseline conditions, fish

The physical stream environment of Beaver Creek before diversion in the spring of 1973 is described. The fish population existing at that time is analyzed.

Renewable Resources Consulting Services Ltd. 1974. Fisheries investigation of the Muskeg River and Hartley Creek. Prepared for Shell Oil Ltd. and Home Oil Ltd. 127 p. not released.

Renewable Resources Consulting Services Ltd. 1975a. Northeast Alberta regional plan project: phase 1-Wildlife. Prepared for Ekistic Design Consultants Ltd. Edmonton. 25 p.

Northeastern Alberta
effects, oil sands development, wildlife

This brief report discusses wildlife occurring within the Athabasca oil sands region along with the current status of research. Brief discussions of the expected effects of oil sands development on wildlife populations are given.

Renewable Resources Consulting Services Ltd. 1977. Aquatic studies of upper Beaver Creek, Ruth Lake, and Poplar Creek, 1975. Syncrude Canada Ltd. 203 p.

AOSERP study area
effects, diversion, aquatic life

Environmental studies were conducted on upper Beaver Creek, Ruth Lake, and Poplar Creek from May to November 1975. The purpose of the investigations was to gather information to describe and understand the impact of the diversion of Beaver Creek through Ruth Lake to Poplar Creek. Physical and chemical data were gathered in Beaver Creek; physical, chemical and biological data were collected from Ruth Lake and Poplar Creek.

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

Utah
effects, water levels, aquatic vegetation

Changes in vegetative productivity are described following a three inch rise in water levels of a small marsh. Vegetation production increased by 32% in the shallow areas but decreased by 35% in the deeper areas. Other changes noted were: an increase in the size of the marsh; an increase in the amount of food near duck nesting areas; and a more luxuriant growth of alkali bulrush.

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

Manitoba
effects, water levels, waterfowl

Large population decreases in lesser scaup resulted from abrupt decreases in water level during two years of drought. Nesting was inhibited, and the presence of mudflats rather than brush around pothole perimeters led to excessive predation.

Roos, T. 1957. Studies on upstream migration in adult stream dwelling insects. In Rep. Inst. Freshwater Res. Drottningholm 38: 167-193.

Sweden
effects, colonization, macroinvertebrates

The mass movements of lotic female insects in upstream directions are investigated and discussed. Clear evidence is provided for the existence of a colonization cycle involving upstream migration and drift.

Rosgen, D. L. 1976. The use of colour infra-red photography for the determination of suspended sediment concentrations and source areas. In Proc. 3rd Federal Inter-Agency Sedimentation Conference, Denver, 1976.

Montana
remote sensing, suspended sediment

Present concepts and special techniques for applying colour infra-red photography in sediment studies are presented. The concentrations and sources of sediment produced during peak snowmelt runoff were determined by photo densitometric analysis coupled with specifically located ground control stations. Photo density was correlated with suspended sediment and turbidity. Both produced strong correlations which were significant at the 99% confidence level.

Ruff, J. F., J. W. Keys, and M. M. Skinner. 1974. Clarkes Fork Yellowstone River remote sensing study. Amer. Soc. Civil Eng., J. Hydraulics Div. 100: 719-729.

Montana
remote sensing

Remote sensing was used to gather information on suspended sediment concentrations and water temperatures.

Ruhr, C. E. 1957. Effect of stream impoundment in Tennessee on the fish populations of tributary streams. Trans. Amer. Fish. Soc. 86: 144-157.

Tennessee
effects, impoundment, fish

Fish samples from streams that were accessible from an impoundment and streams that were in an unimpounded watershed were compared. It was shown that large populations of gizzard shad, carp, smallmouth buffalo and drum in streams originated from impoundments. Lake fish populations, in streams without migration barriers, did not decrease in concentration with an increase in distance from impoundments.

Runnström, S. 1955. Changes in fish production in impounded lakes. Prod. Int. Ass. Theor. Appl. Limn. XII. p. 176-182.

Sweden
effects, impoundment, macroinvertebrates, fish

Fluctuating water levels occurring after impoundment of lakes resulted in a decrease in the littoral bottom fauna, after an increase during the initial period of rising water levels. Size of char and whitefish also eventually decreased, as did growth rates.

Saunders, J. W., and M. W. Smith. 1962. Physical alteration of stream habitat to improve brook trout production. Trans. Amer. Fish. Soc. 91: 185-188.

Prince Edward Island
rehabilitation, fish

Dams, deflectors, and covers were constructed in an experimental stream section. In the following year the standing crop of fingerlings was above average, and the numbers of age 1 and older trout were approximately doubled.

Scherz, J. P. 1971. Remote sensing considerations for water qualtiy monitoring. Proc. Int. Symp. on Remote Sensing of Environment 7: 1071-1088. Ann Arbor, Michigan.

remote sensing, monitoring

Remote sensing provides a detailed overall view from a vantage point, provides a detailed image record to be used to detect change in the area with time, and can expand the limits of the human eye and sense in parts of the spectrum where the eye cannot see. The paper suggests how the successful use of remote sensing in other fields can be extrapolated to water quality monitoring, and points out those factors unique to water quality monitoring which must be understood and dealt with before full practical use can be made of remote sensing for water quality considerations.

Schick, C. D., and K. R. Ambrock. 1974. Waterfowl investigations in the Athabasca Tar Sands area. Canadian Wildlife Service. 34 p.

AOSERP study area
effects, oil sands development, waterfowl

Waterfowl resources in the Athabasca oil sands area are described and evaluated. The possible impacts of surface mining on waterfowl within the AOSERP study area are discussed.

Schneberger, E., and J. L. Funk, eds. 1971. Stream channelization: a symposium. N. Cent. Div. Amer. Fish. Soc. Spec. Pub. 2. 83 p.

U.S.A.
effects, channelization, aquatic life

Numerous papers on the ecological effects of channelization are presented.

Schroeder, L. D., D. R. Anderson, R. S. Pospahala, G. G. W. Robinson, and F. A. Glover. 1976. Effects of early water application on waterfowl production. J. Wildl. Manage. 40: 227-232.

Colorado
effects, water levels, waterfowl

An eight year study was initiated in 1965 to determine if early water application would (1) increase waterfowl production, and (2) be economically feasible as a management practice. Results, and management and economic implications are presented.

Seher, J. S., and P. T. Tueller. 1973. Colour aerial photos for marshland. Photogrammetric Eng. 39: 489-499.

Nevada
remote sensing, wetland vegetation

Colour and colour infra-red aerial photographs of waterfowl habitats were studied to determine their usefulness for marsh vegetation evaluation. Attempts were made to determine the optimum film type, scale, time of day, and time of year for best results. Findings are discussed.

Shell Canada Ltd. 1975. Environmental impact assessment, Lease 13 mining project, Alberta Oil Sands. Prepared for Alberta Dept. of the Environment. Land Conservation and Reclamation Division, Calgary. 257 p.

Shell Canada Lease 13
effects, remote sensing, rehabilitation, resource development, environment

This document is a first phase overview of the Shell Lease 13 project. The project is described and the baseline or existing condition of the Lease 13 area is documented. The anticipated environmental effects of the project are discussed.

Shetter, D. S., O. H. Clark, and A. S. Hazzard. 1946. The effects of deflectors in a section of a Michigan trout stream. Trans. Amer. Fish. Soc. 76: 248-278.

Michigan
rehabilitation, fish

Current deflectors were installed in an experimental stream section. Improvements in habitat quality and in brook trout fishing followed.

Slough, B. G., and R. M. F. S. Sadleir. 1977. A land capability system for beaver *(Castor canadensis* Kuhl). Can. J. Zool. 55: 1324-1335.

British Columbia
monitoring, beaver

Beaver habitat factors were quantified and then related to beaver colony site density by multiple regression analysis. On the basis of separate analyses for lakes and streams, a land capability classification system was developed for beaver. The regression equations are also useful as models of beaver-habitat relationships and can be used for beaver inventory by prediction of beaver colony site density. Conservation of existing aspen *(Populus tremuloides)* stands is considered the most powerful management tool for maintaining or enhancing present beaver land capability.

Smith, R. I. 1970. Response of pintail breeding populations to drought. J. Wildl. Manage. 34: 943-946.

Alberta, Saskatchewan
effects, water levels, waterfowl

Pintails are adapted to wetland habitats that are subject to seasonal and annual instability. It is expected that they are quick to respond to changes in their environment.

Soper, J. D. 1964. Mammals of Alberta. Hamley Press Ltd., Alberta. 402 p.

Alberta
mammals

Gives descriptions of Alberta mammals, along with notes on habits and habitat preferences.

Souto-Maior, J. 1973. Applications of thermal remote sensing to detailed ground water studies. Pages 284-298 in K. P. B. Thomson, R. K. Lane and S. C. Csallany, eds. Remote Sensing and Water Resources Management. Amer. Water Resources Ass., Urbana, Illinois.

Wisconsin
remote sensing

The detection of groundwater seeps and springs by using thermal remote sensing techniques is discussed.

Spence, J. A., and H. B. N. Hynes. 1971a. Differences in benthos upstream and downstream of an impoundment. J. Fish. Res. Board Can. 28: 35-43.

Ontario
effects, impoundment, macroinvertebrates

Pronounced differences were found in the macroinvertebrate riffle fauna upstream and downstream of a flood control impoundment. Changes were associated with a downstream increase in the availability of detritus, a lag of about 4 weeks in the early summer rise in water temperature, a maximum temperature more than 6°C lower than upstream, and alteration of other environmental factors.

Spence, J. A., and H. B. N. Hynes. 1971b. Differences in fish populations upstream and downstream of a mainstream impoundment. J. Fish. Res. Board. Can. 28: 45-46.

Ontario
effects, impoundment, fish

Four species of cyprinid fishes found in a river upstream of a flood control dam were absent downstream. With the release downstream of cold hypolimnial waters from the dam there was a lag of about 4 weeks in the spring rise of water temperatures and a maximum summer temperature 7° C lower than upstream. The four missing fish species had the most southerly distributions, all south of the 64° F (17.8° C) July isotherm and it was concluded that the lower water temperatures were mainly responsible for their absence downstream of the dam.

Stalnaker, C. B. 1977. Abstraction, appropriation, and instream flow needs. Fisheries: a Bulletin of the American Fisheries Society 2: 17-19.

effects, resource development, diversion

A brief overview of the effects of proposed energy development as expressed in terms of instream flow needs. Three means of energy development and their impacts on natural stream systems are discussed: (1) physical abstraction or diversion of flows, (2) use of watersheds as a focus for activity, (3) direct use of water in the stream channel.

Starrett, W. C. 1972. Man and the Illinois River. Pages 131-169 in R. T. Oglesby, C. A. Carlson, and J. A. McCann, eds. River Ecology and Man. Academic Press, New York.

Illinois
effects, diversion, vegetation, plankton, fish

Between 1900 and 1938, diversion of Lake Michigan waters into the Illinois River increased its depth about one metre. Some of the aquatic vegetation in bottomland lakes was adversely affected and inundation of bottomlands killed large stands of trees. New fish habitats were created and fish production improved. Several species of Lake Michigan diatoms and one of cisco were collected from Illinois River waters after the diversion.

Stauffer, J. R., Jr., K. L. Dickson, J. Cairns Jr., and D. S. Cherry. 1976. The potential and realized influences of temperature on the distribution of fishes in the New River, Glen Lyn, Virginia. Wildlife Monograph No. 50. 40 p.

Virginia
effects, temperature, fish

The temperature preferences and avoidance of fishes in the New River and its tributaries were determined. The effects of temperature alterations on fish distribution are discussed.

Stoeckeler, J. H., and G. V. Voskuil. 1959. Water temperature reduction in shortened spring channels of southwestern Wisconsin trout streams. Trans. Amer. Fish. Soc. 88: 286-288.

Wisconsin
effects, rehabilitation, channelization

Late afternoon summer water temperatures at the mouth of a spring channel on a trout stream near La Crosse in southwestern Wisconsin were reduced by 10° to 11°F by shortening the channel by 67% and routing the water through a willow-shaded location.

Stube, M. 1958. The fauna of a regulated lake. Rep. Inst. Freshwater Res. Drottningholm 39: 162-224.

Sweden
effects, impoundment, aquatic life

The flora and fauna of a Swedish lake were investigated prior to the regulation of the lake and two and five years afterwards. Emphasis was placed on aquatic vegetation but macroinvertebrates and fish were also studied.

Surrendi, D., and C. Jorgenson. 1971. Some aspects of muskrat winter ecology on the Peace-Athabasca Delta. Canadian Wildlife Service Report. 113 p.

Peace-Athabasca Delta
effects, water levels, muskrat

The optimum depth of ice and water required for the winter survival of muskrats on the Peace-Athabasca Delta was determined. Supplementary data were also obtained on the relationship of ice thickness and snow depth, and on the vegetation used by Delta muskrats during the fall and winter periods.

Swanson, G. A. and Meyer, M. I. 1977. Impact of fluctuating water levels on feeding ecology of breeding blue-winged teal. J. Wildl. Manage. 41: 426-433.

North Dakota
effects, water levels, waterfowl, wetlands

The impact of changing wetland conditions on the feeding ecology of breeding blue-winged teal is described.

Swift, L. W., Jr., and J. B. Messer. 1971. Forest cuttings raise temperatures of small streams in the southern Appalachians. J. Soil and Water Conserv. 26: 111-116.

North Carolina
effects, vegetation removal

This report describes the changes in water temperature measured in five small streams in the southern Appalachian mountains after the surrounding forests were cut.

Syncrude Canada Ltd. 1973a. Mildred Lake Project: site development and reclamation plan. Prepared for Alberta Dept. of Lands and Forests, and Alberta Dept. of the Environment. Various pagings.

Syncrude Lease 17
effects, rehabilitation

This document includes a section on hydrology which describes the proposed Beaver Creek diversion. Possible channel modifications, control structures and drainage ditches are discussed.

Syncrude Canada Ltd. 1973b. Environmental impact assessment. Volume I: Overview. Volume II: Consideration of resources development alternatives. Volume III: Baseline information. Volume IV: Supporting studies. Edmonton 1973.

Syncrude Lease 17
effects, resource development, environment

This document assesses the probable environmental effects of the Syncrude Lease No. 17 mining project on the environment.

Syncrude Canada Ltd. 1973c. Beaver Creek: an ecological baseline survey. Environmental Research Monograph 1973-2. 39 p.

Syncrude Lease 17
baseline conditions, fish, macroinvertebrates

Quantitative data on fish and macroinvertebrate populations in Beaver Creek in 1971 are provided. The possible impacts of oil sands development on Beaver Creek are discussed.

Syncrude Canada Ltd. 1973d. Migratory waterfowl and the Syncrude tar sands lease. Environmental Research Monograph 1973-3. 67 p.

Syncrude Lease 17
effects, diversion, waterfowl

The utilization of lease number 17 by waterfowl populations is discussed. The possible effects of Syncrude development on these populations are predicted.

Syncrude Canada Ltd. 1974. Remote sensing and the Athabasca tar sands: an overview. Environmental Research Monograph 1974-1. 47 p.

Syncrude Lease 17
remote sensing

Reviews advantages of remote sensing for environmental monitoring in the AOSERP study area, remote sensing techniques, data available, sensor platforms, and uses to date of remote sensing imagery in the AOSERP study area. The possible application of ERTS-1 data to the project area is discussed.

Syncrude Canada Ltd. 1975a. Baseline environmental studies of Ruth Lake and Poplar Creek. Environmental Research Monograph 1975-3. 119 p.

Syncrude Lease 17
baseline conditions, plankton, macroinvertebrates, aquatic plants, fish

This study assesses ecological conditions found in Ruth Lake and Poplar Creek prior to diversion of Beaver Creek through these water bodies to the Athabasca River.

Syncrude Canada Ltd. 1975b. Inventory studies of birds on and near Crown Lease Number 17, Athabasca Tar Sands, 1974. Environmental Research Monograph 1975-4. 171 p.

Syncrude Lease 17
effects, resource development, birds

An inventory of water-associated birds occurring on and near the Syncrude Canada Ltd. Lease No. 17 was conducted. Habitat preferences of the common species, or groups of closely related species were examined quantitatively. Some ecological problems that could result from the Syncrude development are discussed.

Tarplee, W. H., Jr., D. M. E. Louder, and A. J. Weber. 1971. Evaluation of the effects of channelization on fish populations in North Carolina's coastal plain streams. in J. W. Webb, ed. 25th Ann. Conf. Southeastern Ass. of Game and Fish Commissioners, Charleston, S. C. (USA). 17 October, 1971.

South Carolina
effects, recovery, channelization, fish, macroinvertebrates

This study points out the detrimental effects that stream channelization has on aquatic life. The study also indicates that following channelization, and with no channel maintenance, nature can ultimately restore a coastal plain stream to a state reasonably near its natural condition, if no further alterations of the stream bed, banks, forest canopy, or aquatic vegetation occur.

Tebo, L. B., Jr. 1955. Effects of siltation, resulting from improper logging, on the bottom fauna of a small trout stream in the southern Appalachians. Prog. Fish Cult. 17: 64-70.

Illinois
effects, sedimentation, macroinvertebrates

Data is presented on the effects of siltation on the bottom organisms of Shope Creek, a small trout stream which received drainage from a logged watershed. The standing crop of benthic organisms decreased significantly when inorganic silt and sand accumulated.

Thomas, C. H. 1975. Stream channel modification and environmental assessment policies, objectives, and procedures. Pages 10-22 in R. V. Corning, et al., eds. Symposium on stream channel modifications: proceedings. Harrisonburg, Virginia.

U.S.A.
rehabilitation

Data requirements for predicting effects of channel modification are presented, as well as criteria for analyzing physical habitat characteristics of streams. Stream improvement techniques are listed and some are illustrated.

Townsend, J. E. 1953. Beaver ecology in western Montana with special reference to movements. J. Mammal. 34: 459-479.

Montana
monitoring, recovery, beaver

Beaver movements were studied by live-trapping, marking, and subsequent recapture. Most movements were by young beavers about two years old, but movement of single adult males and females and of entire colonies was also noted.

Townsend, C. R., and A. G. Hildrew. 1976. Field experiments on the drifting, colonization and continuous redistribution of stream benthos. J. Animal Ecol. 45: 759-772.

Britain
colonization, macroinvertebrates

An experiment designed to show the relative importance of drifting and bottom movements in colonization of new substrates revealed 82% of colonization to be by drift. It was estimated that average benthic density would be achieved in 37.5 days on new substrates.

Trautman, M. B. 1939. The effects of man-made modifications on the fish fauna in Lost and Gordon Creeks, Ohio, between 1887-1938. Ohio Journal of Science 39: 275-288.

Ohio
effects, channelization, fish

The effects of dredging and channel straightening of two small streams on fish were investigated. Fish collections in unaltered stream sections showed that little change in numerical abundance of various fish species had occurred in fifty years. Fish collections from altered stream sections showed that a drastic change in numerical abundance of the various fish species had occurred.

Uhler, F. M. 1956. New habitats for waterfowl. Trans. N. Amer. Wildl. Conf. 21: 453-469.

Maryland
waterfowl, rehabilitation

Describes an experiment in which waste waters were utilized on waste lands to successfully create new waterfowl habitat.

United States Department of Agriculture. 1969. Wildlife habitat improvement handbook. Forest Service Handbook FSH 2609.11. 146 p.

rehabilitation

A manual of stream improvement techniques with design recommendations. Included are discussions of techniques for direct channel improvement, streamside treatment, maintenance of regulated flow, and maintenance or improvement of water quality.

United States Environmental Protection Agency. 1973. The Control of Pollution from Hydrographic Modifications. Washington, D. C. 188 p.

U.S.A.
effects, rehabilitation

Presents information including guidance for identifying and evaluating non-point sources of pollutants; and processes, procedures, and methods to control pollution resulting from changes in the movement, flow or circulation of any navigable waters. Changes caused by the construction of dams, levees, channels or flow diversion facilities are discussed.

Wales, J. H. 1960. The effects of water diversions on fish. Seventh technical meeting, International Union for conservation of nature, natural resources. Theme 1, Volume IV. Pages 158-164.

effects, diversion, fish

The problems created by water diversions are discussed. The three broad problems are (1) the reduction of natural stream flow, (2) alteration of water quality in the diversion, (3) distribution of fish over wider areas.

Walker, B. H., and R. T. Coupland. 1967. An analysis of vegetation-environment relationships in Saskatchewan sloughs. Can. J. Bot. 46: 509-522.

Saskatchewan
effects, water levels, aquatic vegetation

This study examines the major environmental gradients that control plant species distribution in relatively non-saline sloughs and determines the interrelationships of the major species. Other than disturbance, the factor most responsible for variations in species composition in these sloughs, is water level.

Ward, J. V. 1974. A temperature-stressed stream ecosystem below a hypolimnial release mountain reservoir. Arch. Hydrobiol. 74: 247-275.

Colorado
effects, impoundment, macroinvertebrates

Stream temperatures were higher than normal in winter, lower in summer; they fluctuated less diurnally and seasonally and exhibited a seasonally displaced maximum below a mountain reservoir. The number of species of macroinvertebrates progressively increased downstream from the dam. Immediately below the dam there was low diversity and a large standing crop of macroinvertebrates.

Ward, R. C. 1977. Routine surveillance alternatives for water quality management. Water Pollution Control Federation Journal 46: 2645-2652.

remote sensing

The use of automatic monitoring and remote sensing as means of increasing the effectiveness of traditional grab sampling are reviewed in the context of routine water quality surveillance. Included is a review of the advantages and limitations of each technique, an elaboration of data needs in routine surveillance, and a general analysis of the cost-effectiveness of the data acquisition techniques in different situations.

Warner, K., and I. R. Porter. 1960. Experimental improvement of a bulldozed trout stream in northern Maine. Trans. Amer. Fish. Soc. 89: 59-63.

Maine
rehabilitation, fish

Stream improvement techniques in a bulldozed channel were modestly successful in improving habitat quality and trout populations.

Waters, T. F. 1964. Recolonization of denuded st
by drift. Trans. Amer. Fish. Soc. 93:

Minnesota
recovery, macroinvertebrates

Recolonization of denuded stream bottom
of invertebrates was studied. *Baetis va*
a mayfly, repopulated to 100% in 4 days
winter. The scud, *Gammarus limnaeus* (Sm
within 1 day in autumn and 4 in winter.

Waters, T. F. 1968. Invertebrate drift-ecology a
stream fishes. Pages 121-134 in T. G. N
Symp. on salmon and trout in streams, UE

macroinvertebrates, fish

The phenomenom of invertebrate drift is
significance to fish is discussed. A cr
equipment and procedures is also present

Webster, D. A. 1962. Artificial spawning facilit
Salvelinus fontinalis. Trans. Amer. Fis

New York
rehabilitation, fish

Two kinds of improved spawning areas wer
brook trout habitat. For reasons that w
the author, both types were used by broo
but not in others.

Wezernak, C. T. 1974. The use of remote sensing
Proc. Int. Symp. on Remote Sensing of Er

remote sensing

The concept of a remote sensing trophic
assessment is discussed and a comparativ
and remote sensing data for a group of 1
Results indicate that changes in the opt
a lake, as determined by remote sensing,
the trophic state of a lake.

White, R. J. 1973. Stream channel suitability fo
Soil Conservation Society of America. W
Management: Striking a Balance. Ankeny

rehabilitation, fish

This paper includes a review of literatu
population response to channel improveme
bibliography. Author notes that when st
stream improvement may increase fish abu
compensate for decreased channel length

Whitney, A. M., and J. E. Bailey. 1959. Detrimental effects of highway construction on a Montana stream. Trans. Amer. Fish. Soc. 88: 72-73.

Montana
effects, channelization, fish

A section of channel was modified by removing brush, scouring the stream bed with a bulldozer and straightening the channel. Gross reductions in numbers and weight of game fish occurred in the section.

Wile, I. 1973. Use of remote sensing for mapping of aquatic vegetation in the Kawartha Lakes. Pages 330-336 in K. P. B. Thomson, R. K. Lane, and S. C. Csallany, eds. Remote Sensing and Water Resources Management. American Water Resources Ass., Urbana, Illinois.

Ontario
remote sensing, aquatic vegetation

Aquatic vegetation can be mapped through time-consuming field techniques, but remote sensing is far more rapid and accurate. In this study, aquatic vegetation was mapped using colour and infra-red photography. Infra-red film was particularly useful in distinguishing emergent shoreline vegetation.

Williams, D. D. 1977. Movements of benthos during the recolonization of temporary streams. Oikos 29: 306-312.

Ontario
recovery, macroinvertebrates

The relative importance of each of four main sources of animals is examined experimentally during the annual repopulation of two temporary streams. Animals which have spent the summer drought as dormant forms buried in the substrate are the most important recolonizers. Drift provides an effective means of dispersing clumped individuals at the start of each new lotic phase, and upstream migration is also prevalent at this time.

Williams, D. D., and H. B. N. Hynes. 1976a. Stream habitat selection by aerially colonizing invertebrates. Can. J. Zool. 54: 685-693.

Ontario
invertebrates, colonization

Experiments on site selection by aerially colonizing invertebrates showed that water current and food availability largely determine the qualitative and quantitative nature of the fauna that colonizes a water body. New water bodies were rapidly colonized by a variety of species from nearby lotic and lentic habitats. After some time selection took place to establish communities characteristic of the habitats.

Williams, D. D., and H. B. N. Hynes. 1976b. The recolonization mechanisms of stream benthos. Oikos 27: 265-272.

Ontario
recolonization, invertebrates

Describes the relative importance of different methods of stream colonization by macroinvertebrates. Drift was most important in this study.

Williams, D. D., and H. B. N. Hynes. 1976c. The ecology of temporary streams. 1: The faunas of two Canadian streams. Int. revue ges. Hydrobiol. 71: 761-787.

Ontario
recovery, macroinvertebrates

The mechanisms used by the species of two streams to survive the summer drought are examined. The members of distinct taxonomic groups appear to have selected similar methods. Vertical migrations of the fauna within the stream substrate prior to, during, and after the drought are described.

Williams, D. D., and H. B. N. Hynes. 1977. Benthic community development in a new stream. Can. J. Zool. 55: 1071-1076.

Ontario
colonization, macroinvertebrates

The authors discuss the rapid colonization by macroinvertebrates of a new, man-made stream. Colonization occurred by drift, upstream migration, migration from within the substrate, and aerial migration from nearby water bodies.

Williams, D. D., N. E. Williams, and H. B. N. Hynes. 1974. Observations on the life history and burrow construction of the crayfish *Cambarus fodiens* (Cottle) in a temporary stream in southern Ontario. Can. J. Zool. 52: 365-370.

Ontario
recovery, macroinvertebrates

The crayfish *Cambarus fodiens* is shown to be able to complete its life cycle in a temporary running-water habitat by the construction of burrows in the substrate. It is possible that other inhabitants of temporary streams use crayfish burrows as refuges when the groundwater table retreats.

Wolf, K. 1955. Some effects of fluctuating and falling water levels on waterfowl. J. Wildl. Manage. 19: 13-23.

Utah
effects, water levels, waterfowl

The success of waterfowl production in three lakes in Utah was studied. The greatest mortality to eggs was caused by flooding of the nests. Fluctuating water levels also discouraged some waterfowl from nesting. More favorable conditions for waterfowl nesting can be achieved by stabilizing water levels and by slowing any fluctuations that do occur.

Yearke, L. W. 1971. River erosion due to channel relocation. Civil Engineering - ASCE. 41(8): 39-40.

New Hampshire
effects, channelization

Results of a channel relocation on a section of New Hampshire's Peabody River were studied. The channel was shortened and straightened. Results were upstream erosion and downstream sedimentation as the channel attempted to attain its original hydraulic gradient. Vertical erosion of six meters occurred at one point. Design recommendations for channel relocations are given.

Yurko, W. J. 1974. Speech to Engineering Institute of Canada on the development of the Alberta Oil Sands (Alberta Minister of the Environment), Edmonton, April 17.

AOSERP study area
resource development

Cited in Laycock 1974.

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8. AOSERP RESEARCH REPORTS

1.		AOSERP First Annual Report, 1975
2.	AF 4.1.1	Walleye and Goldeye Fisheries Investigations in the Peace-Athabasca Delta--1975
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5.	HY 3.1	The Evaluation of Wastewaters from an Oil Sand Extraction Plant
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22.	HE 2.3	Maximization of Technical Training and Involvement of Area Manpower
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26.	AF 4.5.1	Interim Report on an Intensive Study of the Fish Fauna of the Muskeg River Watershed of Northeastern Alberta
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