Waterfowl habitat trends in the aspen parkland of Manitoba

by William H. Kiel, Jr., Arthur S. Hawkins and Nolan G. Perret

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Contents

The authors

This study was conducted by Wm. H. Kiel, Jr., Arthur S. Hawkins and Nolan G. Perret. Arthur S. Hawkins wrote the historical account and analysed weather records of the period before 1949. Nolan G. Perret evaluated gross habitat changes as shown by aerial photographs along the study transects. Wm. H. Kiel, Jr., discussed potholes and waterfowl populations of the Minnedosa district in relation to natural and man-made changes in habitat. Hawkins and Perret both contributed data and suggestions to this portion of the report.

Kiel, the senior author, first established survey transects and study areas within the Minnedosa region of Manitoba in 1949 when a graduate student at the University of Wisconsin. He continued the project through 1954, visited the area in 1960 as a member of the United States Bureau of Sport Fisheries and Wildlife and again in 1964 in his present position as a biologist for King Ranch, Inc.

Hawkins first ran waterfowl surveys within the study block in 1946 shortly after becoming a flyway biologist for the United States Fish and Wildlife Service (now the U.S. Bureau of Sport Fisheries and Wildlife). Except for the summers of 1956 and 1958, he visited the area annually through 1966, maintaining photo stations on study areas and making general observations. He is now Mississippi Flyway representative for the U.S. Bureau of Sport Fisheries and Wildlife.

Perret arrived on the scene in 1954 as a biologist with the Canadian Wildlife Service and a member of the international team of biologists who annually conduct investigations throughout waterfowl nesting grounds. He continued to work in the Roseneath area south of Minnedosa in the summers of 1956–59, studying ducks and water areas. He is now CWS staff specialist for migratory bird habitat.

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Perspective

Over one half of the waterfowl breeding in North America nest and raise their young in the southern parts of the prairie provinces and adjacent states. This prairie pothole region includes the aspen parklands. Characterized by rolling terrain, myriads of small ponds and open woodlots, the aspen parkland forms a northern band around a central grassland plain from eastern Manitoba to western Alberta. A mixed wood or transition zone separates the aspen parkland from northern coniferous forests. In that zone deciduous parkland trees intermingle with conifers and give way to solid stands of conifers on the zone's northern edge.

Our discussion centres on a small but representative sample of the aspen parklands, the 4,100-square-mile Minnedosa pothole region in western Manitoba. The Minnedosa region has received much attention from plant ecologists and waterfowl biologists since the 1930's, but a fuller story of the region and its relationship to waterfowl needs to be told.

We arrived on the scene in 1946, after the depression, drought and war had slowed progress. Thus, we were in time to see the last of the old and beginning of the new era of economic development. From 1946 to 1966—two decades covering some of the wettest and driest years on record—we independently carried out related studies in this well-known block of pothole habitat. We then combined our experiences and related the events as we saw them during our two decades of occupancy. To set the stage we drew freely on historical accounts of areas outside as well as within our study area. We examined recent documents concerning the region and re-examined our own data. Our story commences with the glaciers, covers the period when Indians dominated the scene and traces the changes wrought by the white men from pioneer days to the present. The central theme is duck habitat, its genesis, its variability and its relative importance to the species of waterfowl using it.

The waterfowl resource, which has so far survived the onslaught of man and nature, depends upon an adequate supply of suitable breeding habitat. But the wetland habitat is threatened by advancing civilization, and ducks will need help if they are to maintain population levels of recent years. If the reader's awareness is awakened and if he has gained a better understanding and appreciation of the many problems that face the waterfowl resource, our objective will have been met.

Our cut-off date for examining and considering new information was May 1968 when the manuscript was submitted for publication. During editing, three papers published in 1969 were cited. We are aware of several recent works which would have strengthened our story, but could not incorporate them without further delaying publication.

Introduction

This study describes natural and man-made changes in waterfowl habitat in the 4,100-square-mile Minnedosa district of the aspen parkland of Manitoba. The Minnedosa district is important in the continental waterfowl picture due to high density of breeding ducks and consistency of production. However, its naturally fertile soils produce excellent cereal grains. One question we sought to answer was whether or not the high quality duck habitat could be maintained under the pressure of intensified agricultural land use.

The authors' experience in the Minnedosa district from 1946 to 1966 included years both of intensive study and of brief reconnaissance. The way in which waterfowl populations were influenced by weather and water is well illustrated by this period which included some of the wettest and driest years on record.

The historical background on natural and man-made changes in habitat considers broader regions of the approximately 200,000 square miles of Canadian parkland and prairie containing the Minnedosa district. In the later years of the study, obvious acceleration in man-made changes in pothole habitat, such as draining, filling and land clearing, made the future appear bleak for this great duck-producing region. The Canadian Wildlife Service is now operating an ambitious wetlands conservation program, but the land-owners of the Canadian prairies and parklands still hold the key to the future of the wildlife resources of the region. Man's activities can affect the waterfowl picture almost as much as weather, and often in a more permanent way.

The great glaciers of the Pleistocene age, during their periods of expansion and decline, moulded the landscape in the parklands and prairies of Canada and the northern United States. The rolling ground moraines were created during southward movements and slow retreats, while the more steeply rolling end moraines were formed by temporary halts in glacier movements and by meltwaters. The final stages of glacier disintegration created the hummocky moraines which are characterized by knob and kettle terrain with its myriads of small ponds or potholes. South of these uplands, meltwaters accumulated in glacial lakes, and the silt which they carried settled to form the flat lacustrine plains of the central prairie. Vegetation which grew after the ice receded and the glacial lakes disappeared, together with climate and time, determined soil formation. The soils, topography and climate in turn set the stage for the plant associations to follow and for man's use of these natural resources (Ellis, 1938).

Indians and explorers knew the North American prairies as a grassland devoid of trees in the southern part, with an increasing number of aspen and other trees (the parklands) before reaching the solid forests to the north. Huge herds of bison roamed the unbroken expanses, concentrating in areas offering the best food and water conditions. Then, as now, wet years followed dry years. During wet periods, marshes, lakes and ponds were profuse, but during dry periods most basins were empty and their soils exposed and aerated.

Life on the prairies was never static for long; wet years favoured the invasion of woody growth, whereas dry years permitted the grasslands to expand. Fires and grazing animals also encouraged the grasslands: fires affected buffalo and elk distribution and retarded woody plant growth, and the grazing, browsing and trampling of bison and elk retarded the growth of trees and shrubs. Since waterfowl populations respond to the presence or absence of surface water, nesting range and, therefore, duck numbers probably expanded during successive wet years and undoubtedly dwindled in drought periods.

The white man changed the prairies drastically. He removed the bison, restricted the Indians to reservations, then quickly and vigorously tamed the prairie wilderness and remodelled the landscape. Morton (1957) describes the remodelling of Manitoba as follows:
"The old Manitoba of 1870 had been engulfed in the new Manitoba of 1881. In one decade of swift change the province had seen the fur trade give way to the grain trade, the cart brigade to the railroad train.... The loose beauty of the parkbelt, the landscape of shimmering meadows flowing around the clumped poplar bluffs,... was giving way to a new pattern, the rectangular pattern of plowed fields and quarter-section farm. The wandering trail of Indian and trader was cut by fence and furrow and the rigid road allowance of the surveyor was beginning to grid the face of lowland and upland."

In spite of temporary setbacks due to crop failures and depressions, the end result of the white man's arrival has been that very little prairie in the parkland regions of Manitoba and eastern Saskatchewan remains in a virgin condition (Bird, 1961).

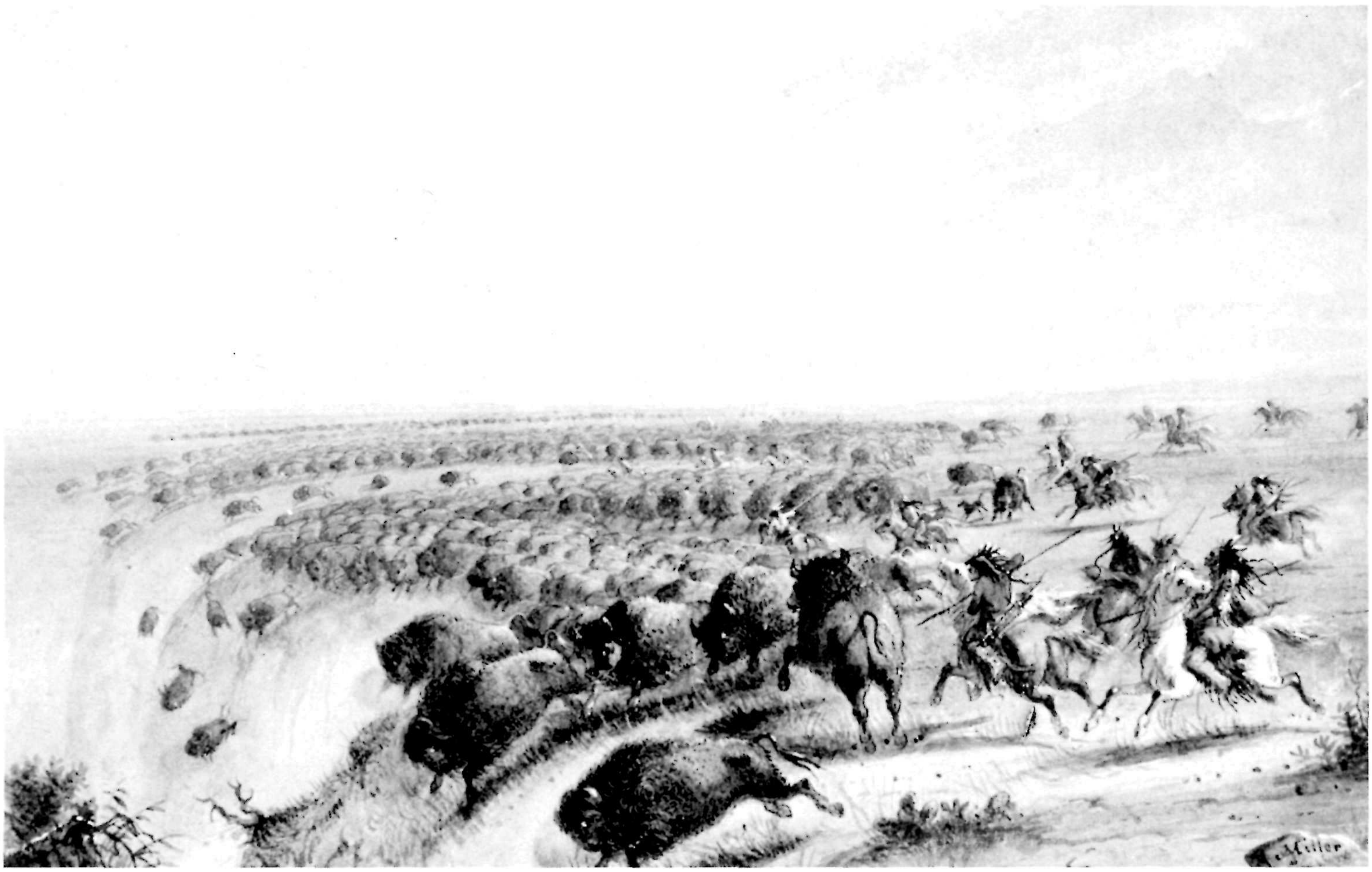
Weather is one of the major factors controlling wildfowl numbers. This was demonstrated to thousands of duck hunters in Canada and the United States during the decade 1955-64, when the abrupt change in the prairie pothole region from a land of plenty to a vast arid land dramatically affected the continental waterfowl supply. Therefore, for long range planning, it is desirable to broadly reconstruct past weather fluctuations and draw some conclusions as to their frequency and probable effects on duck numbers. We used the journals of early explorers or settlers and various interpretations of weather phenomena in reconstructing past weather influences.

Terms describing water areas are used interchangeably in the text following the use of many common local names in Manitoba. Small basins or depressions capable of containing water are known as ponds, potholes, wetlands, kettles and sloughs. Common names for plants and animals are used throughout the text and Latin names listed in the appendix.

Pothole habitat at Roseneath, near Minnedosa, the focal point of many waterfowl studies.

Historical review

One method of slaughtering buffalo commonly practised by the Indians is dramatically pictured in Alfred J. Miller's watercolor entitled "Buffalo Rift". Buffalo were herded and stampeded over an escarpment and those that were not killed in the fall were slaughtered by waiting hunters. Such a "rift" existed near the present city of Brandon, Manitoba.



The early years

The Indians, by setting fires, and the buffalo, through sheer numbers, once greatly affected the waterfowl distribution on the great central plains of Canada and the northern United States. Predatory animals also had some influence on duck nesting success, but far less than that of the settlers and their tools. We examined the dominant influences of pre-settlement and pioneer days through the writings of explorers and historians.

Buffalo

The wallowing of buffalo in dry potholes packed and deepened the basins, determining the vegetation that later grew there. The bare edges of ponds used by herds provided attractive loafing sites for waterfowl, and the droppings deposited in and around the ponds enriched the water and encouraged the growth of aquatic animal life required in abundance by growing ducklings. However, not all the effects were beneficial. Alexander Henry's journal (Coues, 1897) claimed that buffalo had so depleted the grass along his travel route that the horses were starving. Since feeding horses can range over a considerable area, this suggests such heavy grazing by buffalo that large blocks of country might have been unattractive to nesting ducks. The following explains how a herd of buffalo affected a waterhole and the surrounding area:

"The ravages of buffaloes at this place are astonishing to a person unaccustomed to these meadows. The beach, once a soft black mud into which a man would sink knee-deep, is now made as hard as pavement by the numerous herds coming to drink. The willows are entirely trampled and torn to pieces; even the bark of the smaller trees is rubbed off in many places. The grass...is entirely worn away. Numerous paths, some of which are a foot deep in the hard turf, come from the plains to the brink of the river, and the vast quantity

The magnitude of buffalo slaughtered is shown in this photograph taken near Lloydminster, Saskatchewan. It was the site of Chief Poundmaker's last great corral in 1874.

of dung gives this place the appearance of a cattle yard" (Coues, 1897).

The buffalo were extremely abundant until a few years before their demise and there is much speculation concerning how their numbers could have dwindled so rapidly. Slaughter, mainly by white hunters, seems the most plausible explanation since, in the 1860's, the great central plains were inhabited by fewer than 24,000 Indians (Hind, 1859).

Buffalo hunts were colossal events and became an important industry involving thousands of people. According to a census-taker named Ross, one hunting party in 1849 included "603 carts, 700 half-breeds, 200 Indians, 600 horses, 200 oxen, 400 dogs, and 1 cat" (Hind, 1860). During the 1860's as many as four thousand carts from the Red River went annually to the Saskatchewan plains for the summer hunt. There they met many others from the Hudson's Bay posts of the Northwest Territory.

Seton (1937) stated that the last great herd of buffalo gathered in Grand Valley in 1861 where, two decades later, the city of Brandon, Manitoba, was founded. He placed the killing of the last buffalo on the "Big Plain" (the Minnedosa study area) between 1860 and 1865, but 20 years later buffalo skulls still dotted the prairie.

The final chapter in the buffalo saga appeared in the Winnipeg Free Press of November 14, 1887:

"Large quantities of buffalo bones were being found on the prairie around Minnedosa, proving that it had been a popular hunting ground, and parties from as far as Neepawa were collecting the bones, which a Chicago firm was buying for fertilizer, offering an unlimited market."

Indians

The Plains Indian practised range management, through the use of fire, to attract buffalo and elk. Indirectly, these tribes affected the vegetation which ducks used for nesting and created large areas of green browse attractive to geese. Tribes living near the marshlands of the Manitoba basin relished duck eggs and duck flesh. Henry visited Delta Marsh in early July 1806 where he found the Indians of the area collecting eggs and flightless ducks (Coues, 1897).

"Their principal resources has been along the shores of Lake Maninthonobanc [sic (Manitoba)], where wild fowl breed in prodigious numbers. Round the S. end of this lake, and as far N. as the Straits, a low, broken, marshy country extends from one to three miles before we come to terra firma—these extensive morasses being the great resort for wild fowl of all kinds. At the season when swans and other birds shed their feathers, the Indians destroy great numbers by pursuing them in canoes and killing them with sticks. Eggs of all sorts they also collect in abundance—even canoe-loads (canotees)."

The demise of the buffalo was a knockout blow to the Plains Indian. Macoun (1882) reported:

"During the last three years, the great herds have been kept south of our Boundary, and as the result of this, our Indians have been on the verge of starvation. Where the hills were covered with countless thousands in 1877, the Blackfeet were dying of starvation in 1879."

The Blackfeet were starving, yet the Indian is very resourceful in living off the

Miller's brush preserved the life and hardships that existed on the Canadian prairies. His dramatic watercolor, "Prairie on Fire" (cropped), shows settlers attempting to save their encampment from a prairie fire.

land, and the countryside still teemed with other kinds of fish and game, including waterfowl. Macoun (1882) claimed: "Any person in a week could have shot enough ducks and geese to have lasted a family all winter. The abundance of waterfowl . . . is of such importance at this time when Indians are being fed by the Government, that they should be compelled to lay in a stock of feed for themselves during the winter. To see hunters perishing of hunger, or living on supplies furnished by the Government, and at the same time surrounded by millions of birds, is a paradox; but these men carry rifles, and bird shooting to them is small business after buffalo hunting....Colonel McDonald could scarcely persuade some young men to go and kill a few ducks by liberal offers of powder and shot. At the Assiniboine Reserve it was the same, plenty of birds in the neighborhood but scarcely any attempts made to shoot them as the men preferred Government rations to independence. Rifles today are of little value to the plain Indians, and they should be required to exchange these for shot guns at an early day."

The Plains Indian was not prejudiced against eating ducks as shown by middens of Indian encampments containing duck bones (Wood, 1967). But the Indians' hunting season was during the summer when the birds were unable to fly, and clubs, not guns, were their weapons.

Prairie fires

In the early years, prairie fires left their mark both on the landscape and on the memories of their witnesses. Only weather wielded more influence than fire on plant succession. Whether caused by Indians, lightning, or a pioneer's carelessness, frequent and widespread fires prevented the invasion of aspen onto the grasslands and maintained the equilibrium of plant growth.

Prairie fires fascinated the early travellers who described them in their journals. Bishop Provencher, a missionary who visited the prairies in 1819, wrote his superior as follows (Hamilton, G., no date): "Wherever the fire passes there can be no animals for the entire winter. It is a dreadful sight to see the fire start in the dead grass and be swept along by a strong wind. It travels with an astonishing rapidity and even though there is little to feed on, it is sufficient to burn herds (of buffalo) of considerable numbers which cannot escape its velocity, and which, if they do not die on the spot, survive but a short time."

An account by Hind (1860) gives further details:
"It (the prairie) must be seen at night, when the distant prairies are in blaze, thirty, forty or seventy miles away; when the fire reaches clumps of aspens, and the forked tips of the flames, magnified by refraction, flash and quiver in the horizon, and the reflected light from rolling clouds of smoke above tell of the havoc which is raging below....These are some of the scenes which must be witnessed and felt before the mind forms a true conception of the prairie wastes, in the unrelieved immensity which belongs to them...."

Some prairie fires were of tremendous size. Probably one of the largest was described by Hind (1860) as follows: "From beyond the South Branch of the Saskatchewan River (in Saskatchewan) to Red River (in Manitoba) all the prairies were burned last fall, a vast conflagration extending for 1,000 miles in length and several hundred in breadth....The dry season had so withered the grass that the whole country of the Saskatchewan was in flames."

Among the first to appreciate the role of fire in maintaining the grasslands were Campbell and Twining (1878), the surveyors of the international boundary line. They noted that trees and shrubs grew freely where protected from fire and that the grasslands extended unbroken for hundreds of miles where there was no fire protection. They concluded that forests would cover much of the country, were it not for the fires. Similar interpretations were made by Christy (1885) and Bird (1961).

When the first farmers took steps to control prairie fires the forest rapidly extended its range. Thus the white man played a major role in revamping the landscape.

Predators

In recent years, the principal predators on duck nests or ducks in Manitoba have been the crow, magpie, marsh hawk, raccoon, skunk, fox, coyote and Franklin's ground squirrel. Today, the only serious threat to overwater nests is the raccoon, perhaps the most unwanted predator in the Minnedosa pothole country.

The combined effects of all predators in the early days are impossible to assess. They were not important from man's standpoint since all reports indicate abundant waterfowl in suitable habitat conditions. Early writings help little in reconstructing the picture. Seton (1909) described the raccoon as very rare, found only on the timbered banks of rivers in the southwestern part of the province. But Henry frequently noticed it around 1800 in the vicinity of the Red River in northern Minnesota and North Dakota just south of the Manitoba line (Coues, 1897). His list of the fur returns of 8 canoes from the Lower Red River shows 152 raccoons taken in 1805–06 and 76 the year before. A few raccoon skins, their source unknown, showed up annually about this time with furs brought into Portage la Prairie and at Pembina. Those records indicate that the raccoon's recent invasion of Manitoba was not its first.

Another important predator, the skunk, was common on the prairies according to Wood (1885). Seton (1909) agreed that skunks were abundant, especially in the parklands. The two naturalists provided information about the fox. Wood wrote that he saw many foxes on his journeys from Minneapolis via Winnipeg to Brandon in May 1882, and Seton considered foxes common, but less so than when he first arrived.

We found several newspaper reports of encounters with large predators. According to Seton (1909), the wolf was generally distributed but nowhere common, whereas the coyote, a duck egg eater, was as abundant throughout southern Manitoba as before settlement. Timber wolves, even if they relished duck eggs or flesh, were probably not numerous enough to noticeably affect ducks.

Seton (1909) reported that the Franklin's ground squirrel was abundant in the parklands. Then as now, this "grey gopher" undoubtedly broke up many duck nesting attempts.

Christy (1885) observed that crows in western Manitoba were uncommon in the summer of 1883 but increased in September. He did not mention the magpie, but thought the marsh hawk common throughout Manitoba. Seton (1909) classed the crow as common in the southern part of Manitoba, becoming less so farther north; the magpie as irregular and rare; the marsh hawk as abundant.

Bird (1961) and Schorger (1941) associated the increase and spread of crow populations with the expansion of settlement, which increased both food supplies and nesting sites. Crow populations apparently peaked in Manitoba during the early 1940's and declined during the 1950's and 1960's.

Pioneers

Although those who first explored the prairies for colonizing possibilities were not favourably impressed, hundreds of land-hungry pioneers took their chances in a new environment. The Civil War, the Sioux uprising, the severe drought of the 1860's and a transportation bottleneck all slowed down westward expansion. But, in 1859, the transportation bottleneck began breaking when an overland route from St. Paul, Minnesota, to Ft. Abercrombie on the Red River connected with steamboat passage to Winnipeg. Before the railroad

Railroad survey crews such as this crew at Elbow, Saskatchewan, in 1871 heralded the arrival of settlers to the fertile prairie region.

reached Winnipeg the westward movement was well underway, and with the railroad's help it swelled immensely. According to Macoun (1882):

"In June 1871, the country (west of Winnipeg) was still in the state it had been for ages. Annual fires crossed the plains, periodic quarrels occurred amongst the Indian tribes, the buffalo came and went, and the long cold winter passed away and was succeeded by the general warmth of spring."

Coleman (1957) describes the sudden emergence of one settlement:

"In the spring of 1881 the site where the city of Brandon now stands was empty prairie lying on either side of the Assiniboine River. Furrow-like buffalo trails led across it to the saucer-like depression on the western edge which served as a convenient spot in which these monarchs of the plains had once lain down to rub themselves. In 1881 not even buffalo gave life to the empty stretch of soil [but]...their horned skulls and heavy thigh bones testified to the fact that the white man's guns had wiped their race from off the face of Manitoba....Save for the wildlife, the wandering bands of Indians, and the passing boats the prairie was empty and silent ....A little over a year later, unbelievable as it may seem, a city stood on the land that had been so empty and silent."

Railroads, roads and ploughs

Nothing hastened the colonization of the prairies quite as much as the coming of the "iron horse." In 1878 a railroad was constructed from Pembina to Winnipeg. The trans-Canada railroad reached Winnipeg on July 26, 1881 and by 1885 the Canadian Pacific Railway had joined the Atlantic to the Pacific.

Branch lines spread out almost immediately. According to the Winnipeg Free Press of September 18, 1883, "Contractor Ross began laying the track of the Manitoba and Northwestern Railway—northwest from Portage la Prairie, running through the fertile and arable Shoal Lake and Birtle country via Tanner's Crossing (Minnedosa). Mr. Ross told the Free Press he expected to reach Minnedosa by October 1."

Macoun (1882) foresaw wildlife providing benefits for the white man with the coming of the railroad. "The value of the bird crop after the railroad is built will be enormous," he wrote, then added: "but destruction of eggs in the spring by Indians must close." The white man was now in control.

But Farley (1925) equated the coming of the railroad with the beginning of the end for wildlife:

"With the coming of the railroad, a change took place, and one of the most fruitful agricultural portions of the American continent has replaced what is generally accepted to have been the world's greatest hunting ground. This transformation has been gradual and perhaps unnoticed by many of the hardy settlers who have carved comfortable prairie homes on its rich surface, but the animals which were hunted, partly for food, for their furs, or for sport, have all but vanished."

Promoters advertised wildlife as well as good soils to entice early settlers to the area. Macoun (1882) quotes one unnamed promoter as follows:

"Shoal Lake is distant about one hundred and seventy-five miles from the city of Winnipeg. On reaching it the eye of the traveler is suddenly caught with the view of a magnificent sheet of pure, crystal-like water. In spring and autumn especially, myriads of wild fowl are to be seen popping over the surface of these waters. All of this, in connection with deer hunting, affords excellent pastime for the sportsman."

Roads have affected many thousands of potholes and marshes, usually detrimentally.

Travellers in the early settlement years had few routes to choose from across western Manitoba. The original main trail into the heart of the pothole country started at Fort Garry (Winnipeg), passed through, or near, Portage la Prairie, Gladstone, Minnedosa, Shoal Lake and Birtle and ended at Fort Ellice, an important terminus on the

Upper. The vast prairie grasslands fell to the settlers' ploughs as more and more settlers were attracted by the rich prairie soil.

Lower. At the turn of the century the prairies took on a settled appearance. Four million acres of prairie had been broken and farmsteads were established. Farming methods were still primitive but effective and economical.

Assiniboine River midway between the mouths of the Qu'Appelle and Birdtail Rivers. There were also hunters' roads into the buffalo country of the Souris and fur traders' roads to the north. The journey from Portage la Prairie to Minnedosa, a two hour drive today, sometimes took four days or longer during wet springs.

Soon after becoming a province in 1870, Manitoba was divided into townships six miles on a side and containing 36 sections or square miles. Road allowances 1.5 chains (99 feet) wide bounded most sections, forming the basis for a network of roads. In the first 30 years of this century, dirt roads, so long as they were dry and snow free, met most farm-to-market needs. But, since gravel and hard-surfaced roads were rare, there were long annual periods when travel was difficult or impossible. The depression of the thirties set back the road development program, and it improved little during the following war years. However, waterfowl will likely be affected by a new expanding, all-weather road system which, when finished, will crisscross the country a few miles apart.

Although it eventually dealt the *coup de grâce* to the virgin prairie, the plough at first proved a blessing for wildlife. It created an interspersion of habitat types and provided a great deal of edge, both of which favour most wildlife populations. Also, grainfields and the accompanying weeds supplemented the wildlife food supply, and waterfowl responded almost immediately. Within two or three years after agriculture reached the Canadian prairies, Macoun (1882) reported that:

"Geese, ducks, and prairie chickens are taking to the stubblefields in the fall, so that no difficulty will be found by incoming settlers to lay up a supply of fat fowl for the winter."

By 1900, 4 million acres of prairie sod had been broken. By 1936, more than 57 million acres of western Canada were under cultivation and by mid-century, 67 million acres. Drought, depression and surpluses have periodically slowed and even reversed the pace. However, ground once thought unploughable is now being broken by modern machinery, and the end is not in sight. As world food market demands grow, ploughs become bigger, tractors more powerful and special equipment is designed to invade forests and marshes.

Waterfowl and hunter abundance

Although precise population figures for waterfowl and hunters during the early years are unavailable, early accounts gave some hints of numbers and showed that waterfowl were hunted both for food and recreation.

Gunn and Tuttle (1880) discussed the unusually early spring of 1816 which encouraged some Pembina settlers to explore the Upper Red River. Returning, they encountered abundant game, including buffalo, deer and waterfowl on every pond. In contrast, waterfowl were scarce in 1820, perhaps because it was a dry period of hardship and hunger.

Hind (1859), travelling through eastern and western Manitoba and eastern Saskatchewan, often referred to waterfowl abundance. Of the lower reaches of the Qu'Appelle, he wrote:

"Ducks and geese crowded the river for several miles; there were enough of them, I should think, to supply all the markets in Canada....The region drained by the Rapid [Minnedosa] River continues beautiful and rich so that it may with propriety be stated, that for a distance of 75 miles this river meanders through a country admirably adapted for settlement. Ponds and lakes are numerous, wild fowl in great numbers breed on their borders...." Passing Shoal Lake, near Winnipeg, he commented: "in the spring and autumn the lake is covered with wild fowl of every variety. Shoal Lake is a favorite sporting ground of the gentlemen of Fort Garry and the half-breeds of the settlement."

Settlement of the aspen parkland began in an extended wet period when waterfowl population levels were high. Macoun (1882) wrote in 1879 of the previous fall's migration through the pothole country: "it is scarcely credible the myriads of ducks that fill every pond and marsh in September and October and no description could give an adequate picture of the astonishing sight."

In May 1882, and June 1884, Wood (1885) and Christy (1885) reported seeing large numbers of both ducks and geese, including many duck broods, between Minneapolis and Brandon before drainage of the Red River Valley all but eliminated such sights forever.

Early in June 1882, Wood called the area near Brandon the finest country imaginable, with "ducks getting up under your feet at every yard."

Christy (1885) reported on the fall migration of 1883 in the district of our study area:

"During this autumnal movement the number of ducks frequenting the lakes and ponds throughout Manitoba is prodigious. I shall not soon forget the hundreds I saw in the innumerable ponds between Rapid City and the Oak River whilst on an excursion toward Fort Ellice, in the middle of October, 1883. Yet those I saw must have been as nothing compared with the abundance to be seen in some other places. A friend who had several days' shooting... near the south end of the Lake Manitoba, about the end of September, describes the ducks as being so numerous that only the terms 'acres' and 'millions' could adequately express their abundance."

One of the most graphic descriptions of waterfowl numbers in the early eighties came from the pen of Mershon (1923):

"Such clouds of waterfowl as we saw here and at Sibley Lake and Buffalo Lake...I have never seen before and never have since. I remember standing on the edge of the Sam Devore Slough when something alarmed the water fowl and they fairly darkened the sky when they got up, and the roar reminded one of a heavy train moving at a rapid rate of speed over a long, resonant trestle."

This was near Dawson, North Dakota, in 1884, but it supports other reports we have quoted which indicate that duck populations were generally high throughout the region as settlement began.

Thompson's (1890) accounts suggest that the species composition of ducks during the 1880's was, with a few exceptions, similar to that of today. The mallard and blue-winged teal were rated very abundant. Somewhat less so were the pintail, shoveler, green-winged teal and baldpate. The gadwall, now a fairly common nester throughout Manitoba's pothole area, was listed with the wood duck as a rare resident, except along the border. The black duck and cinnamon teal were classed as the rarest dabblers. The gadwall represents perhaps the biggest change in species ranks between the two periods.

Among diving ducks, the redhead was classed as a common breeder and the canvasback as uncommon. Thompson (1890) quotes ornithologist, Rich H. Hunter, as saying that canvasbacks never breed in Manitoba, though Thompson himself claimed that a "few" bred there. Either these records were in error or the canvasback's status in Manitoba has greatly improved. Thompson's statements reflect no other differences in species composition between then and now.

Bird (1961) reported that the Canada goose nested throughout the area, on the larger marshes and along the major rivers. The early literature mentioned goose nesting sites in the Assiniboine River, Oak Lake, Douglas Marsh and West Shoal Lake. After many years of absence, Canada geese have become re-established as nesters at Oak Lake, and between Lakes Winnipeg and Manitoba (the Interlakes region), where production today is probably higher than it was a century ago.

During his travels in July 1806, Henry saw swans (presumably trumpeters) in the flightless stage on Delta Marsh (Coues, 1897). In August, along the Cypress River, he collected two cygnets and one parent for supper.

Seton called the trumpeter a very rare migrant, although in an earlier publication he reported observing several trumpeters on the south slope of Riding Mountain and on the Little Saskatchewan (Minnedosa) River. After a half-century's absence from Manitoba, the trumpeter swan is now breeding at the Delta Waterfowl Research Station.

Middens of excavated fur traders' campsites show that early traders ate ducks. At one such site in North Dakota, Woolworth and Wood (1960) reported that of 12 bird species identified from their bones, 11 were waterfowl. Indians and whitemen ate waterfowl when easily obtainable, but the total impact of this on waterfowl populations was negligible.

About 1880 the white man introduced the sport of duck hunting to the prairies. Fahrni and Morton (1946) describe its success: "What nimrods they were is indicated by the results of the shooting match of September, 1894. Early Wednesday morning, long before sunrise, most of the sports who took part in the shooting match had left for the marshes where millions of ducks made their abode. There is not a better shooting ground in Manitoba than in the Big Grass Marsh. Quietness reigned supreme in town all day, while the thick smoke of battle and the bang of guns was the order of the day on the hunting grounds.

"The first man to return was W. Williams who brought in 33 ducks. He remarked with a twinkle in his eye that his mates were doing better than that and that his side was a sure winner.

"A few minutes later, Captain McMillan and Dr. Armstrong returned with a broad smile of satisfaction on their faces and 93 ducks and 3 sandhill cranes in their buggy. Captain Williams' jubilation was not then so demonstrative. His certainty of victory was still less pronounced when one of his lieutenants returned with only 3 ducks to his credit, and another with one, and two more with 8. But at last when all had returned Mac was defeated by 1,575 points. The total number of ducks bagged was 327; geese 1, sandhill cranes 3."

Shooting matches became popular soon after settlement. In 1894, notices in the Minnedosa Tribune first announced that the Minnedosa Gun Club was holding a live pigeon shoot the following Thursday and, later, that this club had defeated the Rapid City Gun Club by three birds.

The popularity of hunting activity had strained farmer-sportsmen relationships near Minnedosa by 1904, as evidenced by a note in an August issue of the Minnedosa Tribune: "Many farmers of the district have advertised that shooters will be prosecuted for trespassing or hunting on their farms."

But under certain conditions they welcomed hunters, as this item in the Tribune indicated:

"Ducks have been working on the unthreshed barley stooks in large numbers, and farmers, for once were not averse to sportsmen coming on the fields to keep the ducks moving."

Ups and downs in hunting conditions then, as now, were probably caused by changes in water conditions and waterfowl numbers. In 1907, the Minnedosa Tribune reported a good outlook for duck hunting but, in 1912, a poor opening due to a bird scarcity.

Heavy hunting pressure is largely due to the increased populations of the post World War II era. At the turn of the century, according to Wilkes (1967), Winnipeg and Brandon were the only cities between the Great Lakes and the Rockies with over 5,000 people. Calgary, Edmonton, Regina, Moose Jaw and Saskatoon combined had fewer than 11,000 residents. Following a tremendous land boom, these five cities claimed 126,000 people by 1910, over a tenfold increase in a decade, and over one million inhabitants by 1966. Meanwhile, the population of metropolitan Winnipeg passed the half million mark.

Sales of game bird licences to residents and non-residents reflect the number of hunters in Manitoba. Figures provided by the Wildlife Branch of the Manitoba Department of Mines and Natural Resources show annual sales between 1914 and 1945 averaging 7,330. Departures from the average during that period were small, totaling 7,095 the first year and 10,448 the last year of the period. By the mid 1950's the number of licensed hunters averaged about 25,000, more than a three-fold increase over the average for the earlier period. By 1960 licence sales exceeded 40,000, nearly a six-fold increase in less than 50 years.

After 1963, when farmers could no longer hunt on their own property without a licence, permit sales jumped about 30 per cent. Since most Manitoba small game hunters also hunt waterfowl, hunting pressure on waterfowl has increased over the years at approximately the rate reflected by small game licence sales. We have no information on hunter numbers before 1914, but presume they more or less paralleled the gradual human population gains. But, as indicated above, the big increase took place during the period of our study. It reflects better roads, more leisure time and greater prosperity, as well as more people.

Weather, ponds and ducks

Millions of basins and depressions, capable of holding water and producing ducks, dot the northern prairies of North America. The Prairie Provinces of Canada alone have over eight million such areas (Munro, 1967). Crissey (1969) and Cooch (1969) demonstrated a direct relationship between the number of ponds and the duck population size. Crissey insists that the number and condition of these ponds will determine the future of duck hunting in North America. The number of ponds, which are counted by airplane, is now one of the standard measurements used in Canada and the United States in drawing up duck hunting regulations.

Therefore, the duck hunter is concerned with the flooding and drying of prairie potholes, as is the trapper who harvests valuable furs from these wetlands, and the naturalist who studies these areas and their wildlife. But the farmer looks at the same basins and sees a potential grain or hay crop. And when they are full of water, these basins yield him no direct income unless he is also a trapper. At least that was the situation until farmers could profitably lease their wetlands to the two federal governments, since 1961 in the United States (Burwell and Sugden, 1964) and since 1963 in Canada (Munro, 1967).

The coming and going of wetlands affect an area's total environment. Hydrologists observe the relationship between surface waters and the subterranean water supply. Meyboom (1967) suggests that the surface waters recharge the ground water supply in the western Canadian morainic region. He demonstrated earlier that during summer and fall in the pothole region, ground water replenishes small temporary sloughs which in turn contribute to groundwater replenishment during spring and early summer (Meyboom, 1967).

Climatologists share with meteorologists and soil conservationists a concern for downstream flooding when water runs off the land too rapidly, and a responsibility to warn residents in the area well in advance of such happenings. Agriculturalists have long recognized that the amount of precipitation affects grain crops.

Thus, there is a demand for detailed information about surface water and the weather controlling it. Obtaining this information about prairie ponds involves interpreting their condition in the past, forecasting as far as possible into their future and devising a more sophisticated system for recording the current status of the basins. The demand is not easily met as both surface water hydrology and weather interpretation are extremely complex fields.

Weather accounts about the 1800's in literature

Thomas (1964), a meteorologist, found evidence in the journals of early explorers, Umfreville, Thompson, Mackenzie and Richardson, that the prairie climate of yesteryear differed little from that of today. After review, we concluded that these and other early writings sometimes gave clearer pictures of surface water conditions than do today's weather records.

Drought marked the beginning of the nineteenth century in the Red River Valley. Henry's journal had this entry for August 28, 1800: "The drought has been so great this season that there is scarcely any water in [Plumb] river, and the entrance is dry ground; this was thought extraordinary by those acquainted with the country." Of the Sale River, he said, "I am told the water is lower than has ever been known before...." (Coues, 1897). The "Plumb" or Plum River and the "Sale" or LaSalle River flow into the Red River south of Winnipeg.

By 1806 conditions had changed markedly. On July 7 of that year, Henry again crossed the Plum River en route to Portage la Prairie and points west. The Plum, which was an intermittent brook in 1800, was a raging river by 1806: "At two o'clock we came to Plumb River, and were obliged to make a long circuit in the plains before we could find a convenient place to swim." Farther north the Sale River was also in flood as indicated by the entry for July 8: "At eleven o'clock we came to the Sale, where we were obliged to swim our horses." Throughout the account of this trip, which lasted until late August, crossing Manitoba to Mandan, North Dakota, and returning by another route, there are many references to the widespread extreme wetness.

Absence of snow water run-off in the spring of 1817 may have heralded a drought period. According to Gunn and Tuttle (1880), the previous winter was unusually mild and the snow disappeared before March. Out of a cloudless sky on July 18, 1818, a great invasion of grasshoppers, an indicator of drought conditions, came to the Red River Valley. A plague was also reported in North Dakota by Lounsberry (1919). Dry conditions reported by Long's party in August 1823 (Coues, 1897) provide supporting evidence of a drought during that period.

Reporting on weather and crop conditions after the establishment of the Red River Settlement in 1812, Ross (1856) mentioned grasshopper raids during the first few years and the first good crop in 1817. This suggests a dry period between 1812–24, possibly broken by one or more normal years. The best crop up until that time was produced in 1825.

Red River floods

The great Red River floods of the 1800's caused further hardships for the early settlers. Hamilton (no date) described three great floods of the 1800's. The first and greatest flood recorded was in 1826. It reached an elevation of 765.5 feet and an estimated flow rate of 225,000 cubic feet per second. Heavy rains in the fall of 1825 filled all the sloughs and insured a deep frost seal which causes snow melt to run off rather than soak in. A foot of snow fell on October 20 and more followed. On May 4, 1826, the river rose 4 feet. The next day the ice went out of the Red and, two days later, out of the Assiniboine. A thunderstorm on May 6 hastened the break up. There was a torrential downpour on May 10, and on May 17 the rivers were still rising. A gale on May 20 shortly before the crest was reached added to the havoc. The river started dropping on May 23 but hordes of mosquitoes prolonged the misery for weeks to follow.

The flood crest of 1852 was not quite so high as in 1826. The ice broke up on April 25, a rise of 7 feet in a few hours occurred on May 3. Heavy rains of May 5 and 7 prolonged the problem. The normally narrow Red River spread out to a width of 22 miles between Pembina and Winnipeg.

The flood of 1861 was smaller and, by the time it reached Red River Settlement, less damaging. Anticipating trouble, the settlers in lowlying areas started evacuation on April 23, but by May 8 the waters were subsiding.

Colonel Lounsberry (1919) also commented on the major Red River floods experienced at upstream settlements near the U.S.–Canada border:

"There were five weeks in 1852 when there was uninterrupted canoe communication between the Red River and the Minnesota [River], and boats actually made the trip from Pembina to St. Paul. As to conditions that year at Pembina we have the testimony of Charles Cavileer, the collector at Pembina. 'There were no herds of lowing kine and no fields of waving grain.'

"Cavileer and a companion were in the cock-loft of the customs house where they were confined during the flood, excepting as they got out in boats. Cavileer said: 'In this loft with one companion I spent over five weeks surrounded by water over five feet deep, extending from the River O'Maris to the Minnesota Ridge. There were thirty miles of open sea. One night it blew a furious gale. The waves rolled over the roof and every moment we expected the frail building to go over, but we were saved by being in the lee of the Kittson buildings...sometimes we went hunting ducks and geese by rowing around among the timber, and had much success in hunting duck eggs among the driftwood. Notwithstanding the flood, we literally feasted on the fat of the land.'"

Lounsberry spoke of the trader Moorhead's experience in the flood of 1861: "...he was compelled to remain in the garret of his home twenty-two days by the high water of that spring. The water was then five feet higher than it was during the season of high water in 1882, the 'spring rise' remembered by many settlers of that time." We experienced another major flood during the course of this study. In May 1950 Red River towns and Winnipeg were more or less inundated by a disastrous flood which again created a huge "sea" between Winnipeg and the U.S. border.

Water, mud and settlement

The first major movement westward from the Red River Valley in the late 1870's and early 1880's coincided with a wet period, and weather information became more complete with expanded settlement. According to Morton (1957) "the years from 1876 to 1881, years of much rain and high water in the rivers, had also seen the steam navigation of the Assiniboine begin." Brandon's original lowland site on the Assiniboine's north side would have been wiped out in its first year except for the foresight of some of its founders. The town was relocated in the highlands shortly before a tremendous flood inundated the lowland site with several feet of water late in June 1881. A weather station was not needed to point out the super-saturated condition of the watershed.

Florence M. Brown, Minnedosa historian, pieced together the following clear-cut evidence about water conditions from the unpublished diary of her father, Henry Rose, and field notes of other early settlers:

When the Tedfords arrived in 1877 they found "the country...well flooded. We had to make a crossing at Stoney Creek which was so swollen the oxen began to swim and tubs, etc. began to float downstream." Stoney Creek is between Neepawa and Minnedosa. During the years of our study it was usually dry and never carried a large volume of water.

The Robert Modill family reached Gladstone, then Palestine, in 1877 and stopped. Because "the land around Palestine seemed to be so flooded with water" they moved in 1879 to the higher land near Riding Mountain "going at first through several miles of water before reaching dry road." That was in July, normally a dry period in that area.

In June 1879, the Joseph Black family moved to Minnedosa. It took them four days to travel 70 miles due to rain, mud, detours around sloughs, getting stuck, almost losing their oxen in fording a stream, wet clothes and blankets, clouds of mosquitoes and other hardships.

The Boyds reached Minnedosa also in 1879 after similar experiences: "There was lots of water—got stuck and had to hitch two teams to pull the wagons out of the mud."

Also in 1879, Henry Rose scarcely had time to unload at his homestead a few miles east of Minnedosa before a late April storm dropped a foot of wet snow. Afterwards, he commented that "every pond was full and creeks overflowing through the cuts of old beaver dams, which were often the only place we could cross...wild game was very plentiful, especially ducks." During the following winter "the snow was very deep...on the level from 3–6 feet [and] many banks in the bluffs still remained May 1 (1880)."

The above information establishes that the ponds of our study block were full to capacity at the beginning of settlement in the late 1870's and early 1880's.

In 1874 and 1882, there were also heavy spring run-offs of snow melt which usually reflect ample surface water. MacFadden (1953) reported that the Assiniboine River was unusually high during the spring of 1874 and high enough in the spring of 1882 to delay navigation. By that fall, however, navigation was impeded by water dropping in the Assiniboine, "and eventually it was realized that steamer navigation on its waters had come to an end." These statements indicate that the stream flow during the early settlement years was excessive and steady in the general wet period across the plains.

According to Macoun (1882): "The summer of 1879 was an unusual one characterized by excessively heavy rainfall, with cold, raw weather in the early summer months. These conditions...appear to have been felt over the entire area of the plains to the Red River Valley...the mean temperature of even the latter part of the summer appears to have been rather abnormally low."

Hamilton and Albina (1948) recalled the weather conditions of the early years near Regina, Saskatchewan, as follows: "The first years (1882–83) were wet. There was water everywhere and the sloughs on the prairie were brimfull. Wherever there was traffic there was mire, and the rain came down in torrents."

The period 1874–82 was unusually wet on the eastern prairies, but the pivotal year toward drought is open to some doubt. Whereas Hamilton was much impressed by the wetness around Regina in 1883, Strange (1953) (referring to the cultivated parts of the prairies) claimed that 1883 was a particularly bad drought year. We are unable to explain this discrepancy.

Drought and mud cracks

A "normal" weather year is exceptional on the prairies. Morton (1957) summarized the settlers' first tastes of droughts: "Drought was a serious handicap in scattered years, in the decade of 1836–46, and in the years from 1862 to 1868...Red River suffered not only a want of government but from 1862 to 1868, a want of rain. After wet season in the late 1850's a dry spell began in 1862. (In 1864)...the water mills stood idle by the parched creeks; hay was in short supply; the steamer International made only one trip in the third dry summer. Grubs and grasshoppers damaged the crops, and in the fall prairie fires swept the plains and burned the swamps to the clay. In 1865 the grasshoppers were a plague, and the season again dry. The next two years gave some relief from drought and grasshoppers but in 1868 the two combined to cause an all but complete crop failure."

Hamilton and Albina (1948) vividly described the first drought faced by the settlers at Regina, who initially had experienced nothing but extreme wetness: "Then (1884)...it began to dry up and kept on drying. We were to learn that, however unpleasant the moisture might be, it was preferable to the long continued drought that parched grass and grain and every growing thing. Cracks opened in the baked prairie and there were legends of horsemen falling into them and suffering grievous injury....It seemed as if it could not rain anymore. Strong winds blew every day, fresh enough in the morning, but by noon as hot as if they were being belched from the mouth of a furnace...the decade from 1885 to 1895, for the most part was one of famine. There were only two seasons when the harvests were normal and during several drought-stricken years the crops failed completely....The famine ended in 1895."

Wing (1937) said the Prairie Provinces experienced severe drought in the mid-eighties and again in the early nineties, lasting until almost 1900.

Strange (1954) singled out 1885–87 and 1889 as particularly bad drought years and Sir Frederick Stuport (Thomas, 1964) concluded that 1897 ended a comparatively dry precipitation cycle in Alberta. In North Dakota, at least one wet year (1892) occurred during the drought period (Tuttle, 1893).

Soon after the prairie sod was broken and dry soil was exposed to the high winds common on the prairies, severe soil drifting and dust storms became a problem. Significant soil erosion by wind was recorded at the Indian Head Experimental Farm in Saskatchewan in 1887 (Hopkins *et al.*, 1946) and at the Brandon Experimental Farm in Manitoba in 1890 (Archibald, 1939). The accelerated filling of potholes by wind-displaced silt commenced at that time.

Early weather records

Pictures of early weather conditions before weather stations were established must be incompletely pieced together from the only available records scattered through the journals of a few hardy travellers.

Thomas (1964), with whom our findings agree only in part, reported that the first 36 years of the nineteenth century on the Canadian prairies apparently had a normal assortment of dry, wet, cold and warm years. Throughout the prairies a very dry period from 1837 to 1848 was followed by a wet period lasting until about 1859. Then came the floods of 1861, the subsequent hot, disastrously dry weather of the 1860's and the wet years of the 1870's.

Whereas Thomas considered the first third of the nineteenth century as quite normal for the prairies, we found strong evidence of significant departures from normal, although we were unable to determine their magnitude or duration. The summer of 1806 must have been one of the wettest ever; and the conditions causing the record flood of 1826 obviously affected surface water conditions over a broad area. Probably surface water conditions in Manitoba were very good for at least a few years around 1806 and again in 1826. The late 1850's was another wet period. Drought prevailed around 1800, 1816 and 1823 and there are some indications of a succession of dry years between 1812 and 1823. Other drought periods were 1836–46, and 1862–68, followed by a trend toward wetness and the very wet years as settlement began.

Comparisons with North Dakota records indicate the more significant weather patterns. North Dakota journals support Thomas' conclusions on drought in the 1860's (Waldo, 1936; Collins, 1895; Kane, 1951).

Records from weather stations

The first western Canadian weather station began operation at Winnipeg in the 1870's; the first in western Manitoba at Minnedosa in 1881. Several more stations were added by 1890. By 1900, 36 stations in Manitoba and 50 farther west were supplying weather information. In 1966, Canada's Meteorological Branch published a list of 50 stations in Manitoba alone which had supplied a lengthy series of precipitation data covering the period 1931–60 (Potter, 1965). The Searle Grain Company Ltd has, in recent years, routinely obtained rainfall reports from 600 gauges located in the grain-producing region of the Prairie Provinces.

Meteorologists including Thomas (1964), Currie (1954) and Kendall and Thomas (1956), reviewed the official weather records as far back as they went and drew some general conclusions:

1) During the 1870's, the early 1900's (to 1905) and the late 1950's, the prairies were unusually wet.

2) Typical moisture conditions occurred from 1950 to 1954.
3) The periods 1837–48, 1861–68, 1905–19 and the 1930's were exceptionally dry. A normal variation on the prairies of irregular dry, wet, cold and warm years intermingled with these relatively lengthy periods.
4) Conditions in Manitoba during the period of record keeping have been more stable than in the other two prairie provinces.
5) It is not possible to forecast trends based on the information now available.

Annual precipitation may be summarized in several different ways. Both the weatherman and agricultural weather analysts assume that ten inches of snowfall equal one inch of rain in computing their totals. But whereas the weather bureau totals the monthly rainfall and snowfall equivalent for the calendar year, January 1 through December 31, agricultural weather analysts work with a "crop year" beginning on August 1 and ending on July 31 of the following year. They divide the crop year into three periods: August 1–October 31 (after the crop is made and before freeze-up), November 1–March 31 (the cold months), and April 1–July 31 (the growing season).

Annual precipitation totals for a calendar year may differ widely from those for a crop year for any given year. For example, at Minnedosa in 1926, precipitation totalled 18.50 inches during the calendar year but 10.49 inches during the crop year. Generally, the totals resulting from the two methods are closer, and become closer as more years are averaged together, since the figures used in the two methods are identical with only the months re-arranged.

Duck habitat conditions for any given year are better reflected by crop year than by calendar year precipitation. Soil moisture conditions for the next growing season are determined largely during the fall period, August 1–October 31, before freeze-up puts a stop to further soil conditioning. A wet freeze-up results in the formation of a frost seal which determines the degree of run-off from the snow melt of the following spring. Most of the snow which may greatly influence early spring surface water conditions accumulates from November 1 to March 31. However, intermittent freezing and thawing during winter and sublimation may cause the snow to dissipate with little or no contribution to surface waters. Conversely, a wet snow only a few inches deep may, under certain conditions, end up as water in depressions. Late winter snows may contribute more to ponds than twice as much snowfall in early winter. An inch of rainfall on frozen ground may add more water to potholes than three inches on dry soil during the growing season. Brush and tall emergent vegetation surrounding ponds serve as natural snow fences causing snow to pile up in drifts which melt directly into the pond. Without the surrounding cover less snow accumulates and less ends up in the pond.

Usually, winter snowfall exceeding 50 inches has a measurable effect on surface water conditions the following spring. April 1–July 31 is the most important period for grain and pasture crops on the Canadian prairies since over half the annual precipitation normally occurs then. Timing may be almost as important as amount for either grain crops or ducks but what is adequate moisture for crops may be grossly inadequate for ducks.

Rainfall must be heavy or fall on frozen, saturated or unvegetated soil to recharge a pothole. But since several inches of rainfall per month during the growing season usually guarantee good soil moisture conditions and help maintain the levels of the brood potholes, this period too is important in any evaluation of duck habitat conditions.

From both the agricultural and waterfowl management standpoints, it is more useful to express annual precipitation by crop year rather than by calendar year system, which combines the cold weather precipitation of two years. We have used both systems, however, because of the greater availability of calendar year data. And although severe drought conditions probably always depress duck production, abnormal wetness does not always guarantee a bumper crop of ducks. Excessive water may drown nests, flood out desirable nesting cover or food supplies and cause heavy losses among newly hatched broods.

Connor (1933) developed another method for evaluating moisture conditions. His soil moisture index and quotient recognized that soil moisture varies directly with the precipitation and inversely with the temperature of the soil. In the Connor system the crop year precipitation is divided by growing season temperatures to give the index in terms of percent of average. Records at one weather station in our study block (Minnedosa) are evaluated in this manner. Connor's soil moisture index values for given years considering temperature, and the crop year precipitation totals disregarding temperature, show similar trends. Therefore the temperature factor can be ignored in a gross evaluation of this kind.

Searle Grain Company study

A precipitation study by the Searle Grain Company Ltd starts with the beginning of rainfall record keeping and includes weighted reports from 600 rain gauges well distributed through the cultivated parts of the Prairie Provinces (Table 1).

Strange (1954) tabulated and analyzed prairie rainfall records for the period 1885–1954 with data from the 600 water gauges. He grouped these figures to represent a crop year rather than a calendar year. About three-quarters of the annual precipitation falls during the average "crop year" which starts August 1. An updating to 1965 of Strange's tables is included in the following comments.

Strange found that the period 1885–1916 was about 10 percent wetter than the period 1917–53. During the earlier period, 5 semi-drought years were recorded compared to 10 such years in the later period. He noted that "semi-drought years usually appear one at a time in the midst of a series

Table 1
The five driest and wettest crop years*, according to the Searle Grain Company tables.

Alberta		Saskatchewan		Manitoba		Prairie provinces	
Year	Rainfall (in inches)	Year	Rainfall (in inches)	Year	Rainfall (in inches)	Year	Rainfall (in inches)
driest							
1910	6.86	1961	6.68	1931	7.94	1961	7.83
1889	7.67	1937	6.97	1929	8.32	1929	7.96
1949	7.80	1929	7.07	1886	8.50	1889	8.43
1886	7.86	1924	7.77	1889	8.61	1924	8.91
1892	8.03	1894	8.06	1910	8.72	1918	8.95
wettest							
1900	19.30	1901	17.63	1901	21.93	1901	21.06
1915	19.22	1955	16.81	1927	19.83	1927	16.64
1927	18.40	1891	15.60	1963	19.43	1955	16.63
1901	17.86	1927	15.29	1885	18.89	1899	16.59
1902	16.66	1963	14.94	1891	18.75	1902	15.34

*Crop year is the previous fall plus the following crop growing period. Winter precipitation is excluded. These are weighted averages.

of good rainfall years, but in Saskatchewan there have been three different periods [having] three years in succession...with considerably less than average rainfall, namely, 1917, 1918 and 1919; then 1929, 1930 and 1931, and later 1936, 1937 and 1938."

Since 1954, Saskatchewan has suffered through another series of drought years. Only 1960 interrupted the drought years from 1956 to 1959 and 1961 to 1962. For the seven years, 1956–62 total rainfall during the growing season was 65.1 inches. For comparable months between 1929 and 1935, it totaled 69.8 inches and 67.6 inches between 1935 and 1941. These were the driest 7-year periods in 81 years in Saskatchewan. Thus, by the Searle Grain Company's weighting system, the moisture deficiency during the drought of the '60's was greater than during that of the infamous '30's. Due to improved agricultural practices and fortuitous timing of the rain showers, consequences to the farmer were far less severe during the more recent drought. But the effect on waterfowl of these droughts was about the same, indicating that our water conservation measures fail to safeguard the surface water requirements of a large duck population.

The Searle's records over an 81-year period show that 6 out of 13 outstandingly wet years on the three prairie provinces occurred during a 13-year period, 1899–1912. The wettest year of all was 1901. Probably the surface water acreage peak for the twentieth century was reached in its first decade. The acreage in the mid '50's may not have been far behind, but since then drainage and other permanent landscape alterations preclude another peak equal to that of the past, regardless of the amount of rainfall.

Prairie Province water picture during 1900's

The first wave of pioneers sloshed through mud and water to their new prairie homes. Then came drought which lasted, with some interruptions, for two decades. The rains came again with another great invasion of settlers at the turn of the century. The deluge hit Alberta in 1900 and spread over Saskatchewan and Manitoba in 1901. By 1904 surface water conditions in Saskatchewan were so impressive that George Tuxford described in his diary the tremendous water bodies which permitted paddling a canoe many miles across open prairie (Wilkes, 1967). He believed that 1904 would be remembered as the year of great floods following a winter of unparalleled ferocity. The prairies may never have had a greater acreage of surface water than during the first decade of this century.

The new settlers first saw another aspect of the prairies in 1910 when a bad drought hit but it soon subsided. A severe 3-year drought lasted from 1917 through 1919.

The '20's saw a drought in 1924, two wet years, 1927 and 1928, and the beginning in 1929 of the great drought of the '30's. We interpret surface water conditions as mediocre in the early '20's and excellent just before dwindling to almost nothing in the '30's, as the second great drought since settlement descended over the land.

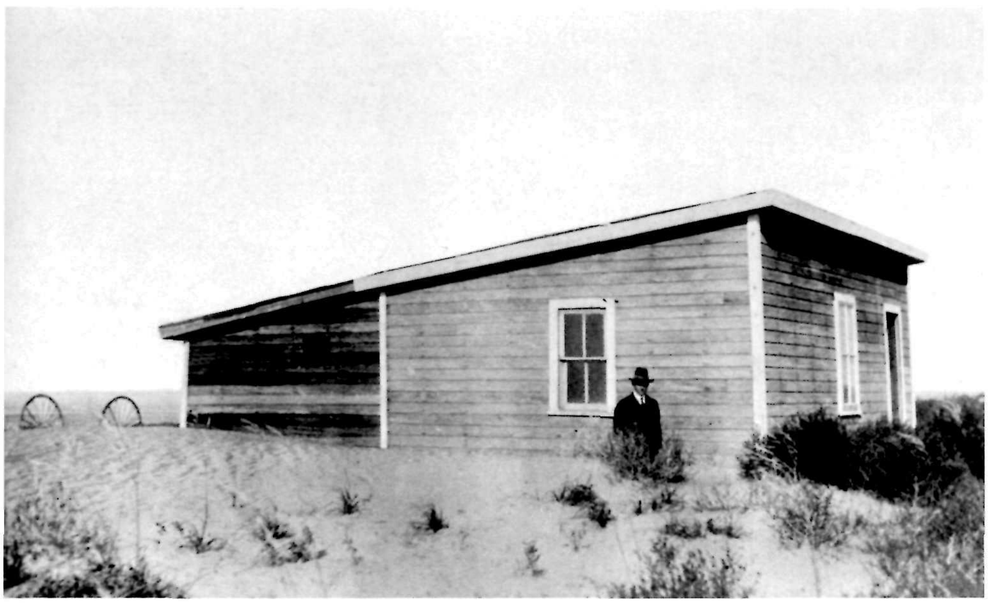
The '40's and early '50's included some good and some bad years for duck ponds, but since wet and dry periods were interspersed, fairly stable conditions resulted.

In the mid '50's a major wet period filled most prairie ponds to capacity. By that time, we were annually counting the ponds. The number of ponds increased about 50 percent from the early to mid '50's in May, from about 4 million to 6 million. Then, as a new drought developed, the pond count declined to a low of about 1.5 million in 1961, after a one-year recovery in 1960 to near the levels of the early '50's. Gradually, rains and snows of the mid '60's refilled ponds until overall habitat conditions were approaching those of the stable years in the '40's and early '50's. Drought in 1967 caused a severe setback in pond numbers and quality, but the decade ended with most ponds again full and ducks staging a remarkable comeback.

The "dirty thirties"

Hambidge (1941) observed that "In 1905 ...hardly any part of the Great Plains had a semi-arid climate....Five years later in 1910 most of the southern and parts of the northern Plains were experiencing a climate

Soil drifting following the severe drought from 1917 to 1919 resulted in this Saskatchewan farm being abandoned in 1920. All vegetation on the farm was destroyed and outbuildings and equipment were covered.



as dry as that of a desert." Drought struck again from 1917 to 1919, but the most memorable drought was that of the '30's.

Thornthwaite (1941) found striking resemblances in the precipitation patterns of 1880–1900 and 1920–40. "In both a series of rainy years was followed by a disastrous drought. Both wet periods occurred when there was great pressure for more farm land and encouraged rapid immigration that led to extension of the cultivated area and to overgrazing. Each drought set in motion an emigration that grew into a rout. In both cases the series of rainy years had been mistaken for normal climate, with disastrous results. Relief measures were instituted in the 1890's as well as in the 1930's and experts were assigned the task of working out programs for rehabilitation and for the permanent occupancy of the Great Plains."

The effects of poor farming practices came to a head during the drought of the 1930's. As Archibald (1939) put it: "only the desperation caused by nine consecutive years of extreme drought and ravages by insects has impelled the adoption of the best available advice moulding it into a definite framework on which to build a sound land utilization plan for the future." To slow the wind, the Highways Department planted some 400,000 Siberian pea hedges over a 3-year period. Many still remain, a living monument to the most severe and prolonged drought since settlement began.

The Prairie Farm Rehabilitation Act was passed in April 1935 to combat drought and depression through better land and water use.

As the great drought moved in from the south, the nesting grounds began to shrivel. Salyer (1934) wrote:
"The last normal nesting seasons on the prairie breeding grounds was in 1929.... Today [1934] that part of the hereditary nesting grounds of migratory waterfowl within the United States lies a veritable desert, forsaken by the birds...the vast numbers of potholes and all but the deepest lakes were so dry that miniature whirlwinds of dust raced over their surfaces. Alkali deposits gleamed in the sun. The water-table level sank out of reach of ordinary means of measurement....The sturdy human stock of the prairie lands will endure. Their herds will grow fat again. But can the earlier inhabitants, the winged millions, re-establish themselves in all their former abundance?"

Preble (1935) was a bit more optimistic: "*Sportsmen and naturalists in the fall* [of 1934] were prepared to expect only meager returns from the nesting grounds that still remain in the drought-stricken areas of our northern plains both in the United States and Prairie Provinces, but farther north there are still suitable breeding grounds that offered hope for the future—if an adequate seed stock is maintained."

The northern prairies escaped the worst of the drought until 1937. Furniss (1938) reported on the Prince Albert district in central Saskatchewan:
"... until the late summer of 1936 conditions on the whole were very satisfactory when compared with other points, even though there has been a gradual lowering of water levels during the last fifteen years. The last two summers, exceedingly hot and dry, have dried up breeding sloughs and potholes and any advantage which the district had when compared with other surrounding areas has almost disappeared... water levels reached their lowest ebb in the fifteen years of observation carried on by the writer and in the lifetime experience of the oldest settlers."

Fluctuations of large lakes

Major wet and dry periods are often followed by fluctuations in the levels of large lakes. Taverner (1919) commented on Shoal Lake which is about 50 miles northwest of Winnipeg:
"Shoal Lake was high in 1867 when visited by Gunn, also in 1901 when Chapman and Seton were there. The Wards arrived on its shores about 1889 and Ward, Sr., declared that at that time the lake was low. It is evident from the reports of Arnold and Raine that the water was fairly high in 1894 and the Wards say it reached its maximum about 1899....Mr. Young returned to Shoal Lake the spring of 1918 spending April 23 to October 2 on the same ground we had occupied the previous spring.... Where we had waded thigh deep in the

spring was dry and growing hay....Consequently the ducks and water birds...deserted the vicinity and very few bred in 1918. (Note: Winnipeg recorded its lowest precipitation reading in 1917; its highest in 1898.)...Mr. Seton informed me that Shoal Lake, in common with all in Manitoba, has a fashion of rising and falling in periods of about seven years."

The Manitoba Water Control and Conservation Branch has plotted mean monthly lake levels for Lake Winnipegosis and Lake Manitoba. When record keeping started in 1913, the lakes were unusually high but dropping. Until 1921, they fluctuated moderately around what was later established as the 40-year mean. Sharp rises occurred in the early and late 1920's, mid '30's and late '40's with a 50-year peak in the mid '50's. Troughs occurred in the early '30's, early '40's and early '60's. Lake Manitoba has not been used to gauge important changes in precipitation amounts since 1962, when it was stabilized by a new control structure at Fairford.

Bossenmaier and Marshall (1958) studied Whitewater Lake in southwestern Manitoba and summarized its water levels: "The lake's depth from 1880 to 1910 varied between 4 and 9 feet: maximum known depths occurred consistently from 1900 to 1910. Between 1912 and 1930 the level dropped to the 0-2 range except during 1916 and 1927–28 when heavy precipitation restored depths to near 4 feet. The lake was dry or nearly so during the severe drought between 1930 and 1938. Depths were 2–4 feet from the early 1940's to 1947, and 4–6 feet from 1948 through 1951. In 1952 the level fell again to the 2–4 foot range."

Bossenmaier (1968) furnished further information from his field notes: Low water levels of Whitewater Lake prevailed from 1953 until record fall rain in 1957 raised the lake level about two feet within a few days. Levels rose to a peak in 1960 but dropped sharply in 1961. In 1962 they recovered again and remained fairly constant until 1967 when, at freeze-up, only about two feet remained in the deepest part of the lake. Bossenmaier concluded: "should a drought occur in 1968 of the same severity as experienced in 1967, there is little question but that Whitewater Lake will be completely dry or nearly so in the fall..."

Fluctuations within the Minnedosa district study area

Records from five active weather stations within our 4,100 square mile study block were combined to show precipitation in inches for three periods of the year during the years of our study, 1949–66 (Table 2). During the late summer and early fall period (August 1–October 31), the rainfall averaged 4.97 inches; during the winter months (November 1–March 31) the snowfall equivalent plus rainfall averaged 4.25 inches; during the growing season (April 1–July 31) it averaged 8.75 inches. Thus, for the average year precipitation totalled 17.97 inches. However, for each of the three periods, the spread in inches of precipitation from low to high approached or exceeded the average itself. The spread between the high and low annual total exceeded the annual total of the driest year.

Although the total annual precipitation for the study area over the years averaged about 18.0 inches, there is sometimes for any given year a wide lack of agreement between stations only a few miles apart. Precipitation totals for Minnedosa and Rapid City, only 12 miles apart, frequently differed by 2 to 3 inches per year and in the growing season of one year, differed by 6.7 inches. Even that is not surprising because a cloud burst or hail storm affecting only a few sections of land is not rare on the prairies. Before the time of our study period, in one extreme case (1885) it was abnormally wet in Minnedosa and abnormally dry at Brandon, although the two weather stations were only 26 miles apart. Incidentally, the long term averages from the Minnedosa station are strikingly similar to those for seven stations located within our study area as follows:

Period	7 station average	Minnedosa average*
August 1–October 31	4.94	4.88
November 1–March 31	3.82	3.73
April 1–July 31	8.96	9.08
	17.72	17.69

*The snowfall average of 43.4 inches for Minnedosa compares closely with 45.7 inches for the seven stations together.

Departures of up to 9 inches from the average annual total of about 17.5 inches have been recorded. Thus, the prairies wettest years are comparable to years regarded as normal or dry from Minnesota eastward, while the driest years on the prairies are comparable to those in arid regions.

Examples given above show that it is risky to reconstruct the study area's surface water conditions of the past, based strictly on precipitation records, but the following conclusions seem reasonable:

1) The first year of record, 1881, was one of brim-filled potholes, at least around Minnedosa where more precipitation was measured than for any year since.

2) In contrast, 1889 was a very dry year occurring between a normal and a wet year. Under these conditions, the temporary potholes would disappear and the more permanent type remain. However, a series of dry seasons from 1891 to 1895 undoubtedly resulted in a serious shortage of ponds of all types.

3) Ponds were restored during the good water years at the turn of the century, and gradually diminished toward the end of the first decade of the 1900's.

4) Ponds recovered in 1911, at least in the eastern part of the study area, and fairly normal conditions prevailed until the relatively wet year, 1916. Two drought years followed, causing a decline in pothole numbers and quality.

5) Conditions improved gradually during the early 1920's, but faded again during the latter half of the decade.

6) The drought of the early '30's left its mark on wetland habitat in 1928 and peaked in 1931. Two comparatively wet years

Table 2
Number and size of semi-permanent and temporary potholes from 1949 to 1954.

	Pothole permanency		
	Semi-permanent	Temporary	Total
No. of potholes	67	53	120
Mean size* (acres)	2.8±0.4	0.6±0.1	1.8±0.2

*±standard error of mean.

caused some improvement but 1934 removed these gains.

7) Most of the badly depleted wetlands were probably restored in 1935, a very wet year, but 1936 was dry enough to again deplete the wetlands. There was little improvement until 1941 and 1942. Nearly normal conditions then prevailed, leading into our study period.

The precipitation records for the Minnedosa district support the concept, developed earlier in this report, that gains and losses of wetland habitat through natural causes happen erratically and cannot be predicted very far in advance. During the years analyzed, there are examples of many combinations of wet, dry and normal years. A precipitation condition may prevail over the entire area or differ between stations only a few miles apart. It may last for several years or change from one kind to another and back again over a short span of years.

A landscape almost devoid of ponds in August 1959 changed over winter to one sparkling with water in all its depressions by the following May. A year later, the drought returned and the country was again drab and waterless. We think that an almost identical situation prevailed from 1934 to 1936. Thus, nature can be a quick-change artist with runoff alone controlling the results. There is a close working relationship between soil moisture conditions and runoff. When precipitation is light, surface waters depend on the wetness or dryness of the soil. Parched soils grab the precipitation until saturated, then release any surplus to the water bodies.

Normal rainfall for the district maintains a good balance between the needs of the soils and the ponds. Ponds require above normal precipitation and/or flash-flooding to make maximum use of their storage capacity. Precipitation records reveal when conditions are beneficial or detrimental to the well-being of prairie wetlands, but caution must be used in their interpretation for reasons given above.

The study area and methods

Figure 1. Map of Manitoba showing Minnedosa district in relation to province.

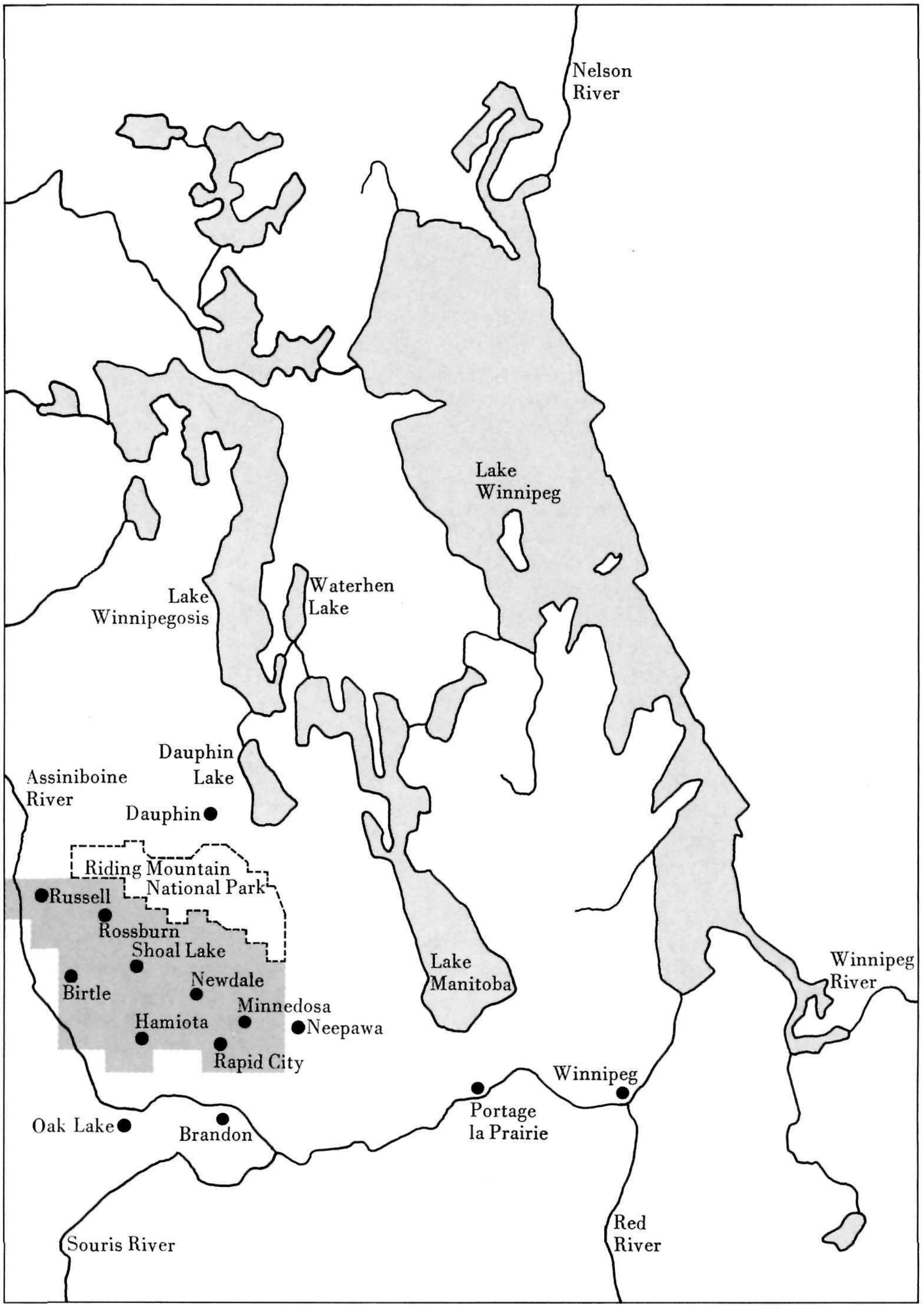
The study area

Our study area, the Minnedosa district, lies largely south of Riding Mountain National Park. It is bounded roughly on the south and west by the Assiniboine River, and on the east by the escarpment between the first and second prairie steppes. A straight line drawn from northwest to southeast through the district would pass near the towns of Russell, Shoal Lake and Minnedosa (Fig. 1).

Minnedosa's outstanding waterfowl production was recognized in early systematic waterfowl surveys (Hawkins, 1948; Hawkins and Cooch, 1948). Whereas waterfowl biologists widely call the 4,100-square-mile district the "Minnedosa pothole country", in waterfowl investigation reports the area is often called the Newdale-Erickson district because of its predominant Newdale-Erickson clay loam soil associations (Hawkins and Cooch, 1948; Kiel, 1949). Since 1947, studies of waterfowl and their habitat have been supported and conducted in the district by many organizations, including the Manitoba Game Branch, Delta Waterfowl Research Station, Wildlife Management Institute, Canadian Wildlife Service, U.S. Fish and Wildlife Service and several North American universities.

The soils of the Minnedosa district are in the northern black earth and degrading northern black earth zone described by Ellis (1938). These soils developed on glacial till and have a high natural fertility. The northern black earth soil zone lies between the 1,550 and the 1,900-foot contours. The Newdale soil association which comprises most of the Minnedosa district has a higher agricultural potential than the Erickson association in the northern and northeastern portions of the district. Northern black earth soils grade into grey-black and grey-wooded soils toward the northern boundary of the district near Riding Mountain National Park. Aspens grow more densely in the northern portion where soils are often quite stony. Because of the undulating topography, both soil associations are subject to water erosion.

Figure 1



The Canada Land Inventory, a co-operative federal–provincial program administered under the Agricultural Rehabilitation and Development Act (ARDA) of 1961, has classified the soils of this district on the basis of their agricultural capability (Ehrlich *et al.*, 1966). Soils of the Newdale association, which occupy at least three-fourths of the district, are largely in two capability classes: about 70 percent are class 2 soils (moderate limitations restrict the crop range or require moderate conservation practices); about 30 percent are class 6 soils (capable only of producing perennial forage crops, and improvement practices unfeasible). The chief agricultural limitation for class 2 soils is adverse topography and, for class 6 soils, excess water.

The remaining one-fourth of the Minnedosa district in the Erickson clay loam association along the northern boundary is divided into five classes with characteristics ranging from moderately severe agricultural limitations requiring special conservation practices, to soils with no agricultural capability. The chief limitations of all Erickson association soils are adverse topography, excess water, and to a lesser degree, adverse soil characteristics. Organic soils in this area are not placed in a capability class.

The climate of the Minnedosa district is described by Ehrlich *et al.*, (1966):

"The mean temperature for June to August is about 62°F, and for December to February, about 1°F. The average frost-free period, above 32°F., for the different districts varies from 85 to 100 days and the growing season averages more than 150 days....

"Precipitation is fairly uniform over the area, averaging about 17.5 inches annually; rainfall efficiency, however, increases from west to east and north. Approximately 75 percent of the precipitation falls as rain during the summer and the remainder as snow during November to March."

The study area is in the eastern part of the aspen parklands where the aspen groves, locally called "bluffs", and grasslands intermingle (Fig. 2). This transition zone between the prairies on the south and the coniferous forest on the north stretches from northwestern Minnesota northwestward to near Edmonton, Alberta (Bird, 1930; Rowe, 1959; Shelford, 1963).

The fertile soils of the Minnedosa district are used for cultivated crops and for grazing. On the basis of acreage planted in recent years, wheat was the most important crop, followed by oats, hay, barley, flax, mixed grains, rye and rapeseed. Cattle, the most important class of livestock, outnumbered sheep by 15 to 1. Land holdings averaged about 530 acres per owner (Ehrlich *et al.*, 1966).

The undulating land has numerous water areas in the depressions called sloughs or potholes. Such topography is the result of movements of continental ice sheets during the glacial period (Ellis, 1938). Size and permanence of the water areas tend to increase toward the northern portion of the Minnedosa district. This district has above average waterfowl habitat in terms of size and permanency of its potholes compared to the remainder of Manitoba's pothole region (Hawkins and Cooch, 1948; Kiel, 1955).

The Minnedosa district provides good habitat for upland game birds, including sharp-tailed grouse, ruffed grouse and Hungarian partridge. White-tailed deer are common throughout the area, and elk and black bear are found in the northern portion. Muskrats, an important fur-bearer, are abundant in the more permanent water areas of the district (Manitoba Game Branch, 1961).

Methods

After an abrupt unforeseen decline in waterfowl numbers in the mid-1940's, better methods of measuring breeding population trends were investigated (Sowls, 1947; Smith and Hawkins, 1948; Hawkins, 1948). Systems of ground and aerial transects and block study areas were developed, some of the earliest ones in the Minnedosa district.

Roadside transects

For our study, in April 1949 we established 12 ground transects in the Minnedosa district. In selecting the transects, we considered both ability of roads to withstand most weather conditions and road distribution, to ensure sampling of the various habitat types within the district (Kiel, 1949). Each transect had 100 well-defined basins at that time containing water and visible from the road. Temporary field puddles were not included. The length of a transect was determined by the density of water areas visible from the road. All transects were ¼ mile wide, the sum of two strips ⅛ mile wide on each side of the road allowance. Altogether the 12 transects extended slightly over 200 miles and included 50.4 square miles of habitat (Fig. 3). Several transects established at the same time by the Manitoba Game Branch provided valuable supplementary information.

Potholes for intensive study

We randomly selected 120 potholes—10 along each transect—for more intensive study in breeding and production surveys. Vegetative cover maps were prepared for measuring quantitative changes in vegetation and land use. Water levels were checked, and some photographic stations established.

Study blocks

In 1949, adjacent to existing transects, we established nine 160-acre study units which were periodically surveyed to test the representativeness of roadside transects.

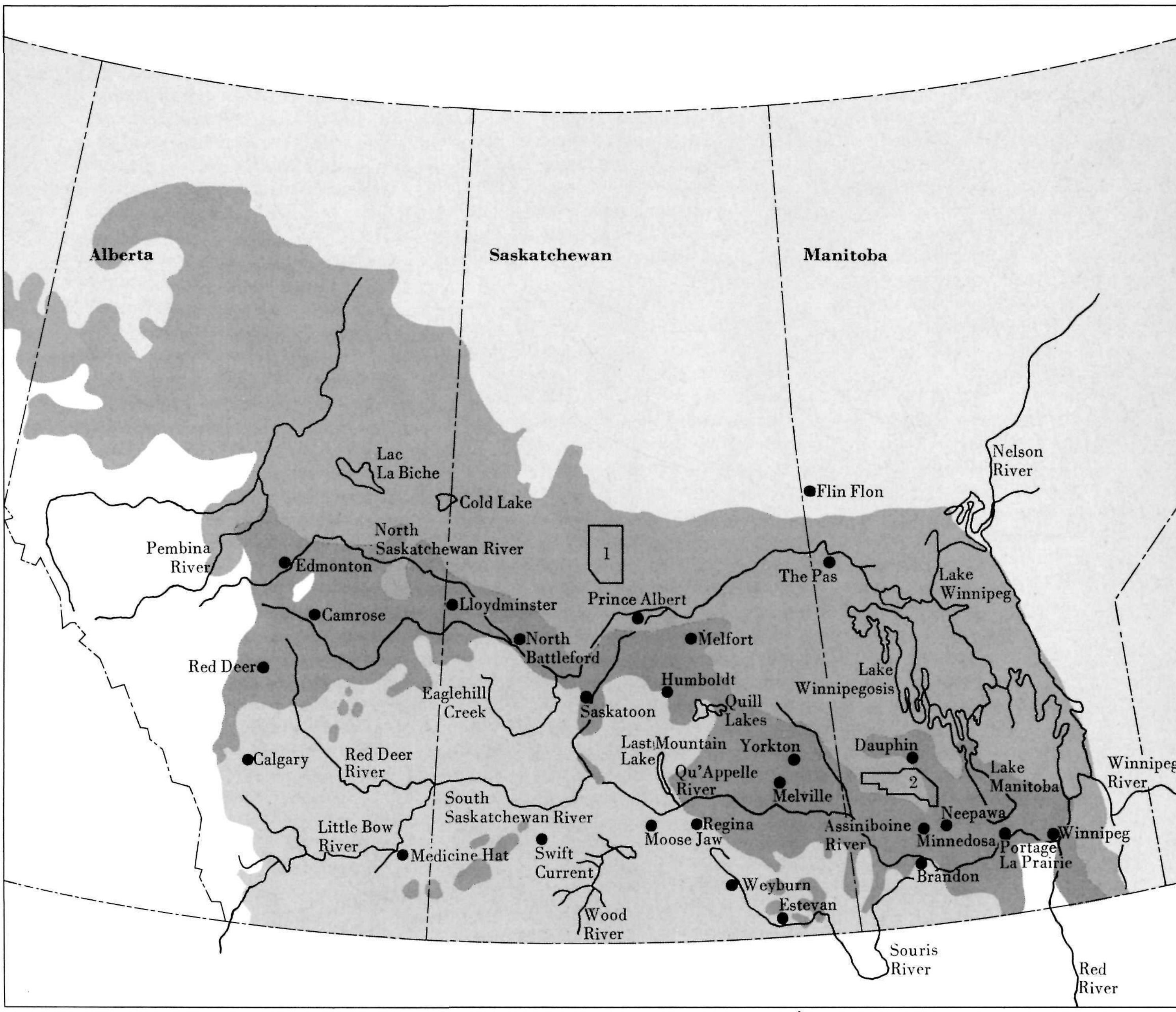
Other tests of possible road influences on ground transects were studied in 1947–49. Comparison of waterfowl densities obtained by aerial surveys with those found on roadside transects in a 100-square-mile block south of Minnedosa showed that duck density along roads compared to that in the block as a whole (Smith and Hawkins, 1948). Habitat conditions of the 100-square-mile area were studied intensively from 1956 to 1959.

Aerial photographs

At the end of the first World War, the RCAF, then called the Royal Flying Corps, began

Figure 2. The aspen parkland (from Rowe, 1959).

Figure 2



Aspen parklands, which include the western aspen grove section and the eastern aspen oak section (Rowe, 1959).

Grasslands.

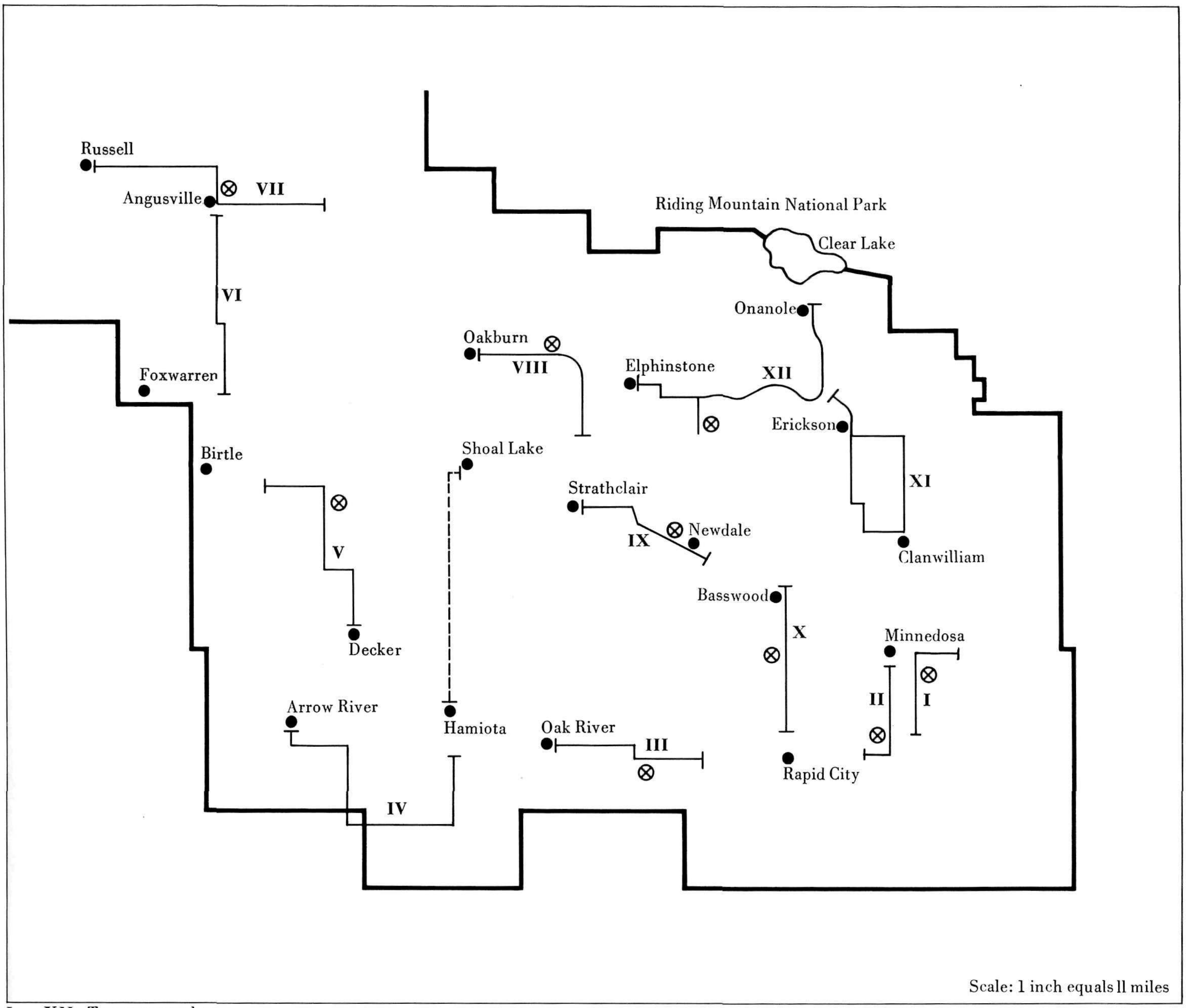
Mixedwoods. Transition between the aspen parklands and the coniferous forest to the north. The association is a mixture of deciduous and coniferous trees.

Coniferous forests.

1 Prince Albert National Park
2 Riding Mountain National Park

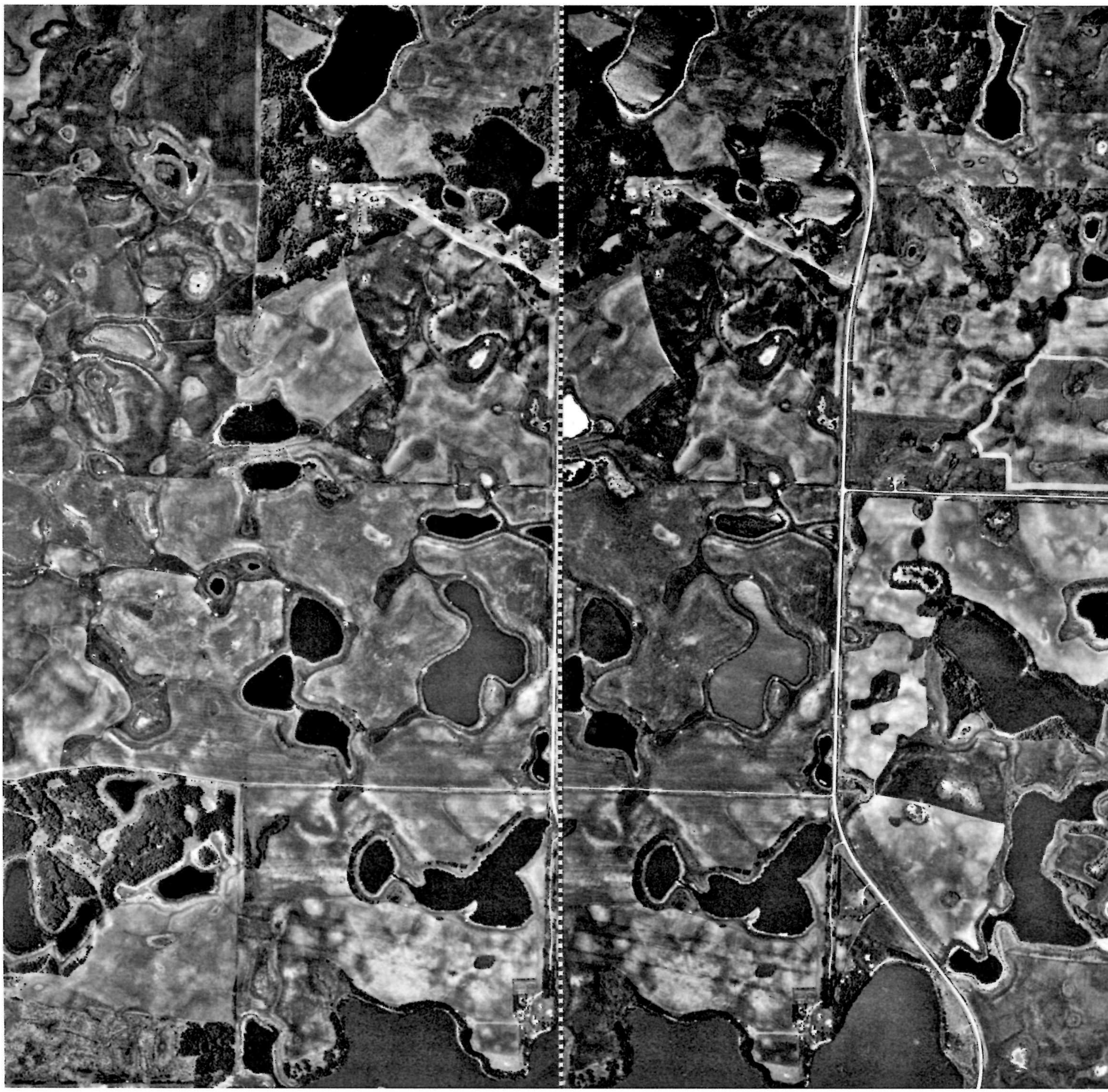
Figure 3. Minnedosa district.

Figure 3

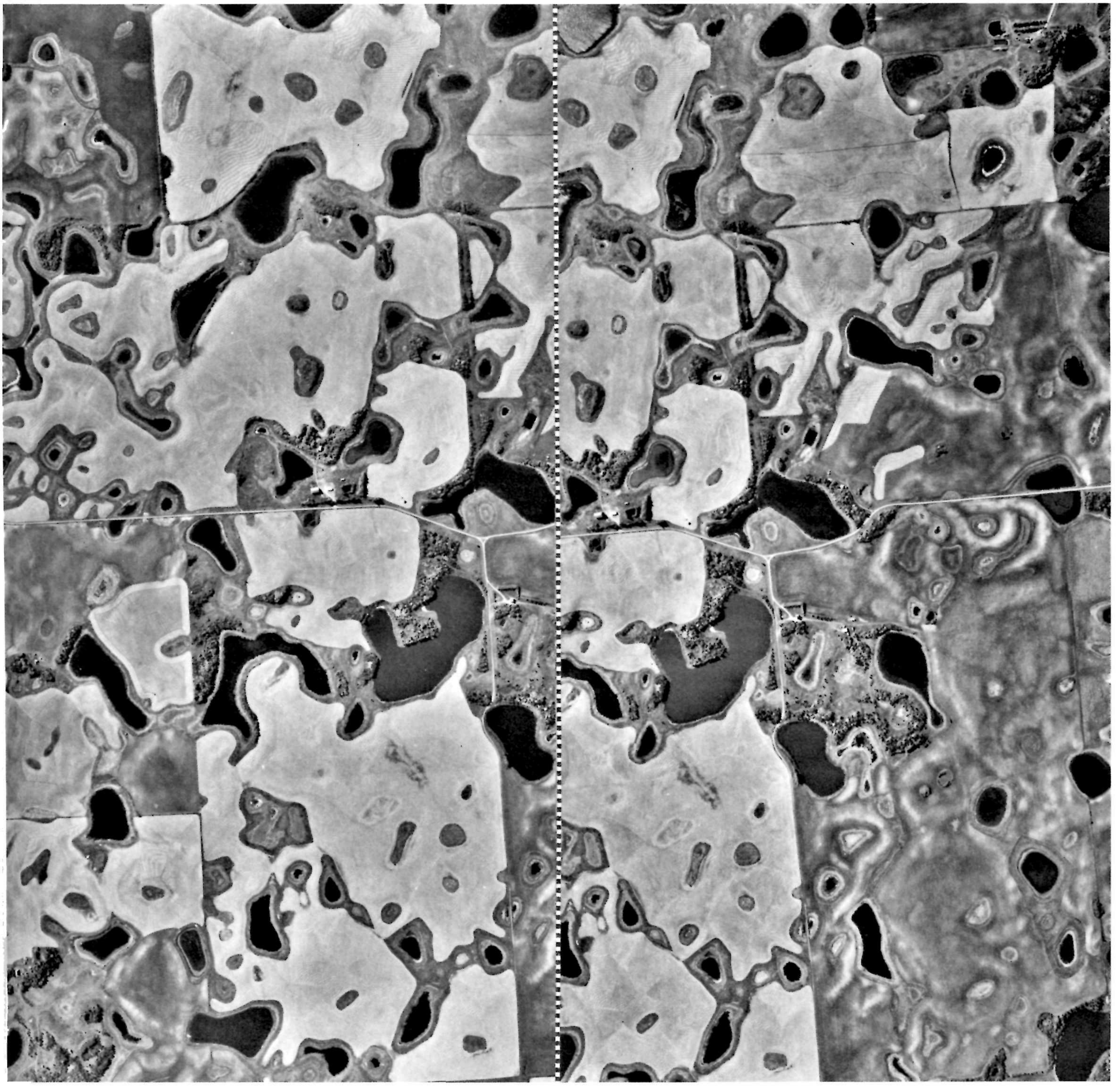


I . . . XII Transect number
Study transect
Manitoba game and fisheries branch transect
⊗ Quarter section study blocks

The northern portion of the Minnedosa district is characterized by steeply rolling terrain with a high preponderance of large permanent water bodies. This stereopair shows that type of habitat immediately south of Riding Mountain National Park.



Gently rolling terrain with small potholes is characteristic of the southern portion of the district. This stereopair shows habitat in the heart of the pothole country south of Minnedosa.



Two types of temporary ponds.
Upper. A slight depression holding sheet water in the spring will dry up in late spring, in a normal year, in time to be cultivated.

Lower. This pond will dry up in early summer, in a normal year, too late to be cultivated. In a dry year it will dry up in time to be cultivated and planted.

Upper. Sedge-whitetop pond. The inner zone of vegetation is whitetop, the outer zones are sedges.

Lower. Bulrush pond. In this pond the inner sedge zone is surrounded by a narrow fringe of cattail.

developing and refining aerial photography for mapping vast areas of Canada. The resulting photographs were catalogued and stored in the National Airphoto Library, established in the mid 1920's, where all aerial photographs taken by the original and subsequent surveys were also catalogued and stored. This source was used to find out how the area looked before our study, and how it changed in the intervening years.

Stereo photographs of the study area, at a scale of 1 inch to 1,320 feet, were available for the years 1928–30, 1946, 1948, 1958, 1962 and 1964. Complete coverage was available for all transects in 1948 and 1964, and partial coverage for the other years. To distinguish man-made and natural features in the photographs we relied upon form, pattern, color tone and shadows. We used a mirror stereoscope with 4-power oculars to pick out details and delineate the various features.

Water areas and types of land use were delineated within transect boundaries ⅛ mile on each side of the road allowance drawn on the aerial photographs. The following categories were used: a) Cultivated and cleared land. This category included all cultivated fields and other cleared land. b) Woodlots and bushland. This category included woodlots or bluffs, forested areas and uncultivated bushlands. c) Wetland. Wetlands included all basins with water as well as dry basins that were not cultivated and showed indications of having held water in past years.

Areas of the various categories were obtained by using a number 91-dot grid overlay, each dot representing ½ acre on the photographs. Wetlands smaller than ½ acre were counted and the size estimated. To compensate for slight differences in scale between photographs the area of each 1-mile transect section was adjusted in proportion to the scale of the photograph.

Pothole classification

Potholes were classified according to size, water permanency and vegetative type

Upper. Wooded pond. Typical of wooded ponds is the fringe of willows with some aspen on the outer edge. This photograph taken in the spring shows high water extending beyond the willow fringe.

Lower. Typical small cattail pond. An almost pure stand of cattail surrounds the shallow pond.

(Kiel, 1955). Pothole size in acres was determined on the site by pacing and estimating distances. Marginal zones of emergent aquatic plants such as rushes, sedges and whitetop were included in the pothole areas. Wild barley, commonly found just outside these zones, was not included. Pothole size as described above changes appreciably in response to wet or dry periods.

There are several systems for describing permanency of small water areas, and descriptive terminology varies considerably (Martin, Hotchkiss, Uhler and Bourn, 1953; Lynch, Evans and Conover, 1963; Evans, Hawkins and Marshall, 1952). We used the permanency rating system described by Bach (1951) for North Dakota. Its categories are: *permanent*—small lakes with wave-swept shores and having emergent aquatic vegetation only near the shoreline; *semi-permanent*—potholes retaining water except during drought periods, usually over 2 feet deep in the spring; *temporary*—potholes drying up by July-August of a normal year; and *runoff puddles* or sheet water—resulting from melting snow or heavy rains, short-lived and without aquatic vegetation. Similar terminology was used recently by Smith, Stoudt and Gollop (1964) to describe the prairie pothole region of North America and is in current use by the Canada Land Inventory (Perret, 1969). Man-made "dug-outs" or stock tanks are a separate class occurring as distinct water areas or at the edge of potholes of the above permanency ratings.

Five broad vegetative types were recognized: sedge-whitetop, cattail, bulrush, willow and spike rush. These types include several other species of aquatics occurring in less dense stands. Acreages of the vegetative cover types were plotted on maps of the 120 potholes selected for intensive study, and submerged vegetation was noted

Habitat—its changing nature

Conditions in the late 1940's

When we began intensive study of the Minnedosa district in April 1949, we did not know whether pothole water levels were normal, or above or below average. Historical evidence and records during the 1949–64 study period show that frequent major fluctuations in water levels are common. We later discovered that 1949 had slightly better than normal water conditions, if the term "normal" can be applied.

In 1949, there were an estimated 2,400 potholes on the transects, a density of 48 potholes per square mile, according to aerial photographs taken of the 50.4 square miles in the 12 transects. Of the 120 potholes selected for more intensive study, 56 percent were classified as semi-permanent and 44 percent as temporary (Table 2). In Table 2, the pothole sizes determined from 1949 to 1954 vary with major water level fluctuations. Road building and drainage activities subsequently caused some permanent changes in pothole size during the course of the study.

For the whole prairie region Smith, Stoudt and Gollop (1964) reported an average of 30 potholes per square mile in a normal year. Maximum densities of 120 potholes or more per square mile were reported for portions of southeastern Saskatchewan by Lynch, Evans and Conover (1963). Ponds in that sector, however, are generally less than 1 acre in size and largely in the temporary class. The Minnedosa district, therefore, is above average in density and permanence of water areas.

A variety of vegetation in a Minnedosa pothole is the rule rather than the exception. Among the more abundant emergent aquatic plants are sedge, whitetop, cattail, willow, bulrush and spike rush. The submerged aquatics include bladderwort, milfoil, duckweeds, pondweeds, water crowfoot and muskgrass (Bird, 1930, 1961; Evans, Hawkins and Marshall, 1952). Plants of the same species frequently occur in rather well defined zones, apparently dependent largely on water depth. In many other instances, species are intermixed.

Table 3
Vegetative classification of potholes from 1949 to 1954.

	Permanency class					
	Semi-permanent		Temporary		Total by type	
Vegetative type	No.	%	No.	%	No.	%
Sedge-whitetop	42	63	48	91	90	75
Cattail	17	25	0		17	14
Willow	6	9	5	9	11	9
Bulrush	2	3	0		2	2
Total potholes	67	100	53	100	120	100

Table 4
Potholes having aspen and/or willow rims, from 1949 to 1954.

	Permanency class					
Type of	Semi-permanent		Temporary		Total by type	
pothole margin	No.	%	No.	%	No.	%
0–50% rimmed	50	75	29	55	79	66
51–75% rimmed	9	13	11	21	20	17
76–100% rimmed	8	12	13	24	21	17
	67	100	53	100	120	100

The study potholes were classified from 1949 to 1954 on the basis of major emergent aquatic plants (Table 3). If there was more cattail in a pothole than any other type of vegetation, it was classified as a cattail type. Sedge-whitetop was the most abundant vegetative type in 75 percent of the water areas. Cattail, willow or bulrush was the major vegetation in only 25 percent of the potholes. But comparatively small stands of these plants in sedge-whitetop potholes often provided the most intensively used nesting cover (Kiel, 1955).

Due to the influence of major water level fluctuations on the relative order of aquatic plant abundance, pothole vegetative type is not a constant. The classification determined during the relatively stable 1949–54 period (Table 3) changed as established by surveys of the Minnedosa district in 1960 and 1964.

In addition to plants growing in the water, marginal vegetation, chiefly consisting of willows and aspen, can influence the ecology of the water area. The degree to which pothole margins were rimmed by aspen and/or willow was recorded during the 1949–54 period (Table 4). Aspen and/or willow rimmed less than one-half of the margin of two-thirds of the 120 study potholes. Woody vegetation rimmed more than one-half of the margins of 25 percent of the semi-permanent and 45 percent of the temporary potholes. During the 1949–54 period farmers sometimes cleared this woody vegetation around potholes and often deposited the debris in the pothole during dry periods. Subsequent surveys show great increases in such activities.

Natural changes—late 1940's to mid 1960's

General habitat conditions

One measure of changes in waterfowl habitat is the percentage of potholes that dry up within the nesting and brooding period. Table 5 shows major changes in water levels and vegetative cover in potholes in relation to crop-year precipitation. Water levels described are those throughout the nesting and brooding season. Summer rains sometimes replenished water supplies in potholes that were dry earlier in the season. The descriptive term, normal, is difficult to define in relation to almost constantly changing water levels. For our purpose, the following definitions were applied: Above normal—few temporary potholes dry by late summer. Normal—most temporary potholes dry or practically dry by late summer. Below normal to semi-drought—all temporary and a few semi-permanent potholes dry by late summer. Drought—all temporary and substantial numbers of semi-permanent potholes dry by late summer.

Terms describing the condition of emergent aquatic plants including cattail, bulrush, sedge, whitetop and spike rush refer both to old or residual growth remaining from the previous growing season and new growth of the current year. Residual emergent vegetation is heavily used by overwater nesting waterfowl, particularly early nesting species such as canvasbacks, redheads and coots.

Water conditions during the 6 years from 1949 through 1954 varied measurably but were relatively stable compared to the extreme fluctuations during the following ten years (Table 5). Four years had above normal crop-year(Aug. 1–July 31) precipitation (Fig. 4 and Tables 5 and 6). In only 1 year of the 1949–54 period, 1952, did a semi-permanent pothole dry up by July 25, roughly the date of the normal peak of the brood season. In 1952, water levels were so low that emergent aquatic plants such as cattail and bulrush were damaged by the common practice of burning edge vegetation of potholes. The semi-drought conditions in 1952 followed two successive crop years with below normal precipitation, 4.2 inches below the normal of 17.7 inches in 1951 and 4.3 inches below in 1952.

A general increase in water levels in 1954 in the Minnedosa district reached a peak in 1956. This increase coincided with four successive crop years of above average precipitation, beginning in 1953 and reaching a peak of 24.7 inches in 1956 (Fig. 4). Water rose to such high levels that it destroyed normal zones of emergent aquatic plants in most potholes (Table 5). As water levels rose, many normally separate potholes

Table 5
General habitat conditions, Minnedosa district, from 1949 to 1964.

	Crop-year Precipitation (inches)*	120 study potholes–percent dry by			General habitat conditions	
		May 31	July 25	Sept. 1	Water level throughout nesting and brooding season	Emergent aquatic plants
1949	20.15	0	0	26	Normal or above	Normal growth
1950	18.92	0	0	3	Above normal	Normal growth
1951	13.51	2	19	40	Normal	Normal growth
1952	13.45	20	45	†	Semi-drought	Some potholes with mud flats exposed between water and zone of emergent plants
1953	21.19	0	0		Normal or above	Normal growth
1954	19.55	6	2	12	Above normal	Normal growth
1955	21.53				Above normal	Stands of emergent plants being destroyed by high water; delayed new growth
1956	24.73				Above normal	Continued destruction of emergents by high water; new growth forming emergent plant zone at higher water level
1957	15.93				Normal but receding	Normal to sparse growth
1958	12.43				Below normal	Most potholes with mud flats exposed between water and zone of emergent plants
1959	13.91	25	67		Drought	Most potholes with mud flats exposed between water and zone of emergent plants; further reduction of over-water nesting cover
1960	20.12		29		Highly variable; above normal to below normal	Old emergent cover sparse; current-season growth very dense
1961	12.09		75		Drought	Most potholes with mud flats exposed between water and zone of emergent plants
1962	18.01		38		Below normal	Old emergent cover sparse; dense current-season growth
1963	22.46				Normal or below	Normal growth
1964	19.20		34		Normal	Normal growth

*See Table 6 and Figure 4 for additional precipitation data
†No data available

joined one or more others to form one larger water area. Depth increased to such an extent that one typical sedge-whitetop slough, never deeper than 4 or 5 feet in previous years, changed in 1957 to a "lake" 8 feet deep, and was used by the Canadian Wildlife Service to rear yellow walleye.

Such unusually high water levels did not persist for long. By late summer of 1957, water was receding rapidly. The drying trend accelerated in 1958, and by 1959, drought conditions prevailed. The rapid decline in water levels over three successive years left newly formed high-level zones of

Table 6
Precipitation (inches) by periods of the crop year. Minnedosa district, from 1949 to1966. Based on stations at Birtle, Hamiota, Neepawa, Rivers and Russell (analysis of weather records).

Crop year*	Aug. 1– Oct. 31	Nov. 1– March 31	April 1– July 31	Crop-year total
1949	4.21	4.13	11.81	20.15
1950	3.31	3.60	12.01	18.92
1951	3.95	3.49	6.07	13.51
1952	4.63	2.49	6.33	13.45
1953	6.44	4.41	10.34	21.19
1954	4.56	3.82	11.17	19.55
1955	7.27	4.25	10.01	21.53
1956	4.77	8.12	11.84	24.73
1957	3.51	4.19	8.23	15.93
1958	5.60	2.85	3.98	12.43
1959	3.81	3.65	6.45	13.91
1960	8.78	3.78	7.56	20.12
1961	3.82	3.39	4.88	12.09
1962	4.03	5.66	8.32	18.01
1963	6.51	4.02	11.93	22.46
1964	4.29	5.59	9.32	19.20
1965	3.27	4.79	10.34	18.40
1966	6.71	4.30	6.86	17.87
Avg.	4.97	4.25	8.75	17.97†

*Crop year begins Aug. 1 of previous year and ends July 31 of year shown.
†Normal is 17.7 inches based on 1936–60 records.

emergent aquatic plants without water in most potholes. Of the 120 study potholes, all of the temporary and 40 percent of the semi-permanent areas were dry by July 25, 1959. Water levels were at their lowest point for the past quarter-century in the Minnedosa district.

Perret (1962) observed similar changes in the 100-square-mile study block from 1956 to 1959. All depressions were full of water early in 1957, but levels began to recede in late summer. Spring runoff and rains replenished the basins early in 1958, but water levels did not hold up and by the beginning of August, 52% of the depressions were dry. The summer of 1959 was similar except that some basins were dry in the spring, and by August 80% were dry, including some classified as permanent during normal years. But, some temporary or semi-permanent water areas with a known history of drying up were greatly enlarged during the wet period and retained water during the 1959 drought.

Although highly variable, ranging from above to below normal, water conditions in 1960 improved considerably. Precipitation for the crop year was 2.4 inches above normal, and current season growth of emergent aquatics was extremely dense. Recovery was temporary, however, and drought conditions prevailed again in 1961 when all of the temporary and 55 percent of the semi-permanent study potholes were dry by July 25. In 1961, the driest year of our study, a deficit of 5.6 inches followed the single crop year of above-normal precipitation. Again, a wide expanse of mud flat separated emergent plants from the water in most wet potholes. Three years of above average precipitation followed the drought of 1961, and water levels gradually improved until they were approximately normal by 1964, continuing through 1965 and 1966.

Pothole water levels are highly sensitive to precipitation variations. Deviations of 20 percent or more from normal precipitation noticeably change pothole habitat, and the changes are accentuated by two or more successive years of above or below normal precipitation.

Despite habitat deterioration in the drought years of 1959 and 1961, the Minnedosa district contained some of the best remaining waterfowl habitat in the entire prairie pothole region. It attracted ducks displaced from drier areas although its potential for providing habitat for successful waterfowl reproduction was far below normal.

Trends in overwater nesting cover

Vegetative cover maps of the 120 potholes provided the basis for acreage estimates of emergent aquatic plants in four years, 1949, 1954, 1960 and 1964. Figure 5 illustrates changes that occurred during the four survey periods. The total combined acreage of emergent plants and open water varies slightly between survey periods because of changes in pothole size due to major water level fluctuations and drainage and filling activities.

From 1949 to 1954, a period of relatively stable water levels, there was some increase in cattail and sedge-whitetop cover and slight declines in open water and the bulrush,willow and spike rush types. No detailed surveys were made on the 120 study potholes during the high-water years of 1955 and 1956 nor during the following three years of declining water levels, but during the abnormally wet years in the 100-square-mile block south of Minnedosa Perret (1962) observed large-scale destruction of emergent plants by high water. When pond water levels increased in 1955, deeper water surrounded the stands of emergent vegetation, such as cattail and bulrush, and they began dying out, whereas shoreline associations of whitetop and sedge flourished under the new conditions. By 1956 flooded cattails

Figure 4. Crop year* precipitation, Minnedosa district from 1949 to 1966. Average of 5 stations—Birtle, Hamiota, Neepawa, Rivers and Russell.

Figure 4

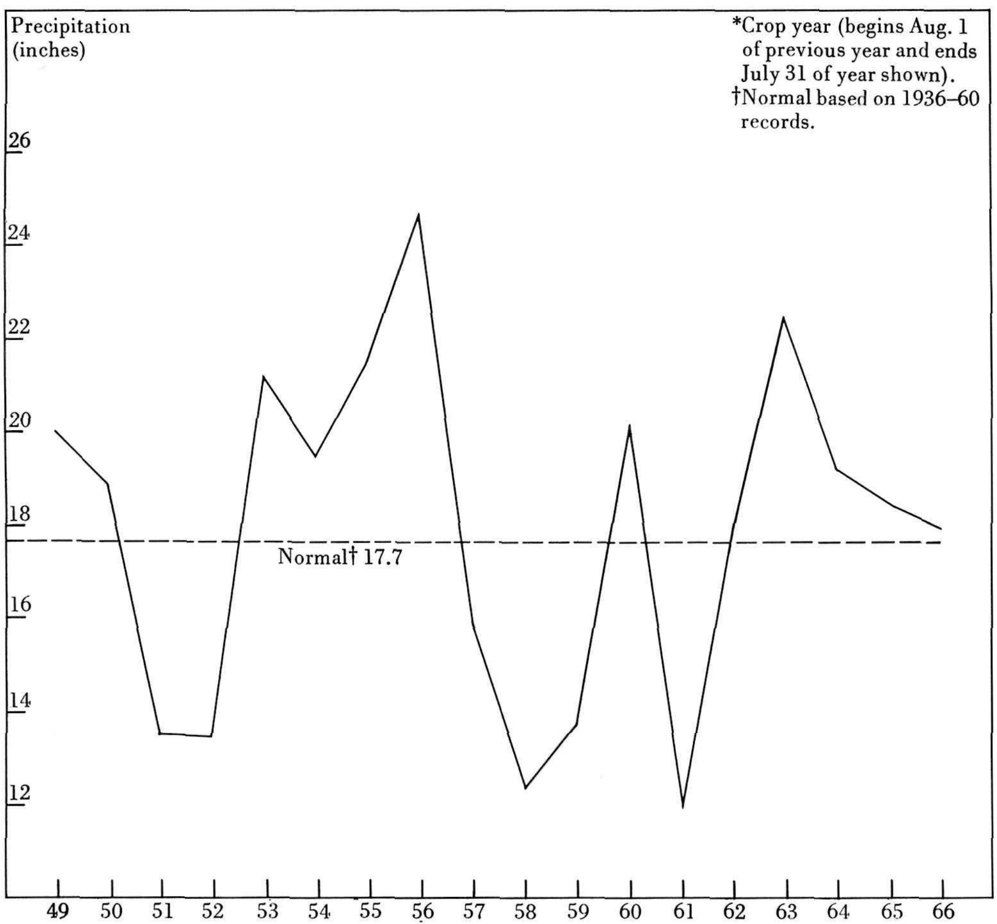


Table 7
Vegetative class of 2,000 ponds in the 100-square-mile study block, 1957 and 1959.

	Vegetative class				
Year	Sedge-whitetop	Cattail	Bulrush	Spike rush	Denuded
1957	44%	15%	15%	26%	
1959	19%	4%	7%		70%

began disappearing and the old shoreline whitetop zone began its decline. The trend continued in 1957, and by the spring of 1958 emergent vegetation had disappeared from most ponds, only a narrow band of whitetop and sedge remaining along the water's edge. Thus the water receded in 1959 exposing bare mud flats, and very little overwater nesting or brood cover was present (Table 7). The spike rush association was so far removed from the water's edge that the zone was included in the denuded category. Seedlings of whitetop, sedge and bulrush invaded the mud flats by late summer, laying the ground for recovery with the return of near normal water conditions in 1960.

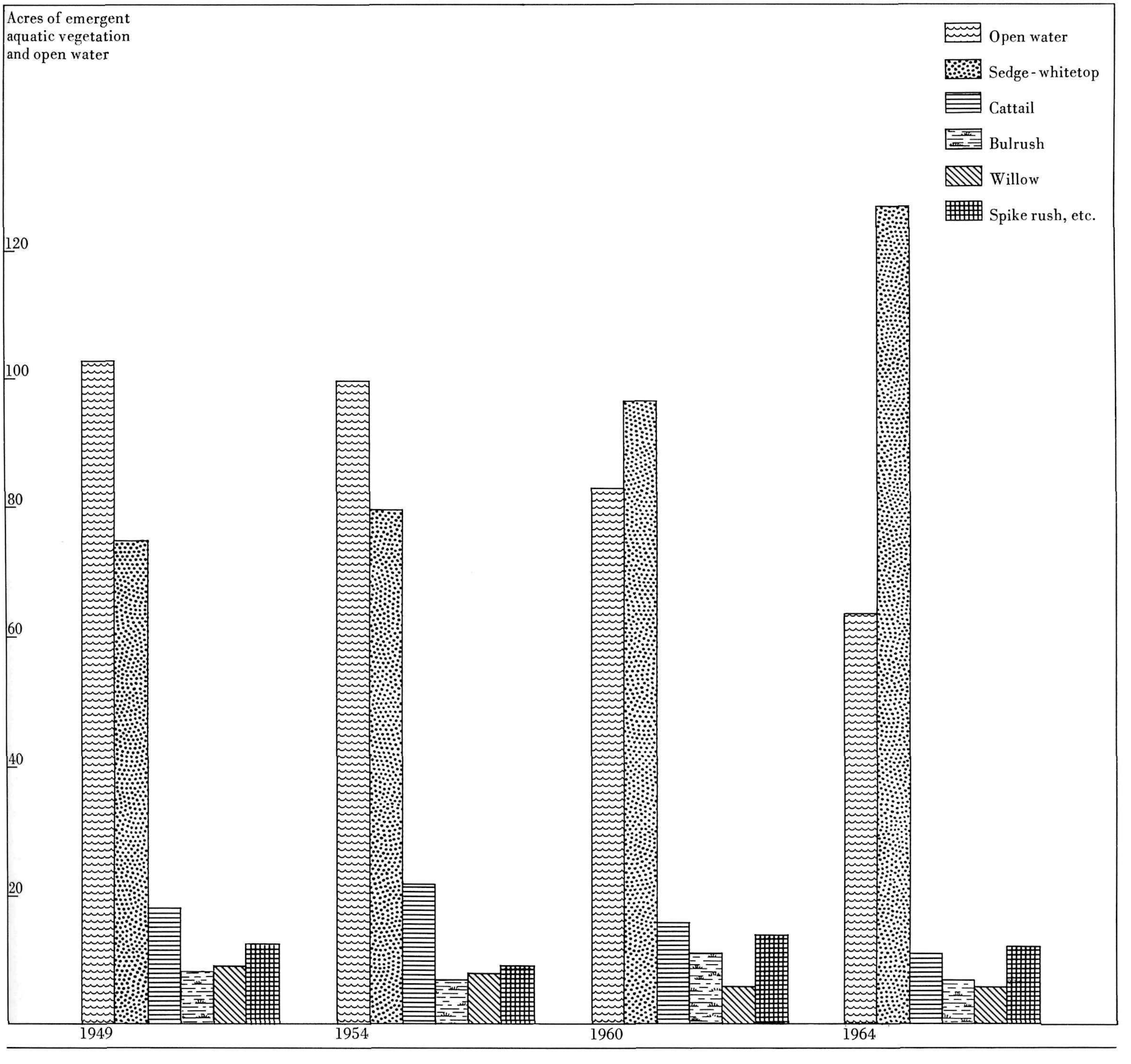
The 1960 survey of the 120 study potholes, when water levels ranged widely from above to below normal, revealed a profuse current-season growth of sedge-whitetop in potholes recovering from the drought. Open water, cattail and willow declined in acreage from 1954, and sedge, whitetop, bulrush and spike rush increased. After 1961, another dry year in which emergent plants were separated from the receding water by mud-flats, general moisture conditions improved gradually until 1964. In that year of normal water conditions, sedge-whitetop again grew profusely, the whitetop often reaching shoulder-height in the potholes. It was the only vegetative type whose acreage increased over 1960. Acreage of open water had declined in 1964.

In summary, sedge-whitetop increased acreage in each survey since 1949; was 68 percent more abundant in 1964 than in 1949. Cattail increased from 1949 to 1954, then declined in the following two surveys and was about one-half as abundant in 1964 as in 1954. Bulrush remained fairly constant except in 1960 when it was 63 percent above the level of 1954 or 1964. Willow declined gradually in acreage, due principally to flooding, bulldozing and burning. Spike rush remained relatively stable; lowest acreage was recorded in 1954.

However, acreages of vegetation and open water were not measured during the high-water period of 1955 – 56 and the drought conditions of 1959 and 1961. Perret observed a drastic reduction of all types of emergent vegetation as water levels reached their highest level in 1956 and declined to drought conditions in 1959. Changes recorded in 1960 and 1964 reflect the influences of those major water level fluctuations on emergent vegetation. From 1949 through 1954, a period of relatively stable water levels, the 120 study potholes were checked yearly for vegetative changes and showed an uninterrupted trend in abundance of emergent aquatics (Fig. 5).

Figure 5. Trends in overwater nesting cover from 1949 to 1964 (120 potholes).

Figure 5

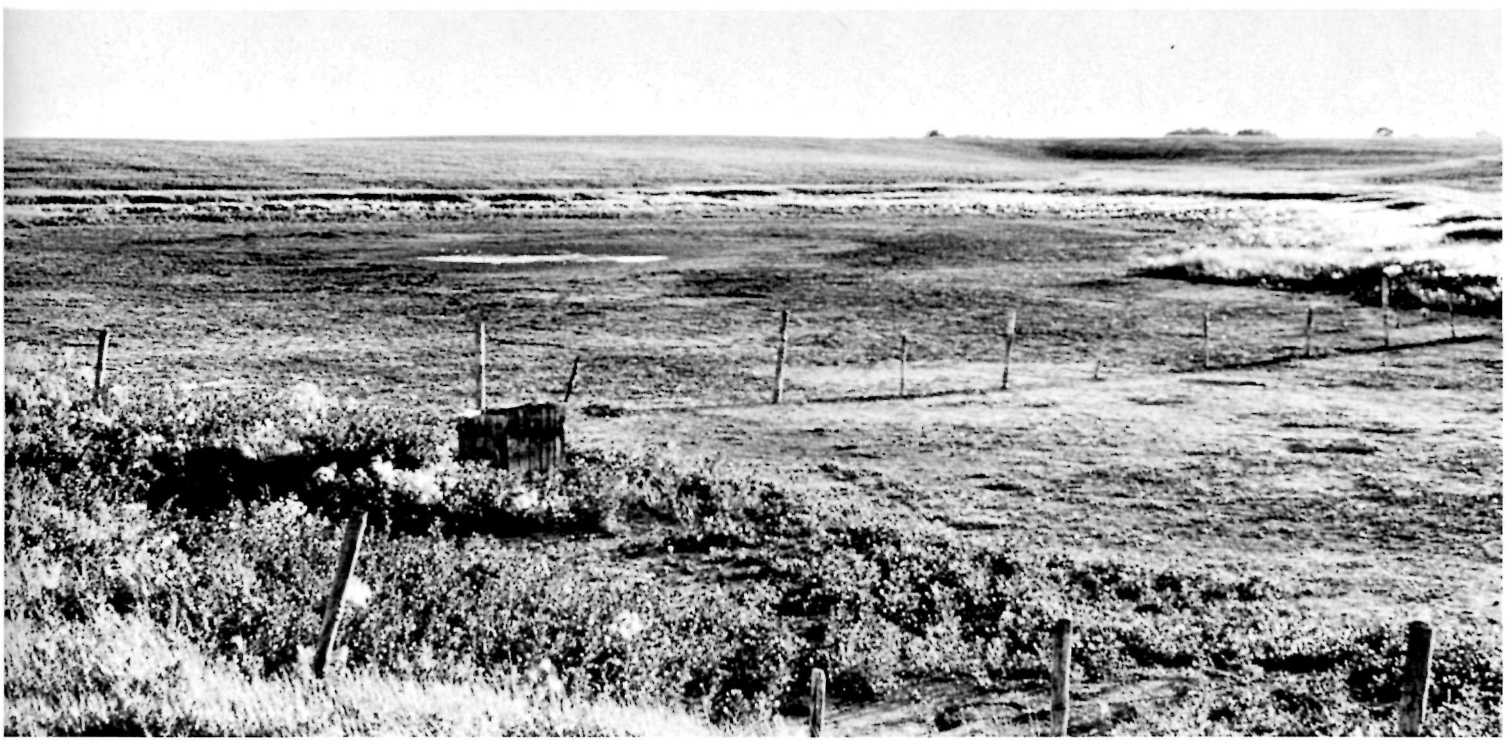


Upper. Typical sedge-whitetop pond during a normal year. A thriving plant community surrounds the pond providing excellent habitat conditions for waterfowl.

Lower. After two years of high water levels the sedge-whitetop community has disappeared. The wooden structure in the water is a well casing put in the basin when it was dry during the drought years.

Upper. The pond began to dry early in the summer of 1959. No vegetation remains along the water's edge.

Lower. By July 1959 the pond is almost dry and marsh ragwort is invading the basin. The well casing now suits its surroundings.



Semi-permanent ponds.
Upper. Sedge-whitetop pond photographed during a normal year.

Lower. Cattail pond photographed during a high water year. The ponds depicted in both photos are valuable for waterfowl production and will retain water except during drought.

Throughout the abnormally wet years that followed, practically the only potholes with nearly normal zones of emergent aquatics were those with natural outlets which prevented water rising much above normal levels. There was proportionally more open water in the very wet years and also in the drought period when new high-level emergent plant zones were left high and dry by the receding water.

In the Minnedosa district sedge-whitetop was by far the most abundant emergent vegetative type, comprising from one and one-half to more than three times the acreage of all other types combined during the four surveys. Cattail, spike rush, bulrush and willow followed in order of abundance. Despite their smaller acreage, cattail and bulrush provide important nesting cover for several waterfowl species. All emergent aquatics, including cattail and bulrush, have some value as nesting cover; they also provide escape cover for adults and broods, and enhance production of aquatic invertebrate animals important as waterfowl food.

Potholes in wet and dry years

Duck populations in the prairie pothole region rise and fall in almost direct proportion to the abundance or scarcity of surface water (Smith, Stoudt and Gollop, 1964; Leitch, 1964). In unusually wet years, even the numerous small water areas classed as run-off puddles or sheet water without definite basins produce ducks (Lynch, Evans and Conover, 1963). Therein lies some of the explosive potential for high duck production on the prairies of Canada. Even in years of more normal water conditions, waterfowl use the short-lived puddles intensively early in the nesting season. The value of the more permanent potholes, once these ephemeral water areas dry up, is evident, since duck broods must find water within walking distance or perish (Evans, Hawkins and Marshall, 1952). Ducks Unlimited in Canada has worked towards providing permanent water for broods in areas frequently subjected to drought (Gavin, 1964; Keith, 1961).

Semi-permanent ponds.
Upper. Sedge-whitetop pond photographed during a normal year.

Lower. Cattail pond photographed during a normal year. The ponds depicted in both photos retained water and supported ducks during drought in 1959.

Drought years such as 1959 and 1961, in the prairie pothole region, produce mixed reactions in the waterfowl breeding population returning to nest. Many waterfowl pass over the dry prairies or stop only briefly, then fly to the more stable waters of northern portions of the Prairie Provinces, Northwest Territories, and Alaska (Hansen and McKnight, 1964). The production of these displaced ducks in the strange northern environment is lower than their normal production in prairie pothole habitat.

Breeding birds that stay in the pothole region shift from drier to wetter areas such as the parklands, with higher annual rainfall and lower rates of evaporation than the grasslands. Some of the best parkland habitat is in the Minnedosa district, where spring duck populations during the two drought years were above the average duck density of the 1949–64 period. However, production of broods in the drought years declined drastically. Based on a single midsummer census made each year from 1949 to 1954, there was an average of 105 duck broods on the 120 study potholes each summer. But only 25 broods were counted in 1959 and 32 in 1961. Diving ducks, largely over-water nesters, suffered almost total loss of production in 1959 and fared only slightly better in 1961.

The behavior of much of the duck breeding population differed noticeably in the dry years. Flocks composed of both drakes and hens, sometimes numbering in the hundreds, were common on the larger potholes at a time when pairs should have been dispersed and the females laying or incubating. Those that made a nesting effort were largely unsuccessful. Coots reacted to these adverse habitat conditions in much the same way as ducks, and in 1959 their production was practically nil.

As water levels receded in the drought periods, a wide band of mud flat separated emergent aquatic vegetation from the water in most potholes. In 1959, marsh ragwort invaded the mud flats (Perret, 1962). This tall, yellow-flowered plant is normally not a conspicuous part of this district's pothole

Upper. A dugout that became flooded during high waters in the mid 1950's and retained good water levels in 1959. Spoil banks of the dugout appear as islands (centre). Primary vegetation is bulrush; large stands of cattails, whitetop and phragmites were present.

Lower. Pond edges, and often the pond itself, provide a source of hay during dry years.

plant community. Allen G. Smith, biologist, U.S. Fish and Wildlife Service (personal communication) describes its growth during 1960, a drought year in the Lousana study area in Alberta: "About mid-May these mud flats became a carpet of green as seedlings of *Senecio congestus* by the thousands sprouted and began to grow on this newly exposed muck. The plants matured rapidly and made for a beautiful sight all over the parklands. Every pond seemed to be ringed by a lemon-yellow band of considerable width. The following year the *Senecio* had passed out of the picture. It seems able to move waterward when new muck is exposed but cannot take the competition of the usual emergent or moisture-loving plants that surround potholes."

When pothole water levels are low, many farmers burn or mow marginal aquatic vegetation. Those practices immediately destroy nests and reduce nesting cover for the current season, and also reduce the amount of residual cover that would normally be available the following spring for early-nesting waterfowl. Spring run-off sources for potholes are often reduced when farmers burn or bulldoze pothole edges of willow and aspen into the basins in order to cultivate the cleared area and eliminate a snow trap. During the dust storms common in the drought years, drifting soil settles in the pothole basins. Some farmers execute drainage plans, probably formulated in the wet years when abundant potholes with high water levels were a nuisance to farming operations.

Droughts are not entirely detrimental to potholes and waterfowl in the prairie pothole region. They may extend the longevity of potholes by reducing the rate at which organic matter is deposited in the basins (Jahn and Moyle, 1964). Aquatic communities are ever-changing until they reach their final stage, dry land (Oosting, 1948). As Leitch (1964) stated: "Nature is dynamic. All water areas, large and small, proceed through sedimentation and accumulation of organic debris to dry land, their ultimate destiny. Filling is rapid in cold acidic forest

Drifting soil during a dust storm settled in this cattail pond. This sight is common during drought years.

ponds because decomposition is slow, and peat and other organic residue accumulate faster than they can be broken down. In the northern half of the Northern Great Plains, most ponds which must have dotted the immediate post-glacial landscape and persisted through the period of maximum grassland, have long since become bog and spruce forests.

"But the alkaline waters and high temperatures of the prairies promote rapid decomposition. Organic material is soon broken down and mineralized to a form usable by plants. Drought helps this process, for decomposition proceeds quickly when pond bottoms are exposed and aerated. Pond fertility is thus greater when reflooded, and the rate of filling is slowed down. In the long range view, drought, paradoxically, helps keep a pond a pond!"

Periodic droughts, therefore, play an ecologically important role in maintaining prairie pothole fertility. Waterfowl and aquatic forms, from plankton to insects, depend on aquatic plants for food and shelter and are affected by the changes wrought by dry and wet cycles. Pond fauna respond rapidly to changes in environment and ducks respond to these changes in food organisms. During periods of abundance aquatic insects form a major part of the ducks' summer diet. During years when pond fauna is reduced because of a lack of water or aquatic vegetation, ducks seek other foods such as seeds and terrestrial insects (Perret, 1962).

Some aspects of very wet years are unfavourable for waterfowl production. Unusually high water levels, such as those in 1955 and 1956, destroy most stands of cattail and bulrush, prime nesting cover for overwater nesters. Flooding may destroy both some overwater and ground-nests. However, the ability of waterfowl to renest compensates for some nest losses (Sowls, 1955). Above normal water levels thus detract from waterfowl productivity in a minor way in pothole habitat.

In summary, the pothole environment is characterized by change. The major water level fluctuations help maintain the high fertility of small water areas. Waterfowl numbers correlate positively with the abundance of surface water over the prairie pothole region as a whole. Having potholes of above average permanency and size, the Minnedosa district maintained relatively high waterfowl populations even in the drought years. Production, however, dropped drastically. Prairie-nesting waterfowl have a high reproductive potential and can recoup their losses quickly in a favourable habitat. Our chief concern is that man may create a permanent drought in the best duck-producing region in North America by draining and filling the potholes.

Recent raccoon increase

Studies of duck nesting success in pothole habitat of Alberta, Saskatchewan and Manitoba have shown that roughly 30 to 50 percent of the nests of land-nesting species hatch successfully (Keith, 1961; Stoudt and Stinnett, 1955; Kiel, 1955). The ability of ducks to renest after nest destruction increases the percentage of breeding pairs that produce a brood before the end of the season (Sowls, 1955).

In the Minnedosa district during the 1949–52 period, overwater-nesting diving ducks, principally canvasbacks, redheads and ruddies, had higher nest success (73 percent) than land-nesting dabbling ducks (50 percent) (Table 8). Coots had 97 percent nesting success for the 4-year period. Their overwater nesting habit combined with their aggressive nature probably protects coots from most predators. Also, both sexes incubate.

Surveys in 1960 and 1964 showed that overwater nesting success declined from the early 1950's. Those later surveys, conducted for brief periods in June and July, did not measure season-long nesting success. However, based on a small sample in 1960, only 46 percent of 30 diving duck nests were successful. In 1964, we found only one hatched diving duck nest out of 13. A larger sample of 49 coot nests showed

92 percent success in 1960 and a decline to 79 percent success for 128 nests in 1964. Reduced success of overwater nesters in 1960 might partly be attributed to poor habitat conditions in the early spring following the dry year of 1959, but not in 1964.

The reduced success of overwater nesters in the Minnedosa district might be attributed to an abrupt increase of raccoons that destroyed the nests. In much earlier times, the raccoon was reported to have ranged widely over southern Manitoba but was exterminated in many districts and, by the end of the 1920's, was exceedingly rare (Seton, 1929; Soper, 1946). In describing the occurrence of three raccoons near Delta, Manitoba in 1948, Sowls (1949) reported that among local residents, only about one out of 25 had ever seen a raccoon. During the early period of intensive study, 1949–54, we saw neither this clever predator nor its tracks. In a brief survey in 1960, however, one raccoon was seen and tracks were common around pothole edges. Farmers also reported seeing the animals and inquired about them. By 1964, there were abundant signs of raccoon activities around potholes, including duck nest destruction, and several road-killed raccoons were seen.

Sutton (1964) documented the northward range extension of the raccoon in Manitoba (northernmost record, Oxford House, 55°N. latitude, Nov. 1960) and believed the animals were using the wooded streams of southern Manitoba as travel routes to the north. He stated: "By 1958 raccoons had become so abundant in these southern areas that farmers were demanding relief from their alleged depredations. Road kills became commonplace. The museum received many reports of strange animals being taken in farm woodlots, and several hapless wild raccoons, treed in Winnipeg, were 'returned' to the city's zoo by helpful finders."

Further evidence of the recent increase in raccoons is presented in Table 9 showing fur dealers' reports of raccoon pelts taken in Manitoba from 1924 through 1967. In providing these statistics, E. F. Bossenmaier, chief biologist, Manitoba Wildlife Branch, stated: "The fur dealer reports reveal an interesting story which I believe quite accurately reflects numbers of raccoons in the wild in southern Manitoba over the past several decades." Most of the raccoons were taken in the central and western portions of southern Manitoba, the major duck-producing region.

The raccoon is a well known predator on nesting waterfowl throughout its range in the United States (Llewellyn and Webster, 1960). Special precautions are taken to exclude raccoons from artificial nest sites for waterfowl (Bellrose, 1953; Webster and Uhler, 1964). Raccoon populations increased so greatly in the north-central United States in the 1940's and 1950's that noted naturalist Dr. Paul L. Errington advocated reducing their numbers through increased sport hunting (Errington, 1964).

The raccoon is an important new adversary facing nesting waterfowl. Whether the raccoon will become a permanent factor influencing reproductive success of waterfowl in the Minnedosa district is uncertain. However, this district is a particularly important nesting area for the canvasback, a species protected by highly restrictive hunting regulations in recent years due to international concern over its population. Canvasbacks had relatively high nesting success during the early period of this study, 1949–52, but surveys in the 1960's showed a considerable decline in its nesting success. If the raccoon persists in high numbers in this district, its habit of foraging near the water's edge, its adeptness at swimming, and its fondness for eggs and probably ducklings, will make it a factor to be considered in the management of waterfowl.

Table 8
Coot and duck nesting success, Minnedosa district, from 1949 to 1952 (from Kiel, 1955).

	Coots		Diving ducks		Dabbling ducks	
Year	No. nests	% success	No. nests	% success	No. nests	% success
1949	152	95	78	65	48	46
1950	69	93	35	71	21	52
1951	103	100	61	87	32	56
1952	56	98	53	68	48	50
4 years	380	97	227	73	149	50

Table 9
Production of raccoon pelts in Manitoba as reported by fur dealers from 1924 to 1967*.

Period	Pelts entering the fur market	Average number	Average price
1924–46	No pelts		
1947–48	28		$2.00
1948–49	56		2.00
1949–50	77		2.00
1950–51	74	61	2.00
1951–52	82		2.00
1952–53	44		1.53
1953–54	65		1.75
1954–55	146		2.00
1955–56	152		2.00
1956–57	94	145	2.00
1957–58	216		1.34
1958–59	116		1.66
1959–60	587		2.87
1960–61	871		2.33
1961–62	616	663	2.50
1962–63	624		2.58
1963–64	617		2.17
1964–65	375		2.47
1965–66	733		4.00
1966–67	725		3.00

*Data provided by Wildlife Branch, Manitoba Department of Mines and Natural Resources, Winnipeg.

Upper. A semi-permanent wooded pond as it appeared in early spring and later in the summer.

Lower. The woodlot was cleared and burned and the ponds drained to a newly constructed roadside ditch.

Man-made changes — late 1940's to mid 1960's

Road building

We studied the effects of Manitoba's vast road building program on the waterfowl habitat in the Minnedosa district. Aerial photographs reveal that early roads followed the land contours and the paths of least resistance around potholes, large woodlots, and hills. Although road allowances of 1.5 chains (99 feet) were laid out on a 1-mile grid, most roads were little more than winding paths. This was the case in the north of the district as late as 1930; however, there were attempts to straighten and widen the main thoroughfares. By 1946 some of the main roads were straightened and often pushed through the smaller potholes. The 1964 photographs revealed several changes: a) most main roads were straight and wide with the entire allowance cleared of bush, b) potholes disappeared in the right-of-way and ditches were dug along roads and road allowances, and c) many secondary roads had changed from dirt tracks to wide gravel roads with drainage ditches.

Aerial photograph comparisons show that the total area of the 201.6 miles of roads in the 12 transects used in this study more than doubled between 1930 and 1964. The road construction program adversely affected potholes in two major ways:

1) It completely or partly filled the pothole basins to level the road grade.

2) It provided, through roadside ditches, a convenient drainage outlet for landowners considering a pothole drainage project. In a few instances, road construction improved potholes when it provided a dam which increased water depth or increased the watershed area for a particular basin.

Deeper roadside ditches may adversely affect potholes in a less direct way. The creation of a ditch, essentially a new basin, may influence the local ground-water flow patterns (Meyboom, 1967), and alter the balance between nearby ponds and the ground-water until water-holding capacity of the potholes is reduced.

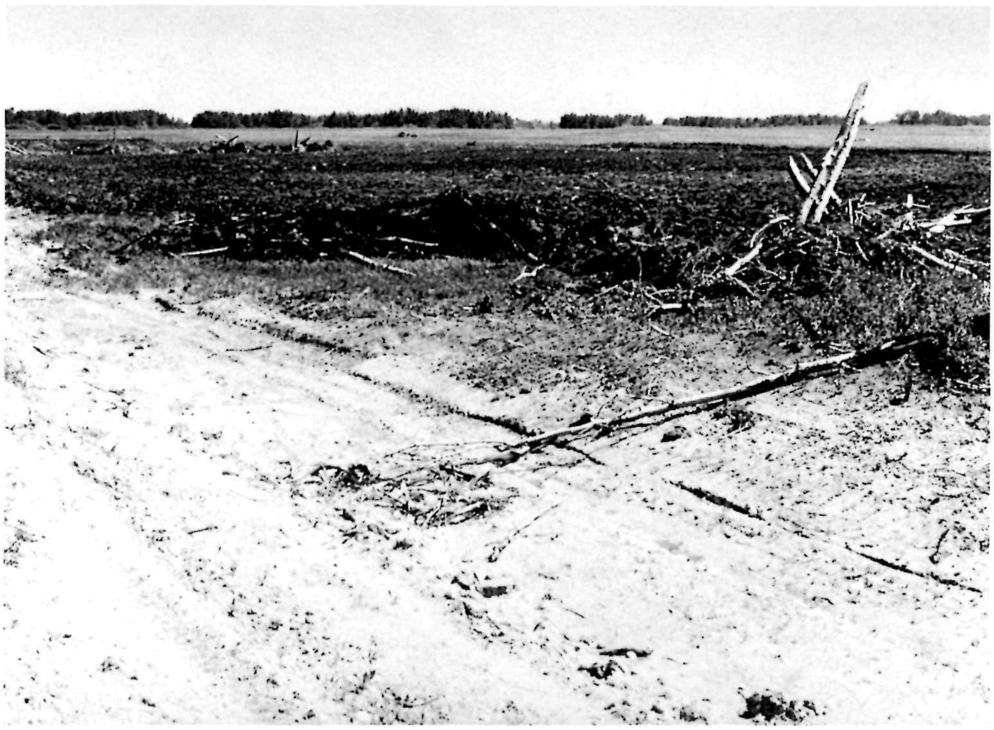


Table 10
Road building effects* on 120 potholes, Minnedosa district, from 1949 to 1964.

Period	Pothole class	No. of times potholes altered by: Road fill	Drainage outlet	Total
1949 or earlier†	Semi-permanent	0	1	1
	Temporary	0	2	2
	Total	0	3	3
1950–54 (5 years)	Semi-permanent	0	0	0
	Temporary	0	1	1
	Total	0	1	1
1955–60 (6 years)	Semi-permanent	2	0	2
	Temporary	1	1	2
	Total	3	1	4
1961–64 (4 years)	Semi-permanent	2	3	5
	Temporary	0	3	3
	Total	2	6	8
Totals	Semi-permanent	4	4	8
	Temporary	1	7	8
	Combined	5	11	16

*3 temporary potholes improved by road building are not included.
†changes recorded in the 1949 survey were limited to those clearly shown by recent evidence.

Table 11
Trends in percentage of transect area in cultivated or cleared land, woodlots or bushland, and wetland. Based on aerial photographs.

Land-type	Percentage of area by years: 1928–30	1946	1948	1958	1962	1964
Cultivated and cleared land	48.0	55.7	58.6	62.2	65.1	68.9
Woodlots and bushland	38.8	30.0	30.0	26.0	24.4	21.4
Wetland	13.2	14.3	11.4	11.8	10.5	9.7
Total	100.0	100.0	100.0	100.0	100.0	100.0

We recorded road building effects on the sample of 120 potholes in the Minnedosa district for four survey periods beginning in 1949 and extending through 1964 (Table 10). Over the four periods, road improvement activities adversely affected 16 potholes. Five were partially or completely filled with soil and 11 were partially or completely drained through roadside ditch outlets. Altogether, equal numbers of semi-permanent and temporary potholes were affected. One-half of the filling and draining instances occurred during the last 4 years (1961–64) of the 16-year period. Three temporary potholes were improved by road construction.

The major adverse effect of the road building program on pothole habitat is its provision of a drainage outlet through the roadside ditches. Before these convenient drainage channels were constructed, it was often too difficult or expensive for landowners to remove the water from their land. Draining a few potholes was easy enough, but more often than not other potholes, benefitting from the additional watershed, became larger and deeper.

Land clearing

Land clearing has gone on since the first settlers arrived. Aerial photographs show that in the 50.4-square-mile Minnedosa transect area, cultivated and cleared land increased steadily from 48 percent of the area in 1928–30 to 68.9 percent in 1964 (Table 11). Correspondingly, woodlots and bushland have declined from 38.8 percent of the area in 1928–30 to 21.4 percent in 1964. A much smaller amount of the gain in cultivated and cleared land is attributed to a decrease in the acreage of wetlands, which is discussed in the section on drainage. Aerial photographs from 6 surveys reveal that the wetland percentage of the sample area varies somewhat due to wet or dry conditions when the photographs were taken. However, there is a trend toward decreasing wetlands. In 1964 wetland acreage dropped below 10 percent for the first time since the 6 surveys began in 1928–30.

Widespread land clearing affects potholes in several ways, and whether the effects on pothole habitat harm or benefit the waterfowl is not always clear. Clearing some trees and shrubs from the margin of a pothole completely rimmed by woody vegetation probably makes the water area more attractive to most waterfowl species. This may be particularly true of the smaller potholes.

The following aspects of land clearing, however, are clearly detrimental to waterfowl habitat: a) Clearing all woody vegetation from the pothole edge and depositing the debris in the basin. This substantially decreases the size and depth of the water area and eliminates both snow drifts that often increase the water supply and much nesting cover, by permitting cultivation closer to the water's edge. A farmer who removes woody cover probably considers potholes to be nuisances and is likely to drain them. b) Clearing bush, largely aspen, within 25 yards of a pothole. Again, this may eliminate snowdrifts which augment spring runoff. Moreover, over much of the district the topography is such that removing natural woody vegetation increases

Upper. Woodlands around this small pond have been cleared and the debris has been deposited in the basin. Within a year the pond will be dry.

Lower. A typical land clearing program. Woody vegetation has been removed and placed in windrows through the ponds. When the ponds have dried, the windrows will be burned and the basins cultivated.

Two types of land use practices. The left side of the circular pond has been cultivated to the water's edge. Emergent vegetation is still standing. On the right, uncultivated side of the pond cattle were allowed to graze. The emergent vegetation was grazed but the woody vegetation and weeds were untouched. The channels leading from pond to pond were improved by the farmer to speed up spring run-off.

water erosion from knolls. The rate at which a pothole is filled with silt depends largely upon farming practices on adjacent land. Clearing also eliminates the value of aspen "bluffs" in screening wind borne soil during dust storms. c) Cultivating the pothole basin. During dry years, farmers sometimes disc and cultivate potholes cleared of marginal woody vegetation for grain crops or use them for hay production. In the next wet period, although the deeper basins may contain water, they are likely to be shallower and less permanent than before cultivation. And many farmers who cultivate basins in dry times become reluctant to lose the new cropland and consider permanent drainage (Burwell and Sugden, 1964).

From 1949 through 1964, 44 (37%) of the 120 sample potholes were altered by land clearing activities. These 44 potholes were altogether affected 57 times by one or more of the practices of clearing woody vegetation of the pothole edge, clearing nearby upland and cultivating the basin (Table 12). Clearing edge vegetation was the most common practice (26 times), followed by clearing nearby upland (20 times), and cultivation of basin (11 times). The cultivation of basins was restricted to temporary potholes, and 9 of the 11 occurrences were recorded in the last 4 years of the 16-year period. The widespread drive among farmers to reclaim more wetland is unmistakably gaining momentum. Land clearing practices altered more potholes in the last 4 years (1961–64) of the study than in the previous 12 years combined, and the trend is continuing. Heavy equipment contractors using improved techniques are changing the parkland landscape rapidly compared to the gradual changes of a decade or so ago. As Burwell and Sugden (1964) point out, "Improved techniques and heavier equipment have reduced the cost of land reclamation at a time when higher costs of farm operations and declining farm income have stimulated development of more arable lands. Wetlands are all that remain to be reclaimed in many districts."

Drainage

If applied in a blanket pattern over the prairies and parklands, drainage will create a permanent drought for waterfowl and eliminate the heart of duck production habitat in Canada.

We studied the extent and the trends of drainage in the Minnedosa district. For the 1948–64 period, aerial photographs show a 15 percent decline in wetland acreage in the 50.4 square miles of transect area (Table 11). Since 1949, 19 (16%) of the 120 intensively studied potholes have been partially or completely drained (Table 13). Over one-half of all drainage efforts were recorded during the last 4 years (1961–64) of the 16-year period. The smaller and shallower temporary potholes bore the brunt of the drainage activities. Twelve (23%) of 53 temporary water areas were affected by drainage compared to seven (10%) of the 67 semi-permanent potholes. Six of these seven were drained during the last 4 years of the study.

Sixteen out of 20 draining attempts had partial rather than complete results, but even partial drainage seriously affects size and permanency of potholes. Semi-permanent areas may become temporary and lose much of their value as brood habitat, whereas temporary potholes become short-lived spring runoff puddles. Complete drainage probably will follow.

Draining wetlands for agricultural purposes began before the last few decades. The disappearance of potholes and marshes in the midwestern portion of the United States is well documented. The loss of wetlands to drainage from Iowa northwestward into the Dakotas has been substantial and practically complete in some regions. Kenney and McAtee (1938) reported that drainage of productive wetlands, chiefly in the northern Great Plains, was one of the prime factors reducing the continent's waterfowl population. In both Canada and the United States, certain government agencies subsidize and encourage drainage

Table 12
Land clearing history on 120 potholes, Minnedosa district, from 1949 to 1964.

Period	Pothole class	No. of times potholes altered by: Clearing edge	Clearing nearby*	Cultivation of basin	Total
1949 or earlier†	Semi-permanent	0	0	0	0
	Temporary	0	0	0	0
	Total	0	0	0	0
1950–54 (5 years)	Semi-permanent	1	5	0	6
	Temporary	4	3	0	7
	Total	5	8	0	13
1955–60 (6 years)	Semi-permanent	3	1	0	4
	Temporary	8	0	2	10
	Total	11	1	2	14
1961–64 (4 years)	Semi-permanent	5	9	0	14
	Temporary	5	2	9	16
	Total	10	11	9	30
Totals	Semi-permanent	9	15	0	24
	Temporary	17	5	11	33
	Combined	26	20	11	57‡

*Bush, largely aspen, cleared within 25 yards of a pothole and probably changing the pothole ecology.
†Changes recorded in the 1949 survey were limited to those clearly shown by recent evidence.
‡44 potholes were altered one or more times.

Table 13
Drainage history on 120 potholes, Minnedosa district, from 1949 to 1964.

Period	Pothole class	Number of times potholes altered by: Partial drainage	Complete drainage	Total
1949 or earlier*	Semi-permanent	0	0	0
	Temporary	4	0	4
	Total	4	0	4
1950–54 (5 years)	Semi-permanent	0	0	0
	Temporary	1	1	2
	Total	1	1	2
1955–60 (6 years)	Semi-permanent	0	1	1
	Temporary	1	1	2
	Total	1	2	3
1961–64 (4 years)	Semi-permanent	6	0	6
	Temporary	4	1	5
	Total	10	1	11
Totals	Semi-permanent	6	1	7
	Temporary	10	3	13
	Combined	16	4	20†

*Changes recorded in the 1949 survey were limited to those clearly shown by recent evidence.
†19 potholes were altered by drainage.

while other government agencies seek to preserve and restore wetland areas (Ellis, 1962; Janzen, 1964; Munro, 1967). Wildlife values are gradually gaining universal recognition, but progress in wetland preservation is slow due to conflicting demands of other land uses.

According to Burwell and Sugden (1964), drainage of Canadian wetlands began in the late 1800's, reached a peak in the 1920's, declined during the drought of the 1930's, resumed in the 1940's, and is continuing. We observed an accelerating drainage rate in the Minnedosa district. New land clearing and drainage projects in a community stimulate neighboring landowners to begin their own. Heavy equipment contractors and manufacturers often promote drainage projects for business reasons.

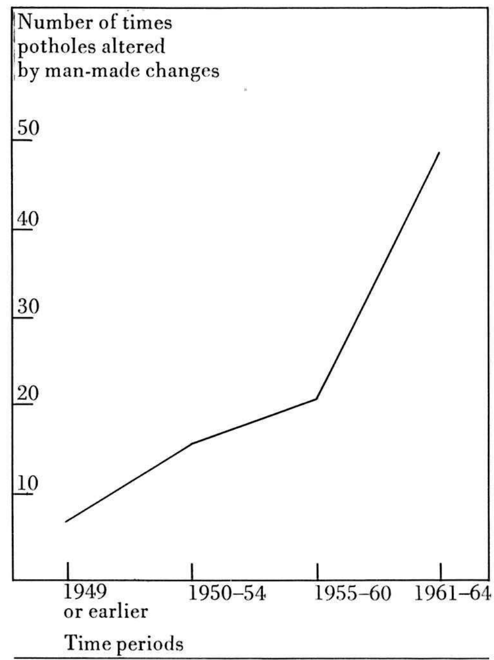
In summary, through road building, land clearing and drainage, man is affecting potholes at an increasing rate. The 120 potholes were affected 93 times by man-made alterations during the 16-year period, 1949–64, and over 50 percent of the changes were made during the last 4 years of the period (Fig. 6). Sixty individual potholes, one-half of the sample, were altered one or more times. Because our observations were on roadside transects, the rate at which we observed road fill adversely affecting potholes is not typical for the Minnedosa district as a whole. Land clearing, however, is largely independent of roads. Rates of pothole drainage may now be higher near improved roads, with convenient drainage outlets through roadside ditches, than over the district as a whole. However, since roads surround almost every section of land, a large portion of the potholes are susceptible to such drainage. And the methods and the heavy equipment are available to conduct blanket-like drainage over the parklands.

Upper. Elaborate structures are not required to drain potholes of surface water. A simple ditch leading to a larger roadside ditch is effective.

Lower. Simple ditches lead from pothole to pothole and finally into the larger ditch along the newly constructed highway.

Figure 6. Trends in man-made changes on 120 potholes, Minnedosa district, from 1949 to 1964. Changes include road building, land clearing and drainage.

Figure 6



Waterfowl populations

Density, species composition and trends

The Minnedosa district is the finest unit of waterfowl production habitat in Manitoba and one of the best in Canada. Statistics on the density and species composition of the waterfowl breeding population were recorded for 1949 through 1954, the years of intensive study, and again in 1959 and 1960 (Tables 14 and 15). The censuses were conducted on the 12 transects (50.4 square miles) from mid May to early June when birds of most species in this district are at their breeding peak. Each water area within the bounds of the transect was observed with binoculars. We observed potholes partially or entirely obscured from road view by walking to an unobstructed vantage point or around the pond, if necessary. We tried to avoid flushing ducks, but, when this occurred, whenever possible we marked the birds down to avoid duplication in the census.

The visibility of waterfowl on the potholes is affected by certain variables including time of day of the census, density of the vegetation in and around the pothole, high or low water levels and behavior patterns of the various species. This discussion describes only generally the density and species composition of breeding waterfowl in the district. Because of their open-water activities, scaup, canvasbacks and redheads are easily visible and probably overrated compared to other species. Because blue-winged and green-winged teal are small and more easily concealed by vegetation, they probably represent a higher proportion of the actual population than this census method indicates. In calculating density and species composition for ducks (Tables 14 and 15) we made corrections assuming a 50:50 sex ratio (number of drakes seen x 2). This was done to correct for phenological differences between years which result in varying percentages of hens being engaged in nesting and not visible. No adjustment was made to correct further for species whose population sex ratio may not be 50:50. Such un-

Table 14
Waterfowl breeding density, Minnedosa district. Based on mid May to early June censuses on 12 transects comprising 50.4 square miles.

	Ducks per square mile*								
Species	1949	1950	1951	1952	1953	1954	6 yr. avg.	1959	1960
Mallard	28.5	28.3	23.6	32.0	31.7	29.1	29.2	30.3	27.1
Gadwall	4.6	4.0	3.5	2.8	1.4	1.5	3.0	3.1	2.4
Baldpate	7.9	7.6	6.3	5.7	5.7	6.1	6.6	8.1	6.1
Pintail	8.3	8.0	9.4	8.7	9.6	10.6	9.1	6.7	10.6
G-w. teal	4.1	4.6	4.9	4.6	2.0	2.8	3.8	3.0	2.8
B-w. teal	21.1	28.3	21.0	16.3	17.8	17.8	20.4	38.5	20.9
Shoveler	4.6	4.9	4.5	2.7	3.4	3.4	3.9	5.6	6.9
Redhead	5.1	6.0	4.0	3.2	4.4	3.8	4.4	4.0	2.8
Canvasback	8.1	8.9	7.0	6.6	5.5	7.4	7.2	5.0	4.0
Scaup	10.7	12.5	12.3	13.7	14.0	12.1	12.6	33.3	14.0
Ruddy	3.2	10.4	3.5	1.3	2.5	3.4	4.1	2.0	4.2
Others	1.9	3.3	3.0	2.0	1.8	1.5	2.3	2.5	2.6
Total ducks per sq. mi.	108.1	126.8	103.0	99.6	99.8	99.5	106.1	142.2	105.2
Coots per sq. mi.	12.4	8.7	8.4	4.7	9.7	11.8	9.3	6.8	21.6

*These figures are corrected to include a hen for each drake seen. This adjustment is an attempt to allow for differences in nesting phenology between years.

Table 15
Percentage composition of the waterfowl breeding population, Minnedosa district. Based on mid May to early June censuses on 12 transects comprising 50.4 square miles.*

Species	1949	1950	1951	1952	1953	1954	6-yr. avg.	1959	1960
Mallard	26	22	23	32	32	29	27	21	26
Gadwall	4	3	3	3	1	1	2	2	2
Baldpate	7	6	6	6	6	6	6	6	6
Pintail	8	6	9	9	10	11	9	5	10
G-w. teal	4	4	5	5	2	3	4	2	3
B-w. teal	20	22	20	16	18	18	19	27	21
Shoveler	4	4	4	3	3	3	4	4	7
Redhead	5	5	4	3	5	3	4	3	3
Canvasback	7	7	7	7	6	8	7	4	4
Scaup	10	10	12	14	14	12	12	24	13
Ruddy	3	8	3	1	3	5	4	1	4
Others	2	3	3	2	2	2	2	2	2
Total ducks	5444	6392	5194	5020	5032	5024		7082	5302

*Based on data corrected for nesting females (drakes x 2). See Table 14.

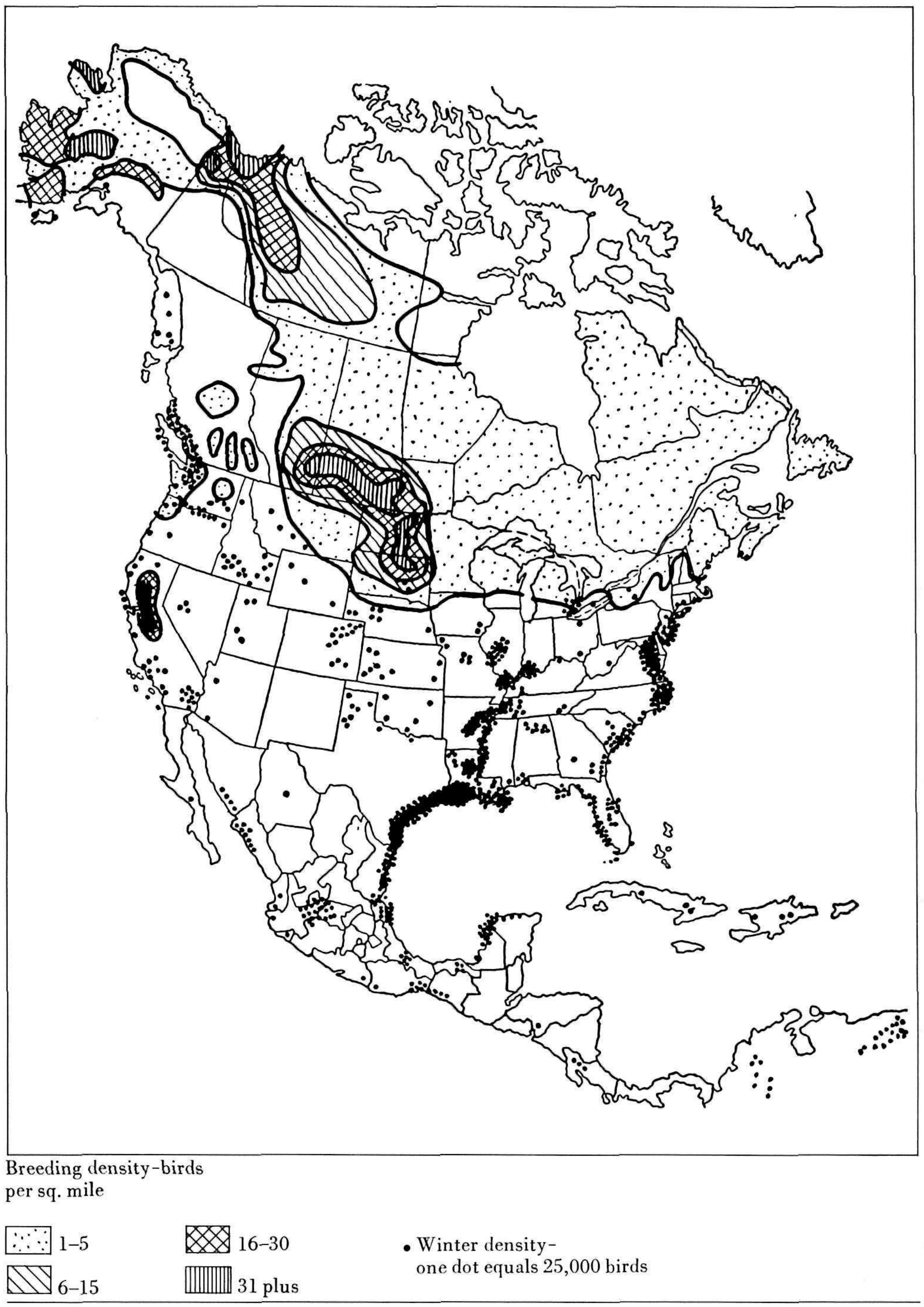
Figure 7. Average distribution of North American breeding and wintering ducks (from Evans, 1964).

balanced ratios, favoring drakes, occur principally among diving ducks (Bellrose, Scott, Hawkins and Low, 1961). Application of a 50:50 sex ratio correction would thus overrate the density and species composition of divers.

From 1949 to 1954 density of breeding ducks averaged 106 per square mile and the variation between years was low ranging from 100 to 127 birds per square mile (Table 14). Coinciding with widespread drought conditions in the prairie pothole region in 1959, the density of ducks in the Minnedosa district rose to 142 per square mile. The following year, 1960, under improved habitat conditions, the population declined to approximately the level of the 1949–54 period. There was an influx largely of blue-winged teal and scaup into the Minnedosa district in 1959 from more droughty areas. Coot numbers in the district have fluctuated considerably in response to varying habitat conditions in the prairie pothole region (Kiel and Hawkins, 1953; Kiel, 1955). The lowest density of five coots per square mile was recorded in 1952 when semi-drought conditions prevailed in the Minnedosa district and excellent water levels were reported in the Saskatchewan pothole region (Gollop, Lynch and Hyska, 1952). The highest density of 22 birds per square mile was in 1960 when habitat conditions in the Minnedosa district were considerably better than in regions to the north and west. Coots sensitively select nesting habitat to avoid drought. They used temporary potholes as nesting sites only in comparatively wet years, and none of 380 active nests were ever stranded on dry land by receding water levels in contrast to many duck nests so affected (Kiel, 1955).

In order of abundance, the mallard, blue-winged teal and scaup constitute over one-half of the duck breeding population. Only in the unusually droughty year of 1959 did bluewings and scaup outnumber the mallard (Table 15). The pintail, canvasback and baldpate follow these three species, in average abundance. Sixteen species of

Figure 7



ducks breed regularly in the district. In addition to the 11 species listed in Tables 14 and 15, the category "others" includes the bufflehead, American goldeneye, ring-neck, white-winged scoter and black duck. The cinnamon teal and wood duck have been observed on rare occasions.

Overview of production potential
We estimate that the Minnedosa district had the potential at the time of our study to contribute at least 1 million ducks to the fall migration annually, considering that the district of 4,100 square miles supports an average breeding population of about 106 ducks per square mile, and assuming average production of 1.3 ducklings per adult (Bellrose, Scott, Hawkins and Low, 1961). To attain an age ratio of 1.3 ducklings per adult, 43 percent of the nesting pairs in a population having a 50:50 sex ratio must produce a brood averaging 6 ducklings. Nesting studies showed that overall nest success was probably higher than this, considering the proportion of diving ducks (over-water nesters) in the population (Tables 8 and 15). The number of ducklings per brood averaged 6.6 for a 5-year period, 1949–53. This overall average, calculated on the basis of yearly averages, represents 2,182 brood counts. Likely the estimate of 1 million ducks migrating from the Minnedosa district in an average year of the 1949–54 period is conservative.

The Minnedosa district is a particularly important breeding area for the canvasback. In the early 1950's, average breeding populations of the district, compared to continental population estimates (Crissey, 1964), indicate that approximately 10 percent of all canvasbacks in North America nested in this district. By 1959 and 1960, the breeding density of canvasbacks in the district had declined 31 percent and 44 percent, respectively, from the average density of the 1949–54 period. Canvasbacks in the continental population similarly declined. Both increased raccoon predation and increased pothole drainage may be factors in the canvasback decline in the Minnedosa district.

On the average distribution map of breeding ducks in North America (Evans, 1964) (Fig. 7), the waterfowl breeding density in the Minnedosa district (106 ducks per square mile) is in the highest category. This is, in part, due to the more permament nature of many of its water areas. During general drought periods in the prairie pothole region, the district attracts ducks in higher than normal numbers and always produces some ducks for the fall flight despite greatly reduced reproduction rates. Its overall consistency of production and high breeding population merit the Minnedosa district's description as one of the best duck producing areas in North America.

The future

The economy of the Minnedosa region in Manitoba is largely dependent on cereal grain production. What is a pothole worth to a farmer in comparison to the grain he can produce in its drained basin for the ever-expanding world food market?

To duck hunters of Canada and the United States, it is critically important to preserve the small wetlands of the prairie pothole region. This 10 percent segment of the waterfowl breeding range in North America produces 50 per cent of all ducks, and an even larger percentage of the more important game species (Munro, 1967). The approximately 3 million duck hunters are now a small minority of the total North American population. However, hunting is a heritage as old as mankind. It had survival value for the pioneers less than a century ago, and has recreational value today. Increases in both human population and the leisure time available have created a need for more recreational choices, not fewer.

The increasing demand for outdoor recreation of all types is spectacular. Landowners in the parklands and prairies should not overlook the prospect of economic gain from the wildlife resources of their land. In the United States many landowners manage their property for sport hunting to provide a supplementary source of income. In addition to waterfowl, the pothole region supports good populations of sharp-tailed grouse, white-tailed deer, muskrats and other game.

Drainage of wetlands may not be in the best interest of agriculture, even from a purely economic standpoint. The relationship of the parkland water areas to soil moisture and groundwater levels and to the highly consistent crop production in an area such as the Minnedosa district has not been fully studied. It might be shortsighted to drain the ponds and then discover their value to crop production in this rather dry region. Farming in harmony with the natural environment to the greatest extent possible may be more productive in the long run. Climatologists have found that land-use practices may directly affect the climates of large land masses. Polluting the atmosphere with dust has affected rainfall to the extent that deserts have been created and maintained. Brush clearing, pothole drainage and land leveling which give the wind full sweep of the landscape on the windy and frequently semi-arid prairies may not be the best way to satisfy the demands of a growing world food market.

With the experiences of the severe drought of the 1930's fresh in his mind, W. G. Ross, K.C., M.L.A., delivered the following address to the Saskatchewan Legislature on March 27, 1939:

"It took the disastrous drought period from 1929 to 1934, not only in Canada but in the United States as well, to bring home to the people of both countries, the dire need for drastic action to save not only wildlife but domestic life as well.

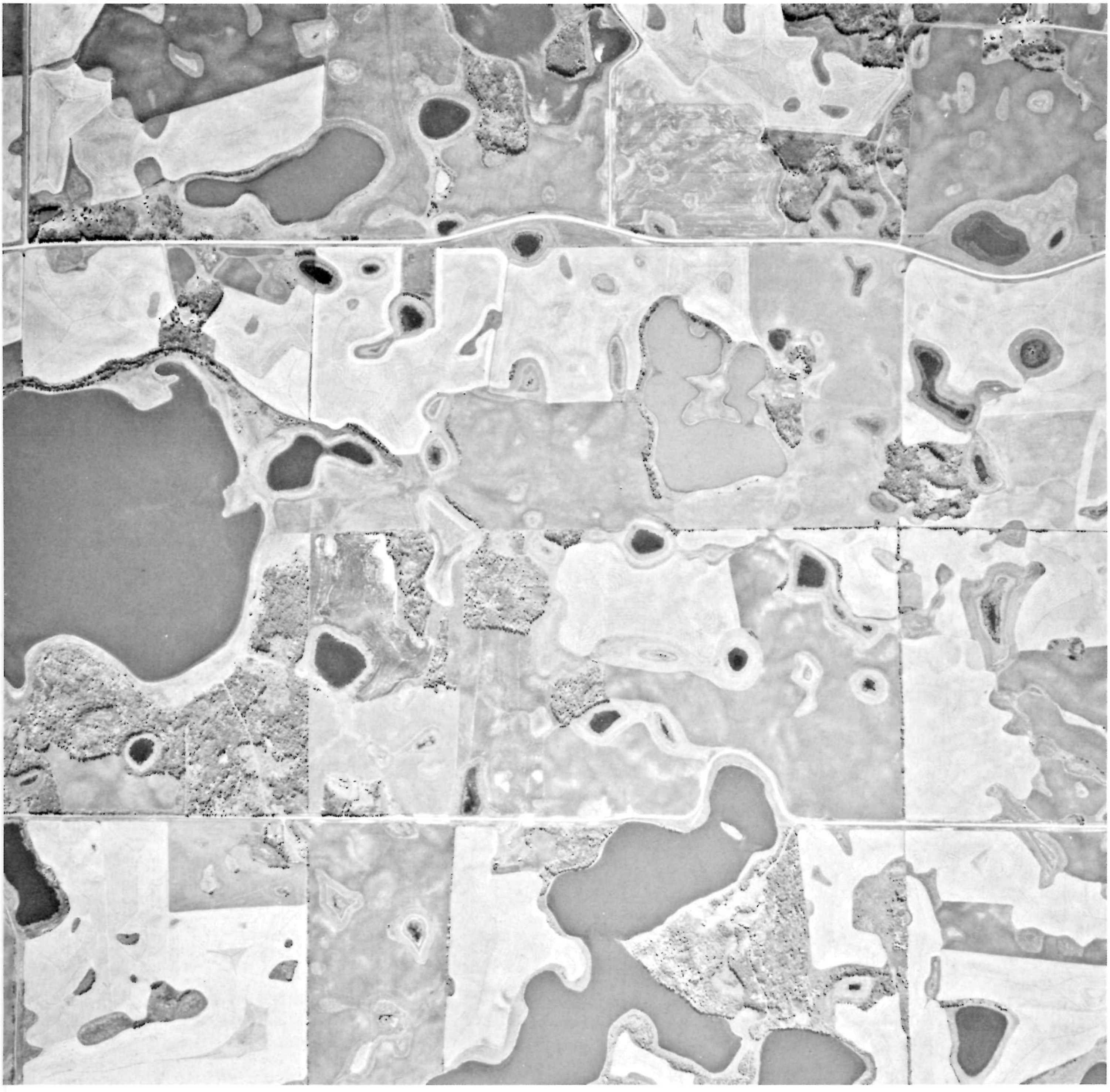
"In light then of our experience since 1929, with drought, wind and insect pests, we ought more than ever to remember, whether as immigrants from other lands, or provinces of Canada, or as native sons of the West, we received, in the opening up of the West, a great national asset in our natural resources. We did not obtain an absolute title to those resources but we did receive them in trust to administer them and manage them, and not to dissipate them. We became entitled to use the increase or the interest on the investment but with an obligation to preserve the capital. If we are to remain true to the trust imposed upon us, we must maintain ourselves in position to hand over to our sons and daughters and those who come after us, the privilege that was ours, of enjoying not only the great out-of-doors but agriculture and life itself to the fullest extent.

"Fifty years of this feverish activity in western Canada, much of it foolish and uneconomic, has...dealt destruction to the myriads of every form of wildlife... valuable marshes have been drained in the prairie areas, only to find that the bottoms were of no practical use to agriculture... The worst drought period known to western Canadian civilization completed the havoc. Whether it is over now, no one knows. Certainly surface water in its natural state has never been as low in the history of the prairies, and in the woods beyond, as it is today."

Parliament in Canada and Congress in the United States have established legislative authority to spend millions of dollars towards preserving wetland habitat, evidence that more and more people, recognizing the value of wetlands, are willing to contribute to their preservation. The preservation program is centered in the prairie and parkland pothole region of the two nations. The U.S. Bureau of Sport Fisheries and Wildlife was authorized in 1961 to spend $105 million for wetland acquisition in a 7-year period, now extended another 8 years to 1976. In 1967, CWS began a $50 million 10-year program to protect potholes from draining, filling, or burning of marginal vegetation. This program will control about two-thirds of the potholes in Canada's parklands and prairies. (Munro, 1967). The landowners receive an income for allowing their wetlands to be used to produce waterfowl and other wildlife for public benefit. This program has since been modified and broadened to include grants and assistance to municipalities, organizations and individuals for protecting and improving waterfowl habitat. In addition, CWS is now purchasing large marsh staging areas and important waterfowl habitat throughout the prairie provinces. These investments are encouraging evidence that the people of North America wish to preserve our heritage in wetlands and wildlife. And there is recognition that if the wildlife production therefrom is used as a public benefit, all segments of the public should assist the landowner in maintaining the wetland resource.

The future of the parkland and prairie potholes and their wildlife rests ultimately with the landowner. His stewardship of the land and its productive potential will be his legacy to future generations. Coming generations may judge us as much for the natural environment we have preserved as for the bushels of grain we have produced.

This airphoto shows typical pothole habitat in the aspen parklands. The future of the parklands and the wildlife it supports rests ultimately with the landowner.



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Appendix

Common and scientific names of animals and plants mentioned in the text (A.O.U., 1957; Miller and Kellogg, 1955; Fassett, 1940; Fernald, 1950)

Ducks	
American goldeneye	*Bucephala clangula*
Baldpate	*Mareca americana*
Black duck	*Anas rubripes*
Blue-winged teal	*Anas discors*
Bufflehead	*Bucephala albeola*
Canvasback	*Aythya valisineria*
Cinnamon teal	*Anas cyanoptera*
Gadwall	*Anas strepera*
Green-winged teal	*Anas carolinensis*
Lesser scaup	*Aythya affinis*
Mallard	*Anas platyrhynchos*
Pintail	*Anas acuta*
Redhead	*Aythya americana*
Ringneck	*Aythya collaris*
Ruddy	*Oxyura jamaicensis*
Shoveler	*Spatula clypeata*
White-winged scoter	*Melanitta deglandi*
Wood duck	*Aix sponsa*
Other birds	
American coot	*Fulica americana*
Canada goose	*Branta canadensis*
Crow	*Corvus brachyrhynchos*
Hungarian partridge	*Perdix perdix*
Magpie	*Pica pica*
Marsh hawk	*Circus cyaneus*
Ruffed grouse	*Bonasa umbellus*
Sandhill crane	*Grus canadensis*
Sharp-tailed grouse	*Pedioecetes phasianellus*
Trumpeter swan	*Olor buccinator*

Mammals	
Bison (buffalo)	*Bison bison*
Black bear	*Euarctos americanus*
Coyote	*Canis latrans*
Elk	*Cervus canadensis*
Fox	*Vulpes fulva*
Franklin ground squirrel	*Citellus franklinii*
Muskrat	*Ondatra zibethicus*
Raccoon	*Procyon lotor*
Skunk	*Mephitis mephitis*
White-tailed deer	*Odocoileus virginianus*
Wolf	*Canis lupus*

Fish	
Yellow walleye	*Stizostedion vitreum*

Plants	
Aspen or poplar	*Populus* sp.
Bladderwort	*Utricularia vulgaris* L.
Bulrush	*Scirpus acutus* Muhl., *S. validus* Vahl
Cattail	*Typha latifolia* L.
Duckweed	*Lemna minor* L., *L. trisulca* L.
Marsh ragwort	*Senecio congestus* (R.Br.) DC var. *palustris* (L.) Fern
Milfoil	*Myriophyllum exalbescens* Fern.
Muskgrass	*Chara* sp.
Phragmites	*Phragmites comumnis* Trin.
Pondweed	*Potamogeton* sp.
Sedge	*Carex* sp.
Siberian pea	*Caragana arborescens* Lam.
Spike rush	*Eleocharis* sp.
Water crowfoot	*Ranunculus* sp.
Whitetop	*Scolochloa festucacea* (Willd.) Link
Wild barley	*Hordeum jubatum* L.
Willow	*Salix* sp.

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