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Surface and Groundwater Withdrawal Management Alternatives in Elk Island National Park, Alberta

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled SURFACE AND GROUNDWATER WITHDRAWAL MANAGEMENT ALTERNATIVES IN ELK ISLAND NATIONAL PARK, ALBERTA submitted by ANDREW JOHN LIVINGSTONE in partial fulfillment of the requirements for the degree of Master of SCIENCE.

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ABSTRACT

The objective to this study was to develop management strategies in which alternative futures options are examined, and selection between them is made. The existing withdrawals for human consumption and domestic use were examined and quantified. Existing utilized and non-utilized water sources were examined and evaluated, regarding present and potential suitability of their waters for human consumption and domestic use withdrawals. A sanitation survey was conducted to assess any potential of contamination of surface and groundwater sources from park sewage disposal facilities.

Potential future water withdrawal demands for human consumption and domestic use were estimated for each of a number of alternative futures in Park use growth, and subsequent facility expansion requirements were outlined. Existing water sources were evaluated against potential withdrawal demands, and potential water sources within and beyond Park boundaries were evaluated. The evaluation included water quality assessment, development feasibility, capital and recurrent cost estimation, and associated legal and administrative considerations.

A variety of short term options were presented and many of these can be implemented. In addition, a variety of flexible, long term options were presented to cover the anticipated range of future water withdrawal demands for human consumption and domestic use in Elk Island National Park.

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"...if there is knowledge, it will be done away. For we know in part, and we prophesy in part; but when the perfect [one] comes, the partial will be done away." 1 Corinthians 13:8-10.

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I. INTRODUCTION

In single use water systems, selection of a water source for human consumption and domestic use usually involves estimating if there will be sufficient quantity to meet year-round demands (White, 1969), and also evaluating whether the water quality will be acceptable for the intended use (AWWA, 1971).

Most single use water systems are designed to supply average and peak water demands without high risk of failure. A system is selected from within some capital cost range, that will be the simplest to operate and maintain. Generally, there has been little evaluation between alternate water sources according to relative cost, and a high value has been placed upon convenience (White, 1969).

Water quality is relative to the proposed use of the water. For human consumption and domestic use, the physical, chemical and bacteriological quality should meet or exceed the Canadian Drinking Water Standards (Health & Welfare Canada, 1979) in order to be both safe and pleasant to use. The quality of raw water may or may not be acceptable for the intended use. If unsatisfactory, treatment can be used to produce acceptable-quality water (AWWA, 1971).

Water withdrawal planning has historically relied upon either a linear demand projection based upon present per capita usage and an extrapolated future population, or upon a geometric demand projection based upon increasing per capita usage and an extrapolated future population (White, 1969). This has created the tendency to over estimate future needs. Also, the single-course plan has been generally unable to accommodate changing conditions that inevitably occur. What is desirable in water withdrawal planning is the identification of immediate steps that are best for the immediate future, but which maintain maximum flexibility for the selection of alternatives in the longer term (Koelzer, 1970). Planning and management should be a continuing process where frequent evaluations and decisions are made in response to new situations that arise as a result of new information, changes in demand or changes in priority. Alternative futures for the long term should cover the spectrum of possibilities that may reasonably be expected to occur (White, 1969).

Elk Island National Park contains a number of private and public, predominantly single use water systems. Since the time the Park was first established in 1913, a large number of water systems, from a wide variety of sources, have been developed, used and then abandoned. Extensive system modification and water treatment has been used over the last 74 years, primarily in an attempt to improve water quality, with generally unsatifactory results. The existing utilized sources, predominantly less than 30 years old, generally provide unacceptable quality water for human consumption and domestic use.

Parks Canada attached high priority to this study on the water systems utilized for human consumption and domestic use. The main objective in my study is to develop water supply management strategies in which alternative futures options are identified and evaluated. The full implications of future choices are examined and selection between them is made. To prepare water supply management strategies, the water quality from existing utilized sources is evaluated and water treatment options are prescribed. Alternate sources are evaluated according to feasibility and relative cost, to provide recommendations for immediate implementation.

2. STUDY AREA

The study area comprises a 400 km^2 area centered upon Elk Island National Park, and includes surrounding land located within the counties of Strathcona, Lamont and Beaver, Alberta.

PHYSICAL SETTING

2.1 Location

Elk Island National Park is located approximately 40 km east of Edmonton, Alberta, in the northeast corner of the Cooking Lake Moraine. The Park consistsof 194 km^2 of rolling woodlands and meadows, with numerous lakes and wetlands. The Park is located within the northern half of Township 52, Range 20, all of Township 53, Range 20, and the eastern half of Township 54, Range 20, west of the Fourth Meridian. Park access is obtained through the main gate on highway 16, 37 km east of Edmonton, the north gate on a paved secondary road 6.5 km south of Lamont, and the northwest gate on a paved country road 16 km east south east of Josephburg.

2.2 Topography

Elk Island National Park is in a hummocky moraine that rises 30 to 60 m above the general level of the surrounding plain, representing a local topographic high. Elevations within the Park generally range from 710 to 740 m above mean sea level. The highest points in the Park are in the southwest (760 m) and the lowest points are along the eastern boundary (704 m).

Topographic features include till knobs and ridges, kettles and prairie mounds, typical of hummocky moraine (Jennings, 1984). There are also areas of low relief, primarily in the south central, southwest and southeast areas of the Park.

2.3 Climate

The regional climate is described as being dry continental, with short warm summers and long cold winters. The warmest month is July (average 16.5±C) and the coldest month is January (average -18.0±C) (Alberta Environment, 1983). Long term average precipitation is approximately 450 mm, with a maximum falling as rain in the months of June, July and August. Winter snowfall averages 100 mm water equivalent. The nearest recording Atmospheric Environment Service Weather Stations are located at Ellerslie, Edmonton International and Municipal Airports and at Namao.

2.4 Soils

Soils within Elk Island National park are classified as Podzolic, or grey and dark grey wooded (Kjearsgaard, 1967). The soils generally have moderately severe to severe limitations for agricultural production; primarily poor fertility, excess soil moisture and poor drainage, and unfavorable topography. Most of the soils are rated class 3 or lower, although in the east central area of the Park there is some class 2 soil, rated as fairly good to good arable soil (Alberta Soil Survey, 1962). There are numerous pockets of organic soils throughout the Park, with a concentration in the northern and central areas.

2.5 Water Balance

Soil moisture storage within Elk Island National park is above average for the general area, due primarily to the prevalent forest cover (Laycock, 1985). In average years surface runoff is derived from snowmelt to a great extent and is not very significant. In years when late summer and fall rains have recharged soil moisture storage, and heavy winter snowfalls have accumulated, spring surface runoff can be very significant. Groundwater recharge is not uniform, but in most years is small due to large amounts of evapotranspiration from the forest cover. Areas within the Park of lower soil moisture storage (eg: cleared land and pasture) and areas of more permeable surficial deposits (eg: outwash sands and gravels) have higher amounts of groundwater recharge (Laycock, 1985).

2.6 Hydrography

The largest waterbody in the Park is Astotin Lake, with an intermittent outlet through Astotin Creek to the northwest. The outlet is controlled by Park staff and the lake level is lowered if required to protect shoreline development (Parks Canada). Tawayik and Little Tawayik Lakes are located in the centre of the Park and have intermittent outlets. Oster Lake is located near the west park boundary, west of Tawayik Lake, and also has no outflow in most years. Flyingshot Lake is located in the southwest of the park, and has no apparent outlet. Goose Lake on the eastern Park boundary adjacent to highway 16 drains via a small stream to the north and east, into Drygrass Lake in the County of Lamont.

There are eight other smaller named lakes within the park. Lake levels have fluctuated considerably in the past, reflecting climatic patterns to some degree but influenced by changes in land use and vegetative cover (Laycock, 1973). All the lakes are shallow and eutrophic.

2.7 Geology

Late Cretaceous bedrock formations subcropping beneath Elk Island National Park are, in ascending order, the Belly River (Kbr), Bearpaw (Kbp) and Horseshoe Canyon (Khc) Formations. The upper surface of the bedrock has been highly eroded and is overlain by surficial deposits of predominantly hummocky moraine (Alberta Research Council, 1978, Carlson, 1966).

The Belly River Formation is approximately 300m thick under the Park and slopes to the southwest. It consists of interfingering successions of marine grey and green shales and deltaic grey and greenish grey sandstones. The thick (15 m - 45 m) basal Belly River sandstone members are absent under the Park. The Bearpaw Formation is approximately 40 m thick under the Park and also slopes to the southwest. It consists of predominantly dark grey marine shales interfingering with nonmarine sandstones and shales. The Horseshoe Canyon Formation is approximately 100 m thick west of the Park but pinches out east of the Park. The formation has a northwest to southeast strike and dips approximately 5 m per kilometre to the southwest. It consists of lenticular beds of nonmarine and brackish grey, green and white sandstones, grey, green and brown shales, coal seams and beds of carbonaceous shale. Most of the sandstone and shale beds are bentonitic.

Surficial deposits within the Park can generally be classified as hummocky moraine, consisting of till with sand and gravel lenses. Prairie mounds and till ridges are predominant. Fluvioglacial outwash and lacustrine sediments are located primarily in the south central, southwest and southeast areas of the Park (Jennings, 1984). Thickness of surficial deposits ranges from 10 - 40 m, being somewhat thicker in the west of the Park (Stein, 1976). Extensive outwash sand and gravel deposits are located northwest of Åstotin Lake, and to a lesser extent southeast of Flyingshot Lake. Preglacial channels filled with sands and gravels are dispersed throughout the Park, concentrated in the southern area (Bayrock, 1972).

2.8 Hydrogeology

The hydrogeological basement under Elk Island National Park is the Cretaceous Belly River Formation; the elsewhere productive basal Belly River Sandstone aquifer is absent underneath the Park. (Alberta Research Council, 1978). Water quality from the Belly River shales and sandstones is poor, with total dissolved solids approaching 3000mg/L, primarily sodium chloride (Stein, 1976). The probable yield of the Belly River Formation is 1-5 ig/minute (4.5-22.5 L/minute) (See figure 4.1).

Above the Belly River Formation lies the Cretaceous Bearpaw Formation which is overlain by the Cretaceous Horseshoe Canyon Formation which pinches out east of the Park. The probable yield of both Bearpaw and Horseshoe Canyon Formations is 1-5 ig/minute (4.5-22.5 L/minute). Water quality in wells completed in these formations is poor, with total dissolved solids ranging from 1000-2000 mg/L, primarily sodium bicarbonate and sodium sulphate (Stein, 1976). In the southwest of the Park, the Horsehoe Canyon Formation is thicker and interbedded with coal seams. Depending upon the degree of fracture permeability within the coal seams, yields of 5-100 ig/minute (22.5-454 L/minute) can be expected.

Regiohal groundwater flow primarily within the bedrock is limited, due to generally low permeability, extensive faulting and higher rates of recharge and discharge through groundwater flow in the surfical deposits. Individual well yield from the surficial deposits is 1-5 ig/minute (4.5 - 22.5 L/minute). Water quality in the surficial deposits is variable, being generally good in upland recharge areas (total dissolved solids less than 1000 mg/L), but poorer in the lowland discharge areas (total dissolved solids 1000-2000 mg/L). The major cations are calcium and magnesium and the major anions are carbonate and bicarbonate (Stein, 1976). Sulphate anions are predominant in the discharge areas, and high iron content is a problem in some of the shallower wells.

Within the surficial deposits, areas of greater permeability exist that can result in higher well yield. Northwest of Astotin Lake and beyond Park boundaries, outwash sand and gravel is rated at 5-25 ig/minute (22.5-114 L/minute) probable yield. In the southeast of the Park, outwash sand and gravel is also rated at 5-25 ig/minute (22.5-114 L/minute) probable yield, and sands and gravels within buried preglacial channels may yield in excess of 25 ig/minute (114 L/minute) (Stein, 1976).

DEVELOPMENT

2.9 **Land Use**

An area of the Cooking Lake Forest Reserve was incorporated as a Dominion Park in 1913, and as a National Park in 1930; to become known as Elk Island National Park. The size of the Park has increased since then with various land aquisitions. Parks Canada has maintained Elk Island National Park as a wildlife reserve (Parks Canada). The Park provides excellent habitat for wildlife, including ungulates, small mammals and birds. Plains bison were introduced into the Park and the present herd size is approximately 500. A herd of 230 wood bison roam the southern isolation area of the Park. In addition, there are approximately 850 elk and 350 moose in the Park at present (Parks Canada, 1986).

2.10 **Vegetation**

Elk Island National Park lies within a 2,500 km^2 pocket of boreal mixed woodland, known as the Beaver Hills. The woodland lies within the larger Aspen Parkland ecoregion of Alberta (Bichlmaier, 1985). Vegetation within the Park is varied. Most of the upland is covered with aspen forest, with numerous scattered individual white spruce. Upland grasslands occur where land had previously been cleared for pasture. White spruce stands are restricted to areas that have escaped fires, and to near the lakeshores.

The lowlands are generally poorly drained and are dominated by balsam poplar stands, with variable numbers of aspen. A dense undergrowth of shrubs and herbs is found in the lowland woods. Wetland vegetation consists primarily of reeds and sedges, with willows on the wetland periphery. Isolated communities of paper birch and black spruce occur adjacent to the wetlands.

2.11 Recreational Facilities

Recreation in Elk Island National Park is a major land use. Recreation is both nature oriented and activity oriented. The numerous lakes and wetlands and 80km of walking and hiking trails provide excellent opportunities for nature observation. An Interpretive Centre at Astotin lake complements nature observation as well as an Information Centre and bison paddock near the main gate.

Activities popular in the Park include camping, picnicing and golfing in summer, and cross country skiing in winter. A public campground is located at Astotin Lake, with a snack bar concession. Canoes and boats are available for rent at Sandy Beach on Astotin Lake, but the swimming beach has been closed in recent years due to the prevalence of swimmer's itch. A group campground at Oster Lake is available for use. Picnic areas are located at Astotin, Oster and Tawayik Lakes, with a new development planned for Flyingshot Lake in combination with hiking trails in the near future. The golf course is well used, and includes a clubhouse. Cross country skiing is centered upon the Tawayik day use area and the Hayburger and Moss Lake Trails.

2.12 Administrative Facilities

Park administration facilities are centered on the west side of Astotin Lake, adjacent to the northwest gate. The Headquarters offices, Warden Station, Maintenance Depot and ten staff houses are located here. At the main gate adjacent to highway 16 is the Information Centre and the Information Station staff house. Other Station staff houses are located at Oster Station near the campground on the west side of Oster Lake, at the former Canadian Wildlife Service (CWS) laboratory in the southwest of the Park, and at Isolation Station in the extreme south of the Park. Isolation Station staff house is presently unused.

3. PRESENT WATER DEMANDS

A memorandum from the Public Health Engineering Division of the Department of National Health and Welfare to the Superintendent at Elk Island National Park documents the water supply problems at the Park that had evolved from the time the Park was incorporated in 1913 (Parks Canada).

By 1955, Park facilities adjacent to Astotin Lake included several picnic grounds, a dance hall, a restaurant, a refreshment stand, a golf course, a Church camp and several cabins for rent, in addition to employee's residences and bunkhouses and a kitchen for workmen. A total of eighteen wells were utilized adjacent to Astotin Lake to supply these faciliites. The wells ranged in depth from 30-300' (9.1 - 91 m), with the shallower wells containing hard water and the deeper wells containing soft water. The hard water apparently contained large amounts of iron and iron bacteria, confirmed by analysis. Occasional high nitrate nitrogen concentrations were reported, and most often attributed to decaying mice that had fallen into the cribbed wells. The soft water contained excess sodium bicarbonate and sodium sulphate and "undoubtedly [were] responsible for cathartic effects to many visitors to the Park."

Treatment employed was primarily annual shock chlorination of the wells infested with iron bacteria, with "considerable temperary improvement." An experimental aeration system was installed on one well infested with iron bacteria "but little improvement in the taste and odor of the water [was] hoped for." The Public Health Engineering Division estimated the cost of a hardness, iron and iron bacteria treatment system to cost $2000 or more per well. Cost of an ion-exchanger for sulphate removal was estimated at $3500 per well. The recommendation given was to install an intake pipe and sand infiltration well into Astotin Lake at a cost of $1000. Algae control in the Lake with copper sulphate was recommended to be continued at a greater frequency. The sand infiltration was intended to reduce both residual algae content and the color of the Lake water. Post treatment for domestic use with a water softener was recommended at an estimated cost of $300 per domestic supply.

In 1986, water withdrawal for human consumption and domestic use at Elk Island National park is estimated in this study as 2,962,300 imperial gallons per year (ig/y) (13,448 cubic meters, m^3). (See Table 3.1) The bulk of the water withdrawn (89%) is surface water from Astotin Lake for use at the Astotin Lake Campground area and at the Administration Headquarters area. Groundwater withdrawal, from eight individual wells located throughout the Park, comprises 11% of total withdrawal for use at Station staff houses, the Information Centre, Oster Campground and North Point day use areas, and for confined animals.

In addition to the water withdrawal examined, significant withdrawal occurs from Astotin Lake for irrigation of the golf course and Administration Headquarters grounds. Unconfined wildlife consumption from waterbodies throughout the Park is less significant.

3.1 Astotin Lake Campground Area

The Astotin Lake Campground area water demand consists of water for the campground, Interpretive Centre, golf course clubhouse, snackbar and for faucets, drinking fountains and washrooms with flush toilets, located throughout the area. Supply is obtained from Astotin Lake through an intake, treated and stored at a plant adjacent to the day use facilities, then distributed throughout the area. The water treatment plant is operated during the May to September period each year.

TABLE 3.1 PRESENT WATER DEMANDS (1986)*

SURFACE WATER:	ig/y	m^3/y
Astotin Campground area	771,000	3,500
Administration Headquarters Area	1,877,000	8,522
SUB TOTAL	2,648,000	12,022
GROUNDWATER:		
Oster Station	73,000	331
Oster Campground	20,000	91
CWS Station	73,000	331
Information Station	73,000	331
Isolation Station	N/A	N/A
Information Centre	45,000	204
North Point Well	3,500	16
Horse Barn Well	17,500	80
Mud Lake Corrals	5,100	23
Isolation Corrals	4,200	19
SUB TOTAL	314,300	1,426
TOTAL	2,962,300	13,448

* Present water demands for surface water are based upon weekly plant operation time estimates provided by park staff, and upon estimates of plant capacity. Groundwater demands are based upon estimated unit consumption rates and estimated levels of demand. As such, errors are inherent and the use of five significant figures in the table and text does not imply great precision.

The design capacity and present operating capacity of the water treatment plant is 50 ig/minute (227 L/minute). The plant is operated for an average of 12 hours per week during the operating season for an annual total of approximately 255 hours. Annual plant production is therefore 771,000 ig ($3,500\ m^3$). Records at the Park indicate that in 1968, the last year that water meter readings were available, the annual plant production was 500,500 ig ($2,272\ m^3$).

Water withdrawal for use at the campground is a significant portion of the total water use at the Astotin Lake campgound area. In 1985, 4,400 campsites were rented out, representing approximately 14,000 individual campers; the average stay at each campsite was 3 days. Per capita water demand for campers can range between 5 - 25 ig/d (22.5-114 L/d), depending upon the degree of utilization of Park communal faucets and washroom facilities (EPA,1973). If an average per capita water demand for campers of 10 ig/d (46 L/d) is assumed, the annual demand for the campground alone is 420,000 ig ($1,907\ m^3$), or 54% of total water use from the plant.

If water demand at the Astotin Lake campground area is assumed to peak on weekends during the summer, then an estimate of peak daily demand is 12,850 ig/day ($58\ m^3/d$) (20 three-day weekends per season).

3.2 Administration Headquarters Area

The Administration Headquarters area water demand consists of water for the Headquarters offices, Warden Station, Maintenance Depot and Staff houses. Supply is obtained from Astotin Lake through an intake, treated and stored at a plant adjacent to the Staff houses, then distributed to ·ch building in the area. The water treatment plant is operated year-round basis.

The design capacity and present operating capacity of the water treatment plant is 50 ig/minute (227 L/minute). The plant is operated for an average of 12 hours per week for a total of approximately 625 hours (Parks Canada). Annual plant production is therefore 1,877,000 ig (8,522 m^3). There are no records of past meter readings available. Mean daily demand is 5,142 ig (23 m^3); assuming a peak factor of 3, peak daily water demand is estimated as approximately 15,500 ig (70 m^3).

3.3 Station Staff Houses

There are four designated Stations located throughout the Park: at Oster Lake near the campground; at the former CWS laboratory; at the Information Centre; Isolation Station in the South of the Park (See Chapter 4). Each Station has one staff house, each supplied by a drilled well. The average number of persons occupying each house can be assumed to be four. If average per capita water demand is estimated as 50 ig/d (227 L/d) (EPA,1973) then each occupied station staff house has an annual water demand of 73,000 ig (331 m^3). Peak daily water demand at each station house can be estimated as four times mean daily demand, or 800 ig/d (3.6 m/d) (EPA, 1973). Isolation Station staff house is at present unoccupied.

3.4 Other Campground & Day Use Areas

Oster Lake group campground, located adjacent to Oster Station, is supplied with water from a drilled well shared with the Oster Station staff house. Water demand at the campground is primarily for registered campers. An average of 2,000 campers per year stay at the campground, primarily in the months of March, April, May, September and October. Average duration of stay is 2 days. If water demand per camper from the staff house outside faucet is assumed to be 5 ig/d (23 L/d) (EPA,1973) then annual demand is 20,000 ig (91 m^3). Peak demand occurs on weekends and is estimated as 480 ig/d (2.2 m^3/d) (20 two-day weekends per season).

The Tawayik Lake day use area has no water source at present and offers no water facilities. The Flyingshot day use area currently planned also does not incorporate water facilities.

The North Point bored well located adjacent to Beaver Bay on the south side of Astotin Lake serves a small day use area. Annual water demand is estimated as 3,500 ig (16 m^3).

3.5 Information Centre

The Information Centre is supplied from a drilled well that also supplies the Information Station staff house. Water facilities at the Centre include washrooms with low volume flush toilets and exterior drinking fountains. The Information Centre is open from April until September each year. Recorded Park visitors at the main gate were 336,043 in 1985; the average annual number of visitors in the last ten years is approximately 350,000 (Parks Canada).

If it is assumed that ten percent of all visitors to the Park visit the Information Centre and use 1 ig (4.5L) each at either the drinking fountains or washrooms, then a water demand of 35,000 ig/y (159 m^3/y) can be estimated (EPA,1973). An additional 10,000 ig/y (45 m^3/y) can be expected for cleaning and housekeeping at the Centre, giving a total annual water demand estimate of 45,000 ig (204 m^3). Peak daily water demand is assumed to occur on weekends and is estimated as 2,150 ig/d(5.1 m^3/d).

3.6 Mud Lake Bison Corrals

Water demand at the Mud Lake bison corrals occurs in winter, when plains bison and elk are confined for short periods prior to shipment out of the Park. Water for the confined animals is provided from a bored well and stock tank. In the winter of 1985-1986, 100 bison were confined for 30 continuous days, and 30 elk were confined for 14 days on five separate occasions. Water consumption by the animals was measured by Park staff and averaged 1 ig/d (4.5 L/d) per head (Parks Canada). Annual water demand can therefore be estimated as 5,100 ig/y (23 m^3/y). Peak demand occurs when bison and elk are confined simultaneously and is estimated as 130 ig/d (0.6 m^3/d).

3.7 Isolation Bison Corrals

Wood bison are confined at the Isolation bison corrals for three weeks in winter, prior to shipment out of the Park. An average of 200 head are confined, consuming 1 ig (4.5L) each per day (Parks Canada). Annual water demand is estimated as 4,200 ig (19 m^3) with an average daily demand of 200 ig (0.9 m^3).

3.8 Horse Barn

Staff horses at Information Station are housed in a barn and supplied with water from a drilled well, independent from the

Information Centre and staff house well. If average daily consumption is assumed to be 12 ig (54L) per horse (EPA,1973), then the annual water demand for the four horses is 17,500 ig (80 m^3). Peak daily water demand (48 ig or 0.2 m^3) is estimated as mean daily demand, since the stock tank is only filled once a day.

Water consumption by bison and elk would undoubtedly increase if the pumped water was freely available. The present provision of 1 ig per head per day is supplemented by considerable consumption of snow by the bison and elk.

4. EXISTING UTILIZED WATER SOURCES*

Astotin Lake is utilized to provide 89% of the water withdrawn for human consumption and domestic use in Elk Island National Park. The Astotin Lake campground plant provides 26% and the Astotin Lake Administration Headquarters plants provides 63% Eight individual groundwater sources provide the remaining 11% of water for human consumption and domestic use. The derivation of these estimates is discussed in Chapter 3.

4.1 Astotin Lake Campground Plant (L1)

The Astotin Lake campground plant was built in 1961 and has been operated on a seasonal basis (May through September) ever since. In 1986, the plant consists of:

- a gravity flow pipe intake into the lake
- a raw water sump in the plant building, connected to the intake
- a cascade aerator
- a microstrainer
- a gas chlorinator
- a clear water sump
- a hydropneumatic storage tank

* The symbols after each water source refer to its location on the map (Figure 4.1 Locations of Water Sources in Elk Island National Park).

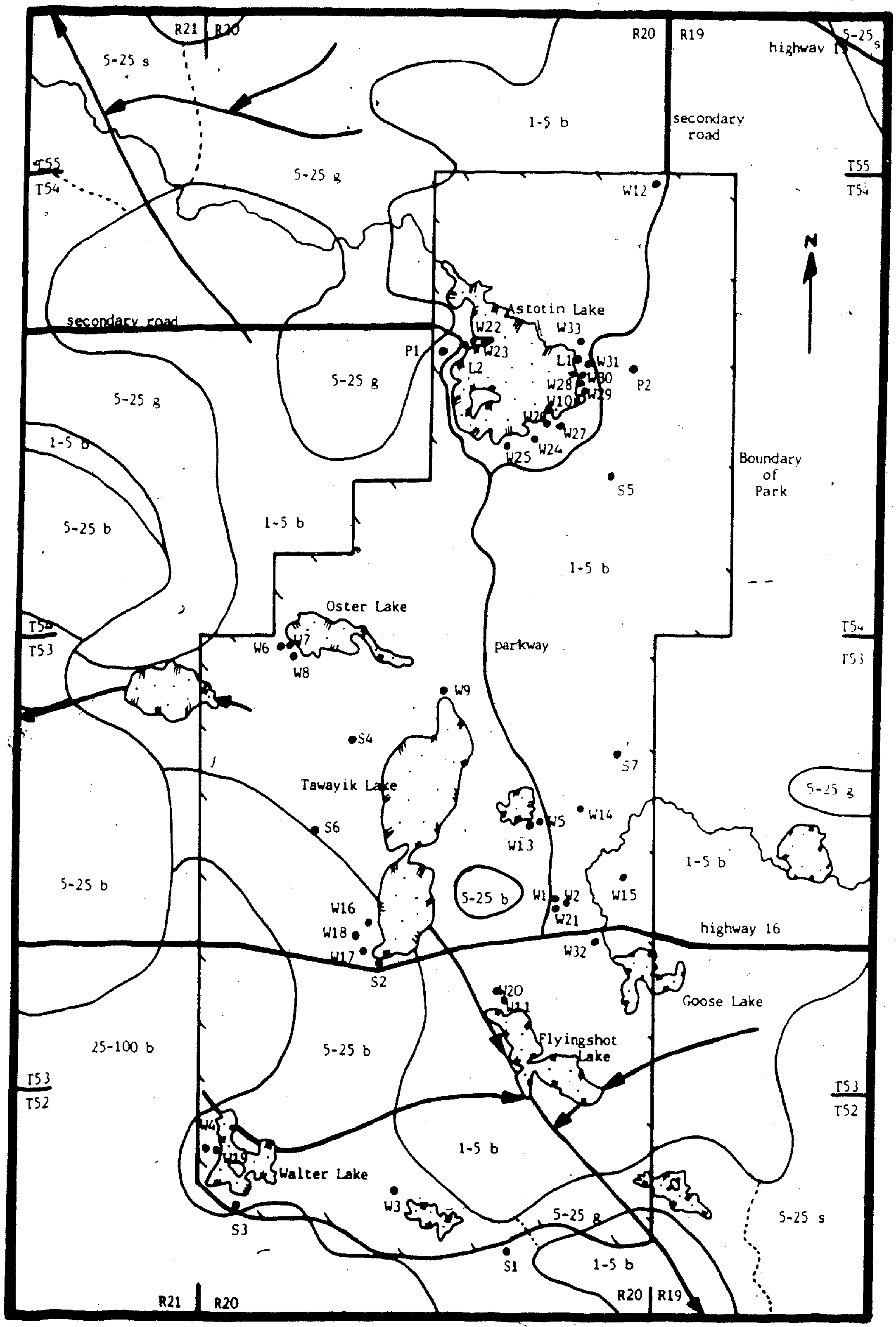

R21
R20
R19
highway 16
5-25 s
secondary road
1-5 b
5-25 g
T55
T54
T53
T52
W12
N
Astotin Lake
W22
W33
P1
W23
L2
L1
W31
W30
P2
W28
W29
W10
W26
W27
W24
W25
Boundary of Park
S5
5-25 b
Oster Lake
parkway
W6
W7
W8
W9
S4
S7
Tawayik Lake
W14
W5
W13
S6
W1
W2
W15
W16
W18
W21
W17
W32
S2
W20
W11
Goose Lake
Flyingshot Lake
25-100 b
W4
W19
Walter Lake
W3
S3
S1

FIGURE 4.1 Locations of water sources in Elk Island National Park

W	well
S	spring
L	lake intake/plant
P	sewage lagoon
1-5 b	yield 1-5 ig/minute in bedrock
5-25 b	yield 5-25 ig/minute in bedrock
25-100 b	yield 25-100 ig/minute in bedrock
5-25 s	yield 5-25 ig/minute in sand
5-25 g	yield 5-25 ig/minute in gravel
T	township
R	range
	thalweg of buried preglacial channel
	Park boundary

Adapted from
Source: Stein, 1976, and Author

Originally, the plant was constructed without the cascade aerator, which was added in 1963. A diatomaceous earth vacuum filter was part of the original plant equipment, but was disconnected in 1968 and is still unused. A water meter was installed sometime after the plant was in operation and removed in 1969. Design specifications and operating records indicate that the plant capacity is 50 ig/minute (227 L/minute).

The galvanized steel gravity flow intake pipe is 250 mm in diameter and extends 40 m into the lake. The intake inlet is approximately 2.1 m below water level and approximately 0.3 m above the lake bed. The inlet is equipped with a grate screen with 40 mm slots. The concrete raw water sump is 1,050 mm in diameter and approximately 6.7 m deep.

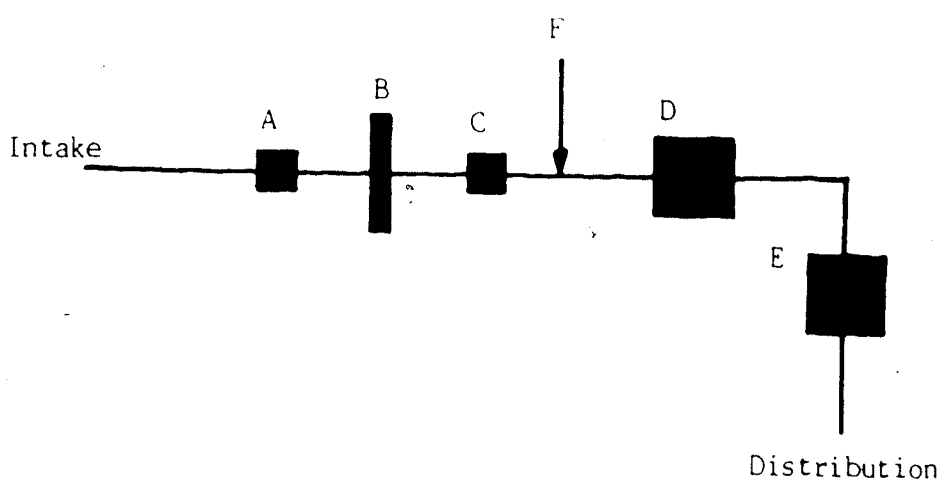
A cascade aerator was added in 1963. Water is pumped from the raw water sump to the top of the approximately 2.5 m high aerator, and allowed to cascade over a series of baffle plates, and discharge into a small concrete storage chamber.

Water is pressurized through the rotating ~~mi~~crostrainer screen, which is intended to be self-cleaning. Particulate organic matter can plug the microstrainer however, and flow from the microstrainer and, hence plant capacity, has been restricted in the past; 30 ig/minute (136 L/minute) in 1964 & 1967. In 1967, the microstrainer was bypassed and remained inoperative until 1968, when it was re-connected. During the time that the microstrainer was bypassed, a cyclone separator was installed on a trial basis, but failed to significantly reduce the particulate organic matter content of the water.

The gas chlorination system originally installed is still in operation. The chlorine gas feed rate is controlled by adjustment of a

Figure 4.2

Astotin Lake Campground Plant 1986 (schematic)



A Raw water sump
B Cascade aerator
C Microstrainer
D Clear water sump
E Hydropneumatic tank
F Gas chlorination

chlorine control valve, in response to variations in water line pressure.

The diatomaceous earth vacuum filters were subject to frequent plugging. Frequent filter backwashing, and resultant media loss, resulted in the consumption of approximately 7 pounds (3.2 kg) of diatomaceous earth for every 1,000 ig (4.5 m^3) of treated water produced in 1967. Several types and grades of diatomaceous earth media were tried in the filter, including precoated media, without successfully improving filter operation. The filter was bypassed in 1968 and remains unused.

A clear water well located after the diatomaceous earth filter collects treated water, which is then pumped into a 22,000 ig (100 m^3) steel hydropneumatic tank. Water is supplied under an average of 50 psi (350 kPa) to the campground area distribution system.

Chemical water analysis reports are available for raw and treated water from the plant, from 1961 until the present. Little variation is evident in the overall chemical quality of the raw lake water during this period (see Table 4.2). The 1986 chemical water analyses (see appendix 1.1 and 1.2) indicate that the raw and treated plant water meets or exceeds the Guidelines for Canadian Drinking water Quality 1978 (Health and Welfare Canada, 1979). A maximum acceptable level for hardness has not been established, since public acceptance of hardness varies considerably; however, it is suggested that hardness in excess of 200 mg/L is considered undesirable. The hardness of the raw lake water, primarily calcium and magnesium bicarbonate, is slightly above the level considered desireable.

TABLE 4.1

MAXIMUM ACCEPTABLE & RECOMMENDED CONCENTRATIONS FOR CHEMICAL AND PHYSICAL WATER ANALYSES

Parameter	*Maximum Acceptable Concentration	* Objective Concentration	** Recommended Limit
Total Dissolved Solids	500	–	1,000
Hardness	–	–	200
Alkalinity	–	–	500
Sulphate	500	<150	500
Chloride	250	<250	500
Nitrate (as N)	10	<0.001	10
Nitrite (as N)	1.0	<0.001	1.0
Sodium	–	–	20
Bicarbonate	–	–	–
Iron	0.3	<0.05	0.3
Fluoride	1.5	1.0	1.5
Calcium	–	–	75
Magnesium	–	–	500
Potassium	–	–	–
Carbonate	–	–	–
pH	6.5-8.5	–	8.5
Color (TCU)	15	<15	–
Taste	–	inoffensive	–
Odor	–	inoffensive	–

*Health & Welfare Canada, 1979.
**Leduc-Strathcona Health Unit, 1984
All values in mg/L except as noted.

TABLE 4.2

SELECTED CHEMICAL ANALYSES
ASTOTIN LAKE CAMPGROUND PLANT

	1961		1964		1986	
	R	T	R	T	R	T
Total Dissolved Solids	448	451	360	682	451	317
Hardness	263	265	230	245	240	145
Alkalinity	142	144	222	235	200	165
Sulphate	180	177	23	202	88	34
Chloride	3	4	0	10	4	2
Nitrate & Nitrite N	0.1	0.1	0	<0.1	0.2	<0.1

R = Raw water

T = Treated water

Values expressed as mg/L

Values rounded

Source: Parks Canada; Author

Bacteriological water analysis reports are also available for the 1961 to 1986 period. The analyses consistently show no evidence of bacteriological contamination, as indicated by the absence of both total coliform and fecal coliform bacteria. The general bacterial population, as indicated by frequent standard plate counts in excess of 3,000/ml, is evidence of high concentrations of micro-organisms in the raw and treated water, which is common in surface water supplies. Adequate chlorine residuals in the distribution system are required to prevent bacterial growth, when standard plate counts exceed 500/ml (Health & Welfare Canada, 1979).

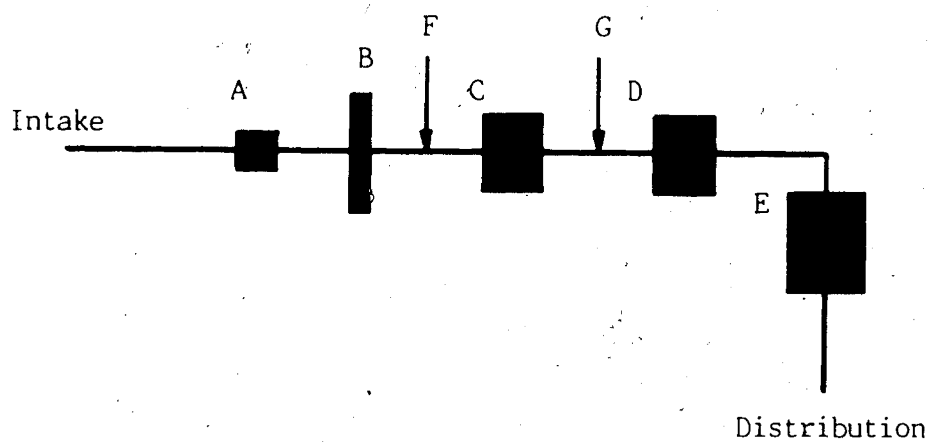
Physical water quality is not well quantified, but objectionable tastes, odors and color are the main reasons for complaints about water quality from the plant. The water is high in particulate organic matter, primarily decomposing algae and aquatic vegetation. The prevalent description of the water's taste and odor is "swampy or organic." The water color is light yellow, typically ranging from 50-200 true color units, which exceeds the recommended limit of 15. Occasional complaints of an objec[illegible]able chlorine taste and odor are caused by variations in the free chlorine residual. Records at the plant for 1986 indicated a free chlorine residual range of 0.1 - 2.0 mg/L so far that year.

4.2 Astotin Lake Administration Headquarters Plant (L2)

The Astotin Lake administration headquarters plant was built in 1963 and has been operated on a year-round basis ever since. The plant has not been modified since construction, and consists of:

Figure 4.3

Astotin Lake Administration Headquarters Plant 1986
(schematic)



A	Raw water sump
B	Cascade aerator
C	Coagulant/flocculation chambers
D	Gravity sand filter
E	Hydropneumatic tank
F	Gas pre-chlorination
G	Gas post-chlorination

- a gravity flow pipe intake into the lake
- a raw water sump in the plant building, connected to the intake
- a cascade aerator
- gas prechlorination
- coagulation and flocculation with aluminum sulphate, with sodium carbonate buffering
- gas postchlorination
- a gravity sand filter
- a hydropneumatic storage tank

Design specifications and operating records indicate that the plant capacity is 50 ig/minute (227 L/minute).

The galvanized steel gravity flow intake pipe is 100 mm in diameter and extends approximately 15 m into the lake. The intake inlet depth below water level is not recorded, but is assumed to be less than approximately 2 m, since the receiving raw water sump bottom is approximately 2 m below lake water level. This should be confirmed by measurement when conditions permit. The concrete raw water sump is rectangular, 900 mm x 1,200 mm x 3,000 mm deep.

Water is pumped from the raw water sump into the elevated cascade aerator, which is approximately 1,000 mm high, and allowed to cascade over a series of baffle plates. Compressed air is introduced concurrent to the water flow by a blower. The water is then prechlorinated with a gas chlorinator, and then flows into a contact chamber. The contact chamber is 1,730 ig (7.9 m^3) capacity.

Aluminum sulphate is fed as a solution into the contact chamber with a positive displacement feeder pump. The feed ratio for the aluminum sulphate solution is approximately 1,000:1 by volume. After detention and mixing in the contact chamber, the water passes into a settling chamber and is post chlorinated with a gas chlorinator. Sodium carbonate is fed as a solution into the settling chamber effluent, prior to filtration, to raise pH back to a neutral range.

In 1966, several other combinations of water treatment were evaluated. A coagulant aid, activated silica, was fed in addition to the aluminum sulphate, in an attempt to improve treated water quality. Also, activated carbon was fed by a volumetric solids feeder into the contact chamber for taste and odor control. Potassium permanganate solution was evaluated for taste, odor and color removal. The three trial evaluations in 1966 did not significantly improve treated water quality, and were discontinued.

The gravity sand filter is 1,050 mm in diameter and contains an approximately 1,070 mm deep filter bed, composed of graded sand with a gravel support bed. The flow rate through the bed is approximately 5 ig/ft^2 (244 L/m^2). Backwash flow rate available is 90 ig/minute (409 L/minute).

Water from the gravity sand filter is collected in a clear water sump, then pumped into a 330 ig (1.5 m^3) steel hydropneumatic tank. Water is supplied under pressure at approximately 55 pounds/square inch (385 kPa) to the administration headquarters distribution system.

TABLE 4.3

SELECTED CHEMICAL ANALYSES
ASTOTIN LAKE ADMINISTRATION HEADQUARTERS PLANT

	1963		1964	1966	1986	
	R	T	T	T	R	T
Total Dissolved Solids	NV	NV	209	380	303	294
Hardness	202	202	184	230	135	135
Alkalinity	202	288	190	195	160	145
Sulphate	NV	NV	38	51	29	27
Chloride	NV	NV	3	5	2	14
Nitrate & Nitrite N	NV	NV	<0.01	0	0.8	0.1

R = Raw Water

T = Treated Water

NV = No value reported

Values expressed as mg/L

Values rounded

Source: Parks Canada and Author

Chemical water analysis reports are available for the raw and treated water from the plant, from 1963 until the present. Most chemical analyses on file are for the treated water. During 1965, the water treatment plant operator kept weekly records of the raw and treated water hardness and alkalinity (calcium carbonate equivalent). Little variation is evident in the overall chemical quality of the raw and treated water during the time the plant has been in operation (see table 4.3). The 1986 chemical water analyses (see appendix 1.3 and 1.4) indicate that the raw and treated plant water meets or exceeds the Guidelines for Canadian Drinking Water Quality 1978 (Health & Welfare Canada, 1979, Leduc-Strathcona Health Unit 1984). Although hardness has exceeded the desireable level of 200 mg/L in the past, it is in 1986 at an acceptable level.

Bacteriological water analysis reports are also available for the 1963 to 1986 period. The analyses consistently shows no evidence of contamination, as indicated by the absence of both total coliform and fecal coliform bacteria. The general bacterial population in the treated water is low, as indicated by frequent standard plate counts of 100/ml or less.

Physical water quality is well quantified. Objectionable tastes, odors and color are the main reasons for complaints about the water quality from the plant. The water is high in particulate organic matter, primarily decomposing algae and aquatic vegetation. The water has an "organic or swampy" taste and odor. The water color is light yellow, typically ranging from 50-250 true color units, which exceeds the recommended limit of 15. Objectionable chlorine tastes and odors are not common; records at the plant for 1986 indicated a free chlorine residual range of 0.1 - 0.3 mg/L so far that year.

Evaluation and discussion of the Astotin Lake Plants is contained in Chapter 9.

4.3 Station Wells

Oster Station staff house well (W6) also supplies the Oster Lake group campground through an outside communal faucet. The well was drilled in 1971 to a total depth of 46 m. The static water level in the well is recorded as 12 m. Well completion details and well yield data are not available, but it is assumed that the well is completed as an open hole in a sandstone and shale aquifer sequence within the Cretaceous Bearpaw Formation. Well yield is estimated as 1-5 ig/minute (4.5-22.5 L/minute). The only water treatment equipment installed at Oster Station is a small in-line cartridge-type sediment filter.

Chemical water analysis reports are available for the Oster Station Well from 1971 until the present. Some variation is evident in the overall chemical water quality during this period (see table 4.4). Apparently, hardness and sulphate levels have decreased, while chloride levels have increased. The 1986 chemical water analysis (see appendix 1.5) indicates that the well water contains excess total dissolved solids, alkalinity, sodium and bicarbonate (Health and Welfare Canada, 1979. Leduc-Strathcona Health Unit, 1984). The maximum acceptable concentration for total dissolved solids has been established by Health and Welfare Canada as 500 mg/L. The Leduc-Strathcona Health Unit comments that "good waters generally have less than 1,000 mg/L." Oster Station well contains 2,363.4 mg/L total dissolved solids (1986). Maximum acceptable concentrations for alkalinity, sodium and bicardonate have not been established. However, a recommendation for a maximum desireable concentration of alkalinity is 500 mg/L. The Oster Station Well contains 1,080 mg/L alkalinity (expressed as calcium carbonate

TABLE 4.4

SELECTED CHEMICAL ANALYSES
OSTER STATION WELL

	1971	1973	1985	1986
Total Dissolved Solids	1,920	1,652	1,740	2,363
Hardness	260	52	61	40
Alkalinity	1,060	1,150	1,170	1,080
Sulphate	370	74	87	165
Chloride	4	176	178	186
Nitrate & Nitrite Nitrogen	3.7	2.1	<0.2	0.1
Sodium	NV	688	666	676
Bicarbonate	NV	1,150	1,425	1,318
Iron	NV	0.08	0.05	<0.1
Fluoride	NV	0.45	0.37	0.12

NV = No value reported

Values expressed as mg/L

Values rounded

Source: Parks Canada and Author

equivalent), composed primarily of sodium bicarbonate. Persons suffering from hypertension or congestive heart failure are advised to consult their physicians concerning sodium-restricted diets when the sodium concentration in their water continually exceeds 20 mg/L. The sodium concentration in the Oster Station Well is 676.2 mg/L (1986).

Bacteriological water analyses show no evidence of contamination at the Oster Station Well. The major complaint with physical water quality is the taste; described as a "soda" taste. This is caused by the high sodium bicarbonate concentration, which is common for wells completed in the Bearpaw Formation.

The Canadian Wildlife Service Station Well (W4) was drilled sometime prior to 1964. No well log is available, so that well depth, static water level, well completion details and well yield data are unavailable. It is assumed that the well is completed as an open hole approximately 50m deep into the Horseshoe Canyon Formation. Well yield is estimated as 1-5 ig/minute (4.5 - 22.5 L/minute). The water treatment equipment installed includes a 30,000 grain ion-exchange water softener with an attached sodium hydrosulphite resin-cleaner feeder.

Chemical water analysis reports are available for the CWS Station well from 1964 until the present. Little variation is evident in the overall chemical water quality during this period (see table 4.5). The hardness concentration is higher than expected from a well apparently completed in bedrock; leakage from higher surficial aquifers into the well is a possibility. The 1986 chemical water anlaysis (see appendix 1.6 and 1.7) indicates that the well water contains excess total dissolved solids, hardness, alkalinity, sodium and bicarbonate (Health & Welfare Canada, 1979, Leduc-Strathcona Health Unit, 1984). The total dissolved solids concentration (1,223 mg/L) and the alkalinity concentration (535 mg/L as calcium carbonate equivalent) are slightly above the maximum desireable concentrations established for the area. The alkalinity is composed of combinations of sodium, calcium and magnesium bicarbonate.

Treatment for hardness removal with the water softener is reducing the hardness from 345 mg/L (Raw 1986) to 35 mg/L (Treated 1986), and as such is successful. However, the ion-exchange process increases the sodium concentration from 200.1 mg/L in the raw water to 363.4 mg/L in the treated water.

Bacteriological water analyses are not available for the CWS Station well. However, a heavy infestation of non-pathogenic iron bacteria was observed in the water system in 1986. The growth of micro-organisms associated with iron creates accumulations of bacterial masses and hydrous iron within the water system, reducing system capacity and causing physical water quality problems such as tastes, odors and colors (AWWA. 1971, Alberta Agriculture, 1978).

The Information Station well (W1) also supplies the Information Centre, and was drilled in approximately 1976. No well log is available, but data obtained by the Alberta Research Council for the Park indicates the well is probably 80m deep (Parks Canada). Well yield is estimated as 1-5 ig/minute (4.5-22.5 L/minute). The well is assumed to be an open hole completed into the Cretaceous Bearpaw Formation, since the Horseshoe Canyon Formation is essentially absent under the eastern

TABLE 4.5

SELECTED CHEMICAL ANALYSES
CWS STATION WELL (RAW WATER)

	1964	1973	1986
Total Dissolved Solids	942	862	1,223
Hardness	370	364	345
Alkalinity	600	606	535
Sulphate	195	148	236
Chloride	1	0	4
Nitrate & Nitrite Nitrogen	~~0~~	2.0	0.2
Sodium	199	203	200
Bicarbonate	360	606	653
Iron	0.10	0.03	0.30
Fluoride	0.09	0.26	0.05

Values expressed as mg/L

Values rounded

Source: Parks Canada, Alberta Research Council and Author side of the Park (Stein, 1976). Water treatment equipment installed includes a 300mm diameter oxidizing iron filter with a potassium permanganate feeder, followed by two additional 300 mm diameter filter tanks presumably containing activated carbon or some other media.

Chemical water analysis reports are not readily available for the Information Station well. Some comparison of analyses can be made for specific constituents (see table 4.6). The 1986 chemical water analyses (see appendix 1.8) indicate that the well water contains excess total dissolved solids, alkalinity, sodium and bicarbonate (Health and Welfare Canada, 1979, Leduc-Strathcona Health Unit, 1984). The total dissolved solids concentration (2,337 mg/L) far exceeds the maximum desirable concentration for the area. The excess alkalinity (960 mg/L as calcium carbonate equivalent) is composed primarily of sodium bicarbonate.

Treatment for iron removal with the iron filter was not necessary when sampled in 1986, since both raw and treated samples contained less than 0.1 mg/L of dissolved iron. However, a raw iron concentration of 0.62 mg/L was recorded in 1985; sufficient to cause discoloration of the water and staining of plumbing fixtures.

Bacteriological water analyses are not available for the Information Station well. However, an infestation of non-pathogenic iron bacteria was observed in the water system in 1986. Complaints of a "rotten egg" taste and odor have been reported, which are characteristic of hydrogen sulphide. Hydrogen sulphide gas is usually either naturally present in some aquifers, or the result of the growth of anaerobic bacteria such as iron or sulphate-reducing bacteria (Alberta Agriculture 1978). The hydrogen sulphide concentration in the raw water was measured in July, 1986, with a Hach HS-7 test kit: the concentration was 0.3 mg/L. After treatment, the concentration was reduced to 0.1 mg/L. Both of these concentrations exceed the recommended limit of 0.05 mg/L.

Isolation Station Well (W3) [illegible] drilled in 1956 to a depth of 79 m. Static water level in the well [illegible] recorded as 6 m and the well yield established as 6 ig/minute (27 [illegible]te). The well was completed with 150 mm diameter steel surface casing to a depth of 49 m, with 100 mm diameter slotted steel liner to full depth. The aquifers are three fractured coal seams ranging in thickness from 50-75 mm and a sandstone seam 200 mm thick, interbedded in shale and siltstone within the Horseshoe Canyon Formation. Water treatment equipment installed includes a 30,000 grain ion-exchange water softener with an attached sodium hydrosulphite resin-cleaner feeder. Upstream of the water softener is a 10 micron cartridge-type in-line sediment filter and a batch polyphosphate feeder.

Chemical water analysis reports are available for the Isolation Station well from 1956 until the present. Considerable variation is evident in the overall chemical water quality during this period (see table 4.7). The changes in hardness, iron and chloride concentrations indicate possible leakage from higher surficial aquifers into the well. The 1986 chemical water analysis (see appendix 1.9 and 1.10) indicates that the well water contains excess total dissolved solids, alkalinity, sodium and bicarbonate (Health and Welfare Canada, 1979, Leduc-Strathcona Health Unit, 1984). The total dissolved solids concentration (1,703 mg/L) and alkalinity concentration (655 mg/L as calcium carbonate

TABLE 4.6

COMPARATIVE CHEMICAL ANALYSES
INFORMATION STATION WELL (RAW WATER)

	Undated	1985	1986
Total Dissolved Solids	1,900	1,760	2,337
Hardness	60	48	50
Alkalinity	1,140	1,108	960
Sulphate	473	323	451

Values expressed as mg/L

Values rounded

Source: Parks Canada and Author

alkalinity concentration (655 mg/L as calcium carbonate equivalent) are above the maximum desireable concentrations established for area. The alkalinity is primarily composed of sodium bicarbonate.

The water softener and associated water treatment equipment has not been used for some time, since the Station staff house is unoccupied.

Bacteriological water analyses show no evidence of contamination at the Isolation Station well. However, non-pathogenic iron bacteria was first noticed in the water system in 1956 (Parks Canada) and is still present. Associated taste, odor and color problems are present.

TABLE 4.7

SELECTED CHEMICAL ANALYSES
ISOLATION STATION WELL (RAW WATER)

	1956	1973	1986
Total Dissolved Solids	1,617	2,376	1,703
Hardness	449	246	105
Alkalinity	820	952	655
Sulphate	455	492	411
Chloride	NV	212	11
Nitrate & Nitrite Nitrogen	0.20	0.1	0.1
Sodium	426	750	453
Bocarbonate	492	952	775
Iron	32.0	NV	<0.1
Fluoride	0.52	0.34	0.05

NV = no value reported

Values expressed as mg/L

Values rounded

Source: Parks Canada and Author

4.4 Mud Lake Corrals Well (W13)

The date of construction of the Mud Lake Corrals bored well is unknown. The concrete cribbing is 760 mm in diameter and the measured well depth in 1986 was 25.2 m. Static water level was measured as 2.5 m. The well is approximately 100 m from Mud Lake and is assumed to be completed in surficial deposits, possibly bottomed-out in the top of the Bearpaw Formation. Well yield is estimated at 1-5 ig/minute (4.5-22.5 L/minute). There is a concrete lid over the well cribbing, and a wooden platform supporting a hand-operated deep well piston pump, that is used to fill a stock tank.

Chemical water analysis reports are available for 1985 and 1986 for the well. The analyses are quite dissimilar (see Table 4.8). The 1986 chemical water analysis indicates that the well water is satisfactory for all classes of livestock, but that temporary and mild diarrhea may result in livestock not accustomed to consuming the water which contains more than 1,000 mg/L total dissolved solids (Manitoba Agriculture). Alkalinity in the range of 500-1,000 mg/L is considered poor, but tolerable for livestock.

4.5 Isolation Corrals Well (W11)

The date of construction of the isolation corrals well is unknown and no well log is available. The well is cased with 75 mm diameter black iron casing and equipped with a deep well piston pump and an electric motor. A portable generator is used to supply power to pump the well when water is needed in the stock tank. The chemical water quality suggests that the well is completed in the Bearpaw Formation,

TABLE 4.8

SELECTED CHEMICAL ANALYSES FOR PARK LIVESTOCK WELLS

	Mudy Lake Corrals		Isolation Corrals		Horse Barn	
	1985	1986	1973	1986	1976	1986
Total Dissolved Solids	582	1,482	1,634	2,234	1,800	2,244
Sulphates	6	244	390	454	5	273
Alkalinity	460	650	938	875	1,030	1,035
pH	7.65	7.60	7.50	7.85	8.10	7.85
Nitrate + Nitrate N	<0.2	0.1	NV	0.1	0.02	0.1

NV = No value reported

Values Expressed as mg/L

Values rounded

Source: Parks Canada and Author

with a probable depth of 50-75 m. The well pumping rate is 2 ig/minute (9 L/minute) with present equipment.

Chemical water analysis reports are available for 1973, 1985 and 1986. The analyses show relatively some variation in chemical water quality during this period (see Table 4.8). The 1986 chemical water analysis indicates that the well water is satisfactory for all classes of livestock (Manitoba Agriculture). Water with a total dissolved solids concentration of 2,234 mg/L may cause temporary and mild diarrhea in livestock.

4.6 Horse Barn Well (W2)

The Horse Barn well located at Information Station was drilled in 1976. Total depth is recorded as 25 m with a static water level at 3 m. The well was pump tested at 8 ig/minute (36 L/minute) with a resultant drawdown of 18.6 m after 5 hours. The recommended pumping rate was established as 6 ig/minute (27 L/minute). The well is completed as an open hole in surficial deposits; the aquifer is a sandy gravel 2,100 mm thick. A manually controlled electric submersible centrifugal pump is installed in the well, filling a stock tank adjacent to the well head.

Chemical water analysis reports are available for 1976, 1985 and 1986. The analyses are somewhat dissimilar (see Table 4.8). The 1986 chemical water analysis indicates that the well water is satisfactory for all classes of livestock (Manitoba Agriculture). Water with a total dissolved solids concentration of 2,244 mg/L may cause temporary and mild diarrhea in livestock.

4.7 North Point Well (W10)

The North Point well adjacent to Beaver Bay on Astotin Lake is a bored well with 500 mm diameter concrete cribbing. The measured well depth in 1986 was 15.7 m and static water level was 1.3 m. The well is approximately 6 m from Astotin Lake and is assumed to be completed in surficial deposits. There is a concrete lid over the well cribbing supporting a hand operated deep well piston pump.

Chemical water analysis reports are available for 1985 and 1986 for the well. The analyses are quite dissimilar (see Table 4.9). The 1986 chemical water analysis (see appendix 1.14) indicates that the water contains excess total dissolved solids, hardness, alkalinity, sulphate, sodium and bicarbonate (Health & Welfare Canada, 1979, Leduc-Strathcona Health Unit, 1984). The total dissolved solids concentration (2,047 mg/L) is well above the maximum desireable concentration established for the area. The alkalinity (735 mg/L), composed primarily of sodium bicarbonate, is slightly above the locally established maximum desireable concentration. The sulphate concentration (590 mg/L) exceeds the Guidelines for Canadian Drinking Water Quality, 1978, and may cause objectionable taste, and gastrointestinal irritation and catharsis in consumers.

Of interest is the 1986 chemical water analysis of the water from Beaver Bay, approximately 6 m for the North Point well (see appendix). It appears that there is little hydraulic connection between the lake and the well, although further examination is required to establish whether or not this is the situation.

TABLE 4.9

SELECTED CHEMICAL ANALYSES
NORTH POINT WELL

	1985	1986	Lake Adjacent to well 1986
Total Dissolved Solids	1,330	2,047	294
Hardness	677	845	130
Alkalinity	698	735	160
Sulphate	352	590	19
Chloride	24	20	5
Nitrate & Nitrite N	<0.2	0.5	0.1
Sodium	194	239	18
Bicarbonate	850	897	195
Iron	21.0	0.1	<0.1
Fluoride	0.41	0.11	0.05

Values expressed as mg/L
Values rounded

Source: Parks Canada and Author

Bacteriological water analyses are not available for the North Point well. The water is slightly turbid and has a light yellow color, probably caused by iron oxide precipitate present when the well is first pumped. After several minutes of continous pumping, the water becomes clearer.

Evaluation and discussion of the existing utilized well water sources is contained in Chapter 9.

5. EXISTING NON-UTILIZED WATER SOURCES

Existing non-utilized water sources at Elk Island National Park consist of abandoned wells that are still relatively intact, abandoned wells that would require extensive reconstruction for future use, test holes drilled and recorded, and springs located throughout the Park.

5.1 Abandoned Station Well

North Gate Station consisted of a staff house and a gate house, supplied with water from an adjacent drilled well (W12). When the staff house was closed and demolished, the Station well was also abandoned. The North Gate Station well was drilled in 1959 to a total depth of 30 m. The aquifer is a surficial sand layer approximately 1,000 mm thick, from 19 to 20 m below ground surface. The well was equipped with a 3 horsepower (2.25kw) turbine pump and evidently produced 25 ig/minute (114 L/minute). The well casing is 112 mm diameter black iron and the well head connection is a concrete pit approximately 3 m deep; the casing extends approximately 300 mm above the pit floor. Total well depth in 1986 was measured as 25.1 m, with a static water level of 10.8 m. Evidently, the bottom 5 m of well has either collapsed or filled with sediment.

In 1986, the well was pumped with a submersible centrifugal pump for approximately one hour at 5 ig/minute (23 L/minute) in order to obtain a water sample for chemical analysis. Well yield was low, since the dynamic water level continually dropped below the pump intake set at 20 m. The 1986 water analysis (see appendix 1.16) cannot be considered to be representative of the true aquifer water quality. However, with a total dissolved solids concentration of 217.9 mg/L, this aquifer should be more thoroughly investigated as a potential source. Previous bacteriological analyses, such as in 1956 and 1966, indicated no contamination of this well.

5.2 Abandoned Campground Wells

There are two abandoned bored wells at Oster Lake campground (W7 and W8). The well adjacent to the Station staff house (W7) is construction with 500 mm diameter concrete cribbing, and the total depth measured in 1986 was 13.7 m, with a static water level of 1.7 m. The other well (W8) located approximately 150 m east of the first well, is also constructed with 500 mm diameter concrete cribbing. Total depth of W8 was measured in 1986 as 15.5 m, with a static water level of 0.7 m. Both wells are equipped with concrete lids.

A water sample for chemical analysis was obtained in 1986 by pumping W7 with a submersible centrifugal pump. After pumping for approximately one hour at 5 ig/minute (23 L/minute) a crude recovery rate of 4.5 ig/minute (20 L/minute) was recorded. A black anaerobic slime was noticed when removing the temporary pumping equipment.

The 1986 chemical water analysis (see appendix 1.17) is relatively representative of water from a surficial aquifer in a discharge area in the Park (Stein, 1976). The water contains excess total dissolved solids (1528.8 mg/L), excess alkalinity (725 mg/L as calcium carbonate equivalent), excess sodium (381.8 mg/L) and excess bicarbonate (884.5 mg/L). The chemical quality is somewhat better than the Oster Station well currently used. Previous bacteriological water analyses reveal contamination of both W7 and W8. In 1966, total coliforms in both wells were 240/100 ml and standard plate counts exceeded 3,000/ml. It is thought that bison congregating around these wells were the source of the contamination (Park Canada). High nitrate nitrogen concentrations were reported also, but corroborating analysis reports are unavailable. Both wells were abandoned for this reason.

An abandoned bored well (W9) at the North Tawayik Lake day use area was measured in 1986 as 6.5m in total depth, with a static water level of 2.1 m. Constructed with 500 mm diameter concrete cribbing and equipped with a concrete lid, the well is similar to the ones at Oster Lake campground. A depth integrated water sample was obtained in 1986 (see appendix 1.18), since it was impossible to remove the well cover and install a pump. The chemical analysis cannot be considered as being representative of the well water, but contains excess total dissolved solids (1,267 mg/L) and excess hardness (600 mg/L).

5.3 Other Abandoned Wells

Nine additional abandoned wells were located in the Park, that would require extensive reconstruction in order to be utilized.

The abandoned abbatoir drilled well (W5), adjacent to the Mud Lake corrals, is constructed with 75 mm diameter black iron casing. The suction and pressure pipes, and injector assembly, of a deep well jet centrifugal pump were left in the well when it was abandoned. A depth integrated sample was obtained in 1986 for chemical water analysis (see appendix 1.19), but the in-situ pumping equipment could not be removed to allow for well depth measurement. The well head connection is a concrete and wood pit approximately 3 m deep, which contained approximately 500 mm of seepage water in 1986. The 1986 chemical water analysis, while not considered representative, indicates the well is probably completed in the Bearpaw Formation. Total dissolved solids concentration is excessive (2,373.9 mg/L), composed primarily of sodium bicarbonate alkalinity.

The old Headquarters Station bored well (W14) is located in the north hay meadow, adjacent to the east fence of the bison paddock. The well has been unused for approximately 40 years (Parks Canada). Concrete cribbing 500 mm in diameter is covered with a concrete lid. Total depth was measured in 1986 as 5.9 m, with a static water of 2.7 m. The well was not pumped for sampling, since the water was obviously stagnant and contained several decomposing rodents.

Approximately 2 km due east of the Information Station is located the site of an abandoned warden Station. The Station well (W15) is located adjacent to the remains of the house foundation, but has been covered with soil. No other information is available on this well.

An abandoned well (W32) is located in the Goose Lake meadows, approximately 1,100 m east and 200 m south of the intersection of highway 16 and the Park main road. No other information is available on this well.

Two abandoned wells (W22, W23) are located due east of the Astotin Lake Administration Headquarters plant, on a peninsula. The wells were once utilized to supply rented cabins that were located on the peninsula, but the wells have since been landscaped over. No other data have been obtained for these wells.

Three other wells have been abandoned adjacent to existing utilized sources. An abandoned well at Information Station (W21) was evidently used in the past. A partial chemical analysis from this well indicates similar chemical quality to the existing utilized station well: total dissolved solids 1,900 mg/L; alkalinity 1,140 mg/L; sulphate 473 mg/L; hardness 60 mg/L. The exact well location cannot be determined.

An abandoned well at CWS Station (W19) is supposedly located near the existing utilized source. No trace of this well can be found, but reference is made to it in Park files. At Isolation corrals, a similar abandoned, unlocated well (W20) is said to have been utilized at some time in the past.

5.4 Test Holes

Twelve test holes have been drilled and recorded at the Park. They were drilled by International Water Supply Ltd. during the winter of 1960-1961, and three were developed into production wells later to be abandoned:

W18 - located on the southwest side of Little Tawayik Lake, approximately 800 m north of highway 16 on a Park trail.
- total depth 25 m
- static water level 3 m
- thin coal aquifer from 23.1 m to 23.5 m interbedded with soft shale of the Horseshoe Canyon Formation
- yield not recorded
- total dissolved solids 1,588 mg/L Alkalinity 1,145 mg/L.
- completed as a production well with screen, but later abandoned

when proposed site of main gate was moved to the east side of Little Tawayik Lake.

W27 - located adjacent to the North Point day use area on Astotin Lake, near the Golf Course.
- total depth 31 m
- flowing well
- sand and coal aquifers from 18.3 m to 19.5 m on top of shale bedrock of the Bearpaw Formation
- yield and quantity not recorded
- completed as a production well with a 100 mm diameter sand screen, but later abandoned due to high iron content.

W28 - located on Sandy Beach approximately 40 m south of Snack Bar
- total depth 25 m
- static water level 6 m
- fine sand and course gravel aquifer from 21 m to 22.3 m
- yield and quality not recorded
- completed as a production well with screen, but later abandoned due to high iron content and sand problem.

W16 - located approximately 450 m north of W18 on the west side of Little Tawayik Lake
- total depth 43.6 m
- static water level 11.4 m
- sandy shale aquifer from 36 m to 38.7 m in the Horseshoe Canyon Formation
- poor quality (salty)
- not developed

W17 - located approximately 400 m south of W18

- total depth 56 m
- static water level 4.5 m
- thin coal aquifers from 24 m to 54 m interbedded with shale in the Horseshoe Canyon Formation
- yield not recorded
- total dissolved solids 3,118 mg/L
- not developed

W24 - located on south shore of Astotin Lake

- total depth 50 m
- static water level 7.5 m
- Bearpaw Formation bedrock encountered at 45 m
- low yield, abandoned.

W25 - located on south shore of Astotin Lake, adjacent to Elk Island

- total depth 75 m
- Bearpaw Formation bedrock encountered at 24 m
- dry hole, abandoned

W26 - located on south shore of Astotin Lake, adjacent to W27 near the golf course.

- total depth 93.6 m
- static water level 6.7 m
- sandy shale aquifer from 56.1 m to 57.6 m in the Bearpaw Formation
- yield 1.5 ig/minute (6.8 L/minute)
- high iron (3.0 mg/L)
- abandoned

W29 - located on Sandy Beach approximately 140 [illegible]h of the snack bar
- total depth 12.5 m
- shallow sand from 1 m - 3 m
- low yield, abandoned

W30 - located on east side of Astotin Lake approximately 50 m north of the snack bar
- total depth 7.6 m
- sand and gravel from 0.3 m to 5.2 m
- dry hole

W31 - located on east side of Astotin Lake approximately 100 m north of snack bar
- total depth 12.5 m
- fine sand from 0.3 m to 3.0 m
- dry hole, abandoned

W33 - located on east side of Astotin Lake approximately 275 m north of the snack bar
- total depth 75 m
- Bearpaw Formation bedrock encountered at 26.8 m
- dry hole, abandoned

The test holes indicate that the groundwater supplies in the areas of the Park tested are either of low quantity or poor quality, or both.

5.5 Springs

There are six distinct springs and one occurrence of soap holes within the Park:

S1 - Baker Springs
- approximately 300 m south of the south Park boundary
- flowing at approximately 1 ig/minute (4.5 L/minute)
- evidence of iron bacteria present
- used in the past as a watering point along the old Edmonton Trail
- evidence of use by wildlife

S2 - spring located at south end of Little Tawayik Lake
- flowing at approximately 0.3 ig/minute (1.4 L/minute)
- evidence of iron present
- evidence of use by wildlife

S3 - spring located south of Walter Lake near southwest corner of Park
- flowing at approximately 1.5 ig/minute (6.8 L/minute)
- evidence of iron present

S4 - spring located approximately 1,100 m south of Oster Lake, and 550 m west of Tawayik Lake
- minor seepage

S5 - spring located on north side of Moss Lake
- minor seepage
- evidence of use by wildlife

S6 - spring located approximately 1,000 m west of Tawayik Lake and approximately 3,000 m south of Oster Lake
- flowing at approximately 0.5 ig/minute (2.3 L/minute)
- evidence of use by wildlife

S7 - several springs in combination with soap holes, located on east Park boundary approximately 3,000 m north of highway 16

- flowing, yield not measured

- 1985 chemical water analysis shows excess total dissolved solids (3,996 mg/L), sodium (1,396 mg/L) and sulphate (1,560 mg/L).

6. SANITATION SURVEY

A sanitation survey was performed in 1986 to identify and evaluate potential point sources of contamination within the Park. The two central sewage collection systems, the four independent Station sewage disposal systems, the Information Centre sewage disposal system, remote campground and day use area toilets, and areas of livestock confinement and congregation were included in this survey.

6.1 Central Sewage Collection at Astotin Lake

The Administration Headquarters central sewage collection system (P1) collects sanitary sewage from the Headquarters offices, Warden Station, Maintenance Depot and ten staff houses it then flows by gravity to a sewage lift station located approximately 50 m north northeast of the Headquarters offices (see Figure 4.1). The sewage is then transferred to a lagoon system located approximately 120 m west of the Headquarters offices. The system was in place in 1963, although modification of the lagoon system was undertaken in 1974. Originally, the sewage collection system served an additional seven rented summer cottages located on a peninsula due east of the water treatment plant.

The original lagoon system consisted of two holding cells, each approximately 7.3 m x 4.9 m x 1.0 m deep, providing a total holding capacity of 36.3 m^3 (8,000 ig). A third holding cell was added to increase capacity. The irregular shaped third holding cell has a capacity of 267.7 m^3 (59,000 ig), to give a present total holding capacity of 304 m^3 (67,000 ig). With estimated mean daily water use for the area served being 23 m^3 (5,142 ig), the holding capacity of the sewage lagoon system represents approximately 2 average weeks of storage.

The third holding cell has an overflow weir (elevation 714.1m) which allows effluent to discharge into a wet area to the south. The wet area eventually drains through a culvert in the Maintenance Depot access road (invert elevation 712.2 m) to another wet area south of the Headquarters offices. This wet area eventually drains through a culvert in the Administration access road into Astotin Lake (invert approximate elevation 712 m). The distance from the lagoon to Astotin Lake is approximately 200 m. Water flow through both culverts only occurs during extended periods of heavy rainfall and during heavy spring run-offs. Both wet areas contain dense reed and sedge growth and receive significant additional runoff from surrounding woodland and grassland. The incidence of lagoon effluent reaching Astotin Lake in significant amounts is probably infrequent, and is most likely to occur during peak spring runoff, which usually occurs after a wet fall and a winter of heavy snowfall accumulation.

Astotin Campground central sewage collection system (P2) collects sanitary sewage from washroom facilities located throughout the area, the snack bar, Interpretive Centre and golf course clubhouse. The sewage then flows by gravity to a sewage lift station located immediately northeast of the campground. The sewage is then transferred to a lagoon system located approximately 600 m north[illegible]east of the lift station. The system was built in 1965 and has [illegible] unmodified since then.

The lagoon system consists of a single holding cell approximately 120 m x 107 m x 1.8 m deep, providing a holding capacity of 10,215 m^3 (2,250,000 ig). With estimated mean daily water use for the area served being 23 m^3 (5,142 ig) for 150 days a year, the holding capacity of the lagoon represents approximately 3 average years of storage.

The lagoon is located east of the surface water drainage divide into Astotin Lake, so that any effluent overflow drains to the south east away from the lake. There is no overflow weir constructed on the lagoon and there is probably little effluent overflow, since net evaporative losses usually exceed annual effluent inflow. In wet years, effluent overflow may occur.

6.2 Sewage Disposal at Station staff houses

Each of the four Station staff houses is equipped with a similar sewage disposal system. The system consists of a concrete septic tank and weeping tile disposal field in a herringbone layout. The average buried depth of the weeping tile is 450 mm, and approximately 600 mm of permeable material is installed in the trench under each weeping tile lateral (Parks Canada).

Basic factors involved in site selection for a weeping tile sewage disposal system include examination of the soil type and thickness, determination of the groundwater table depth and assessment of the topography. In general, at least one metre of unsaturated, permeable soil beneath the weeping tile is recommended. The site should be relatively level and surface drainage from the weeping tile field should be away from wells and surface water (Anderson, 1977). An accepted design practice relates the length of weeping tile installed to the hydraulic conductivity of the receiving soil, and the anticipated daily effluent loading. Coarse sand and gravel is considered too permeable for adequate treatment of the effluent by soil particles and micro-organisms. Heavy clay soils require large weeping tile fields so that effluent loading per unit area of soil is minimized (Otis. 1977).

The treatment of sewage effluent by the receiving soil is a complex process. In general, fecal coliform bacteria are removed after passing through approximately 1m of soil. Phosphate, ammonia and nitrogen are primarily utilized by plants through their root zone under reducing soil conditions. Under oxidizing soil conditions, nitrogen is converted to nitrate, which rapidly leaches downward towards the groundwater table. Heavy metals tend to accumulate in a zone adjacent to the weeping tile (Brown, 1977).

At Oster Station, the sewage disposal system is located on relatively level ground to the southwest of the house, and surface drainage is away from the well site. The soils are relatively permeable and the groundwater table is approximately 2m below ground level. At present effluent loading rates (0.9 m^3/day) no problems are evident with this sewage disposal system.

At CWS Station, the sewage disposal system is located south of the house on relatively level ground. Surface drainage is away from the well site at the north. The soil is permeable and the groundwater table is approximately 2 m below ground level. At present effluent loading rates (0.9 m^3/day or less) no problems are evident with this sewage disposal system.

At Information Station, the house sewage diposal system is located approximately 90m east of the well at the Information Centre. The soil is relatively permeable and the groundwater table is approximately 2 m below ground level. At present effluent loading rates (0.9 m^3/day) no problems are evident with this sewage disposal system.

At Isolation Station, the sewage disposal system is located on gently sloping ground draining south away from the house. The well is located in the house basement. At present the sewage disposal system is not used, so frost heaving of the septic tank and weeping tile could cause problems if and when the system is reactivated.

Both CWS Station and Isolation Station discharge water softener regeneration effluent into their sewage disposal system. The effluent contains high concentrations of sodium chloride and has been shown to be deleterious to the functioning of weeping tile disposal system (Corey, 1977). The effluent's high potential sodium absorption ratio tends to decrease soil permeability by first causing swelling of the soil aggregates and consequent reduction of soil pore space. Through time, soil aggregate breakdown and dispersion occurs, further reducing soil pore space. It is recommended that water softener regeneration effluent be excluded from weeping tile sewage disposal systems.

6.3 Campground and day use area sewage disposal

The main campground and day use area at Astotin Lake is served by a central sewage collection system (see 6.1). Other campgrounds and day use areas rely upon pit latrines for sewage disposal. Elk Island National Park is in the process of converting all existing leaching pit latrines into sealed holding tank types. In 1986, holding tank pit latrines were installed at Oster Lake Campground, Tawayik Lake day use area and at several trail heads adjacent to the main Park road.

Leaching pit latrines are still located at the North Point day use area on the south shore of Astotin Lake, but are located at least 150 m from both the lake and the North Point well. In the winter of 1985, two pit latrines were temporarily located in the Astotin Lake day use area within 100 m of the lake. No problems caused by these remaining leaching pit latrines have been observed or reported.

6.4 Sewage Disposal at the Information Centre

The Information Centre sewage disposal system consists of a septic tank and weeping tile disposal field, similar to those used at Station staff houses. The sewage disposal system is located south of the Centre on gently sloping ground that drains into a wet area. The Centre well is located north of the centre, topographically separated from the sewage disposal system. The soil is relatively permeable, but tends to become organic near the wet area. The groundwater table is shallow, depending upon the level of water in the wetland. Present effluent loading rates are 1.4m ^{3}/day for 150 days per year. The seasonal rest the system receives each winter is probably beneficial and can improve system performance (Otis, 1977). If effluent loading rates increase significantly in the future, problems are anticipated with the sewage disposal system performance due to the shallow groundwater table.

6.5 Mud Lake bison corrals

A livestock confinement area, and the associated animal manure, can have potential impacts upon both surface water and groundwater. Surface runoff from livestock confinement areas should be prevented from entering surface water bodies, by the use of catchbasins or other detention structures. Compaction of the livestock confinement area by animals tends to create an impervious surface layer that reduces infiltration. Also, the compacted surface layer tends to enhance anaerobic soil conditions beneath the area, which inhibits the formation of nitrates. The impervious surface layer breaks down, and hence infiltration and nitrate production occur, when the confinement area is not used for a year or more (West, 1982).

At Mud Lake bison corrals, animals are confined for a maximum of 100 days per year. No evidence of nitrate contamination was found in the bored well (W13) located on the west corral fenceline. The corrals are located approximately 100 m south of Mud Lake, and slope gently towards the lake. Since the corrals are remote from any water sources currently used for human consumption, their potential impact is minimal. However, the impact of the corrals upon Mud Lake requires further examination.

6.6 Isolation bison corrals

Isolation bison corrals are located approximately 200 m north of Flyingshot Lake and slope gently towards the lake. Animals are confined for a maximum of 21 days per year. Intermittent confinement may lead to excess nitrate formation beneath the corrals, with eventual leaching into shallow groundwater. The well at the corrals (W11) is located on the north corral fenceline, on higher ground than the corrals. No evidence of nitrate contamination is present in the well water. Since the corrals are remote from water sources currently used for human consumption and are relatively remote from Flyingshot Lake, their potential impact is minimal.

6.7 Other areas of wildlife concentration

Bison are known to congregate at the Oster Lake campground. Reported high nitrate nitrogen concentrations and recorded total coliform levels in the campground wells in 1966 were attributed to the bison manure, and both campground wells were abandoned (see 5.2). Bison still congregate in the area, but are not able to manure in areas that will impact the present Station well.

Bison also congregate in the Astotin Lake day use area especially in winter. Bison manure on paved and compacted gravel areas such as walkways and parking lots could be entrained by runoff and some could eventually reach Astotin Lake. This could have a minor negative impact upon the Astotin Lake campground plant intake, which is located in the lake near the day use area.

The bison paddocks are operated from May to September annually, and confine up to 500 head. The paddock area is approximately 0.5 km^2 and slopes to the southeast. The creek draining Goose Lake is approximately 900 m southeast from the bison paddocks. Since the paddocks are remote from water sources currently used for human consumption, their potential impact is minimal.

7. POTENTIAL PARK GROWTH PATTERNS

The alternative futures approach in water withdrawal planning is an attempt to expand the time-horizon of the planning process (EPA, 1973. Koelzer, 1970). A range of possible future conditions that may reasonably be expected to occur in Elk Island National Park are identified and quantified. The alternative futures represent various levels of water use, related to various levels of growth (Pacific North-west River Basins Commission, 1979. Arizona Water Commission, 1977).

7.1 Low growth in Park use

In the low growth scenario it is assumed that there will be minimal or no growth in the numbers of visitors to the Park in the next 30 years until 2016. Park entry records for the past 10 years indicate that there has been relatively little change in the annual visitation during this period and averages approximately 350,000/year (Table 7.1). The number of entries recorded at the Park excludes commercial and other through traffic, and also excludes entries through the northwest gate which are thought to be minimal (Parks Canada).

A low growth scenario of no significant increase in Park visitation is feasible considering that there is an observed relationship between public usage levels and water quality in water-oriented outdoor recreation areas in Provincial parks in the Edmonton region (Alberta Environment, 1976).

Figure 7.1 Past and potential growth in Park use

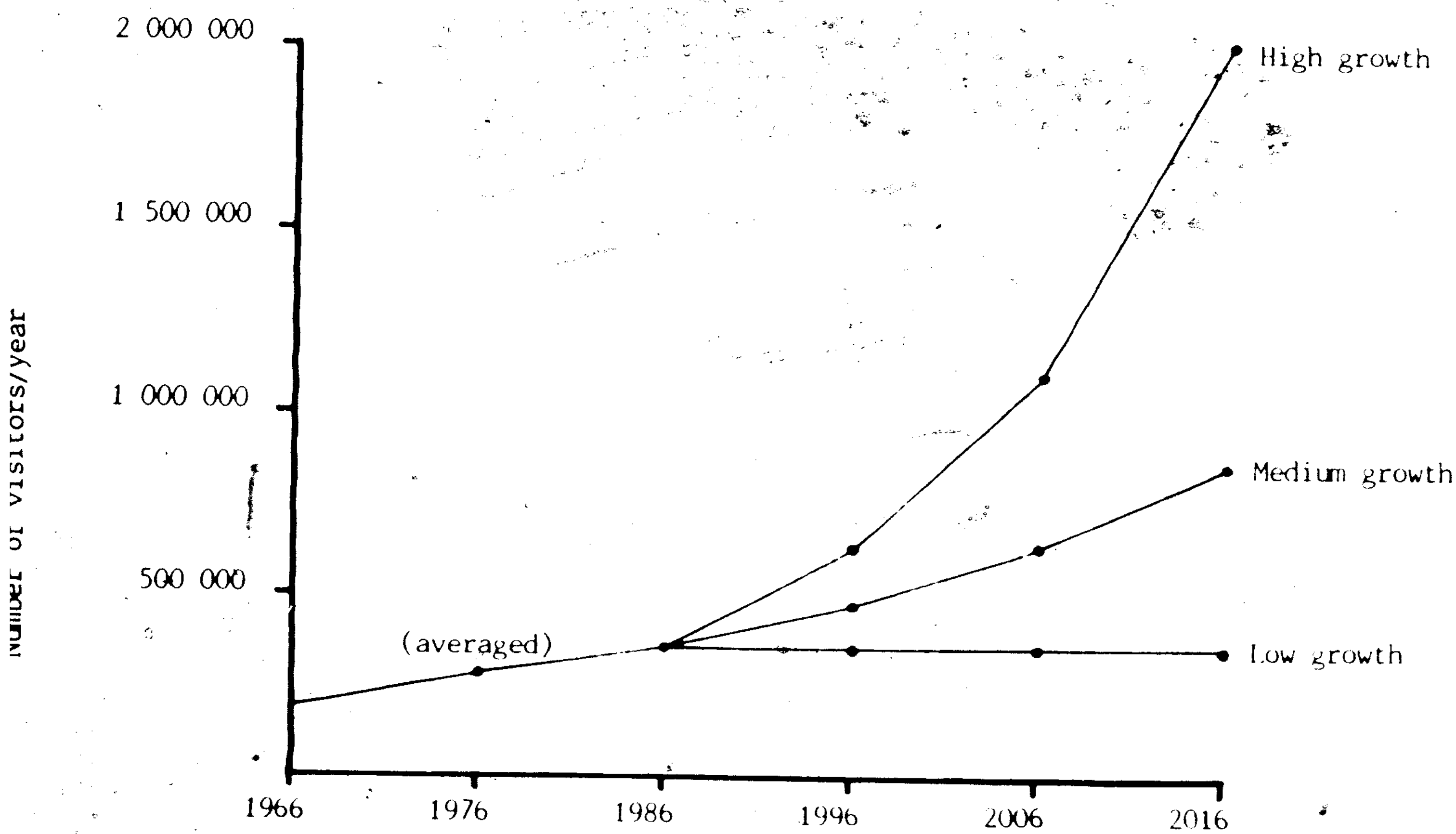


TABLE 7.1

RECORDED PARK ENTRIES 1975 - 1986

Year	Entries*
1976 - 77	279,754
1977 - 78	336,254
1978 - 79	332,471
1979 - 80	315,872
1980 - 81	354,423
1981 - 82	385,091
1982 - 83	359,888
1983 - 84	383,359
1984 - 85	375,912
1985 - 86	336,043
Average	345,907/year

*Pre 1983 entries have been corrected using the Park's current conversion factor of 2.5 entries/vehicle.

Source: Parks Canada

7.2 Medium growth in Park use

In the medium growth scenario it is assumed that there will be a three percent annual increase in park visitation until 2016. Park entry records for the period from 1966 to 1976 indicate an average annual increase in visitation of 3.9% during this period. This growth rate is consistent with the growth observed in Provincial parks during the same period (Alberta Environment, 1976).

The medium growth scenario of a 3% annual increase in Park visitation is feasible considering that the Edmonton region is becoming more urbanized, and urban populations tend to utilize outdoor recreational facilities more than rural populations (Alberta Environment, 1976). Under the medium growth scenario, annual Park visitation of approximately 850,000 is foreseen by the year 2016. Development of additional recreational facilities in the Park will be a major factor influencing the 3% growth scenario.

7.3 High growth in Park use

The high growth scenario assumes that there will be a six percent annual increase in Park visitation until 2016. Population projections for the Edmonton region for the period from 1980 to 2005 indicated an annual average population increase of 5.85% (Associated Engineering Alberta Ltd. 1980). This growth rate is consistent with Provincial population growth rates predicted in 1980.

The high growth scenario of a 6% annual increase in Park visitation is feasible considering that population growth in Alberta is related to economic activity, primarily in the oil and gas industry, which is subject to recurrent periods of high and low growth. Under the high growth scenario, annual Park visitation of approximately 2,000,000 is foreseen by the year 2016. The development of additional recreational facilities in the Park, and the quality of those facilities, will be a major factor influencing the 6% growth scenario.

7.4 Low growth in Park facilities

Under low growth conditions, emphasis upon upgrading and improving existing Park facilities is probable, with no significant expansion occuring:

- completion of the Flyingshot Lake day use area, but not including the provision of a water supply.
- no expansion of the Astotin Lake campground, but provision of water hookups for recreational vehicles at 25% of the camping stalls.
- abandonment ~~of the~~ North Point well at the Beaver Bay day use area.
- re-opening of the Isolation Station staff house to provide service to the Flyingshot Lake day use area.

7.5 Medium growth in Park facilities

Under medium growth conditions, emphasis upon upgrading and expanding Park facilities is probable:

- completion of the Flyingshot Lake day use area and upgrading to a group campground. Provision of a water supply and washroom facilities for an estimated 5,000 campers per year (2016).
- expansion of the Astotin Lake campground to provide capacity for 34,000 campers per year (2016). Expansion of water supply system to service 50% of the camping stalls with water hookups for

recreational vehicles.

- expansion of the Oster Lake group campground to provide capacity for 5,000 campers per year (2016). Expansion of the water supply system from Oster Station to service a washroom facility for campers.
- expansion of the Tawayik Lake day use area to a group campground, with a capacity of 2,000 campers per year (2016). Provision of a water supply and washroom facilities.
- concurrent expansion of Park administrative facilities at the Administration Headquarters area, including construction of staff houses to give a total of 16.
- expansion at Oster, Information and Isolation Station to result in 2 staff houses at each location.
- construction of a staff house at North Gate Station.

7.6 High growth in Park Facilities

Under high growth conditions, emphasis upon expanding Park facilities is probable:

- completion of the Flyingshot Lake day use area and upgrading to a group campground to provide capacity for 12,000 campers per year (2016). Provision of a water supply and washroom facilities.
- expansion of the Astotin Lake campground to provide capacity for 80,000 campers per year (2016). Expansion of the water supply system to provide 100% of the camping stalls with water hookups for recreational vehicles.
- construction of a small lodge/meeting centre with full facilities,

for seasonal use at Astotin Lake.

- expansion of the Oster Lake group campground to provide capacity for 12,000 campers per year (2016). Expansion of the water supply system from Oster Station to service washroom facilities for campers.
- expansion of the Tawayik Lake day use area to a group campground, with a capacity of 4,000 campers per year (2016). Provision of a water supply and washroom facilities.
- construction of an additional paddock for bison confinement in the south area of the Park, and expansion of the existing northern paddock. Provision of an adequate water supply at each paddock.
- concurrent expansion of Park administration facilities at the Administration Headquarters area, including construction of staff houses to give a total of 45.
- expansion at Oster, Information and Isolation Stations to result in 4 staff houses at each location.
- construction of 2 staff houses at North Gate Station.

Evaluation and discussion of future water supply needs is contained in chaper 8. Evaluation and discussion of potential water sources is contained in Chapter 9.

8. PROJECTED FUTURE WATER WITHDRAWAL

The impacts of projected water withdrawal demands for human consumption and domestic use under low, medium and high growth conditions are examined for each use area within the Park. For the purposes of short term planning and for the implementation of immediate upgrading of water facilities, an evaluation of existing water supplies, is provided. Examination of the total array of projected water withdrawal demands will allow for flexibility in the selection of appropriate action as actual Park growth is quantified in the future.

8.1 Astotin Lake Campground Area

The water demand in 1986 for this area is estimated as 3,500 m^3/year for the approximately 150 day operating season. The supply from the treatment plant at 227 L/minute requires approximately 225 hours of annual plant operation to meet this demand. An assumed 223 m^3/day peak demand occurs at the area on long weekends. Maximum plant production based on a 16 hour operating day is 218 m^3/day or 32,700 m^3/year (150 day season).

Under low growth conditions, provision of water hookups to 25% of the camping stalls is probable. Water hookups would increase water demand by approximately 45 L/camper/day (EPA,1973). The number of registered campers in 1986 was approximately 14,000, for an average stay of 3 days so provision of 25% of the campers with water hookups would result in an annual additional water demand of 475 m^3 (2016) and a total annual demand of 3,975 m^3/year (2016). No growth in water demand by day users is foreseen.

Under medium growth conditions, the total water demand at the area is predicted to increase by 3% per year. Water demand (2016) is estimated as being 8,500 m^3/year, plus the increased demand created by the provision of water hookups to 50% of the camping stalls in the campground. With 34,000 campers/year predicted by 2016, with an average stay of 3 days, an additional demand of 2,300 m^3/year is created, to give an anticipated total annual demand of 10,800 m^3/year (150 day season).

Under high growth conditions, the total water demand at the area is predicted to increase by 6% per year. Water demand (2016) is estimated as being 20,100 m^3/year, plus the increased demand created by the provision of full water hookups in the campground, and plus the demand created by a small lodge or meeting centre. With 80,000 campers/year predicted by 2016, with an average stay of 3 days, an additional demand of 10,800 m^3/year is created. If a 30 room lodge is constructed for seasonal (150 day) use and full occupancy is assumed with a daily demand of 450 L per guest (EPA, 1973), then an annual additional demand of 4,000 m^3 is created. Total annual demand at the Astotin Lake campground area is anticipated to be 34,900 m^3.

8.2 Administration Headquarters Area

The water demand in 1986 for this area is estimated as 8,522 m^3/year, on a year round basis. The supply from the treatment plant at 227 L/minute requires approximately 625 hours of annual plant operation to meet this demand. An assumed 70 m^3/day peak demand occurs. Maximum plant production based on a 16 hour operating day is 218 m^3/day or

79,570 m^3/year.

Under low growth conditions, no significant increase in water demand is predicted for this area. Demand is expected to stabilize at 9,000 m^3/year by 2016.

Under medium growth conditions, the total water demand at the area is predicted to increase by 3% per year. Water demand (2016) is estimated as being 20,500 m^3/year.

Under high growth conditions, the total water demand increases by 6%, and is estimated for 2016 as being 48,900 m^3/year. With both medium and high growth conditions, increased demand is attributable to increased staff for administration and maintenance, an increased staff at the Warden Station, and the need for increased staff housing.

8.3 Station staff houses

At Oster Station, no expansion is predicted for water demand for the staff house under low growth conditions. Under medium growth conditions, an additional staff house will be required at Oster Station. Water demand will increase from 331 m^3/year (1986) to 662 m^3/year (2016). Two additional houses at Oster Station are predicted under high growth conditions, for a total of 4, and an estimated water demand of 1,324 m^3/year (2016) is anticipated. If the station well is assumed to have a 20 year safe yield of 4.5 L/minute, and is operated for a maximum of 16 hours per day, then annual production capacity from the well is 1,590 m^3. Additional demands are placed upon this well by the Oster Campground (see section 8.4).

At CWS Station, no expansion in water demand is predicted under low, medium or high growth conditions.

Information Station presently has a water demand of 331 m^3/year (1986). No increase is predicted under low growth conditions, but under medium growth conditions, an additional staff house is required, increasing total annual demand to 662 m^3/year (2016). A total of 4 staff houses under high growth conditions will create a water demand of 1,324 m^3/year (2016). The station well 20 year safe yield can be assumed to be 4.5 L/minute; if operated for a maximum of 16 hours per day it could produce 1,590 m^3/year. Additional demands are placed upon this well by the Information Centre (see section 8.5).

Isolation Station is reopened under the low growth scenario, with an annual water demand of 331 m^3 (2016). Predictions for 2 houses and 4 houses at the Station, under medium and high growth scenarios, creates water demands of 662 m^3/year and 1,324 m^3/year (2016) respectively. The Station well yield is recorded as 27 L/minute; if a 20 year safe yield of 13 L/minute is assumed, then annual production from this well is predicted as 4,550 m^3, if operated for a maximum of 16 hours per day.

North Gate Station does not at present exist, and is not required under low growth conditions. Under medium growth conditions, one staff house at North Gate Station is predicted, with an annual water demand of 331 m^3 (2016). Two houses are predicted under high growth conditions (2016 demand 662 m^3/year). A water source is required to meet future water demands.

8.4 Campgrounds and day use areas

Oster Campground utilizes the Oster Station well as a water source. Current water demand is estimated as 91 m^3/year (1986) with a weekend peak demand of 2.2 m^3/day. No expansion of camping facilities or use are predicted under low growth conditions, so that 2016 water demand will not change from the 1986 demand.

Under medium growth conditions, 5,000 campers per year are predicted by 2016. If provided with a washroom facility with flush toilets, per capita consumption will increase to 45 L/camper (EPA, 1973). Assuming an average stay of 2 days per camper, annual water demand is estimated to be 450 m^3 (2016). Peak demand on weekends is estimated to be 11.5 m^3/day.

High growth conditions indicate that 12,000 campers per year will use Oster Campground (2016). With full washroom facilities, annual water demand is estimated as 1,080 m^3 (2016) with a peak demand of 27 m^3/day.

Tawayik day use area currently has no water demand and is not predicted to have any under low growth conditions. Medium growth conditions require the development of a water source to supply 2,000 campers per year in a campground with washroom facilities. Estimated annual water demand is 180 m^3/year (2016) assuming a 2 day average stay. Under high growth conditions of 4,000 campers per year (2016) with washroom facilities, annual demand is estimated as 360 m^3/year.

Flyingshot day use area is not predicted to have a water source under low growth conditions. If expanded as a group campground with washroom facilities as predicted for medium growth conditions, 5,000 campers per year staying an average of 2 days each would create a water demand of 450 m^3/year (2016). Under high growth conditions, it is estimated that 12,000 campers per year would create a water demand of

1,080 m^3/year (2016).

8.5 Information Centre

The Information Centre is supplied with water from a well shared with Information Station. Current water demand at the Centre is estimated as 204 m^3/year (1986), with a peak daily demand occuring on weekends and estimated as 5.1 m^3/day.

Visitors to the Information Centre as a percentage of total Park visitors is assumed to remain constant at 10% (See Sect[illegible]5). Water use per Centre visitor is estimated as 4.5 L (0.5 L consumption, 4.0 L in washroom), with an additional 25-30% water demand for cleaning and housekeeping at the Centre. Under medium growth conditions, it is estimated that 85,000 persons will visit the Centre in 2016 and a water demand of 500 m^3/year is predicted. Under high growth conditions, annual visitation at the Centre is estimated to be 200,000 persons, creating a water demand of 1,150 m^3/year (2016).

8.6 Mud Lake and Isolation Bison Corrals

Both Mud Lake and Isolation Corrals are used to confine bison and elk that are in excess of the Park's carrying capacity, prior to shipping them to other destinations outside of the Park. No expansion of wildlife numbers beyond those in the Park in 1986 is foreseen under any growth scenario, since park staff have determined that current stocking rates are optimal. Therefore, continued use but no expansion of the corrals is probable. Predicted water demands for all growth scenarios are therefore 23 m^3/y for Mud Lake and 19 m^3/y for Isolation Corrals.

8.7 Other Livestock areas

The horse barn well at Information Station can be assmed to have a 20 year safe yield of 13 L/minute, and an annual production of 4,550 m^3, based upon a maximum operation time of 16 hours per day. Current water demand is 80 m^3/year with 4 horses and no change is predicted under low growth conditions. Under medium growth conditions, 8 horses are predicted with an annual demand of 160 m^3/y (2016). Annual demand under high growth conditions with 16 horses in 320 m^3/y (2016).

Under high growth conditions, it may be desireable to confine bison and ungulates in paddocks. The existing northern paddock could be expanded to hold the current northern herd of 500 plains bison, 700 elk and 250 moose. Annual water requirements would be approximately 3,000 m^3. A new southern paddock holding the current southern herd of 230 wood bison, 150 elk and 100 moose, would have an annual water requirement of 1,000 m^3. Both paddocks could be supplied with raw surface water supplies, independent from any of the preceeding supplies discussed. For this reason, paddock water supplies are not included in any alternative futures.

8.8 Evaluation of existing sources and summary of projected demands

The estimated 1986 water demands and the maximum probable capacity of existing individual water sources within Elk Island National park are summarized in table 8.1. In addition, projected water demands are presented and contrasted against currently available supplies.

The following sources have adequate gross capacity to meet all projected water demands upon them:

- Astotin Lake Administration Headquarters Plant
- CWS Station well
- Isolation Station well
- Mud Lake Corrals well
- Isolation Corrals well
- Horse Barn well

In addition, the following sources have adequate gross capacity to meet projected low and medium growth water demands:

- Astotin Lake Campground plant
- Oster Station well
- Information Station well

Under medium and high growth conditions, new sources are required for the following locations:

- North Gate station
- Tawayik Lake Campground
- Flyingshot Lake Campground

TABLE 8.1 EXISTING & POTENTIAL WATER DEMANDS (Estimates by Author)

(a) Annual Demands m^3/year

Source/Use Area	Maximum Present Capacity	1986 Demand	2016 Low Demand	2016 Medium Demand	2016 High Demand
Astotin Lake Campground	32,700	3,500	3,975	10,800	34,900
Astotin Lake Admin. Hq. Area	79,570	8,522	9,000	20,500	48,900
Oster Staff House	(1,590)	(331)	(331)	(662)	(1,324)
Oster Campground	-	(91)	(91)	(450)	(1,080)
Total Oster Station	1,590	422	422	1,112	2,404
CWS Station	1,590	331	331	331	331
Information Staff House	-	(331)	(331)	(662)	(1,324)
Information Centre	(1,590)	(204)	(204)	(500)	(1,150)
Total Info. Station	1,590	535	535	1,162	2,474
Isolation Station	4,550	-	331	662	1,324
North Gate Station	-	-	-	331	662
Tawayik Lake Campground	-	-	-	180	360
Flyingshot Lake Campground	-	-	-	450	1,080
Mud Lake Corrals	1,590	23	23	23	23
Isolation Corrals	1,590	19	19	19	19
Horse Barn Well	4,550	80	80	160	320
North Point Well	1,590	16	-	-	-
TOTALS	130,910	13,448	14,716	35,730	92,797

TABLE 8.1 EXISTING & POTENTIAL WATER DEMANDS (Estimates by Author)

(b) Peak Demands m^3/day

Source/Use Area	Maximum Daily Production	1986 Peak	2016 Low Peak	2016 Medium Peak	2016 High Peak
Astotin Lake Campground	218.0	58.0	66.0	180.0	582.0
Astotin Lake Admin. Hq. Area	218.0	70.0	74.0	168.0	402.0
Oster Staff House	(4.4)	(3.6)	(3.6)	(7.2)	(14.4)
Oster Campground	-	(2.2)	(2.2)	(11.5)	(27.0)
Total Oster Station	4.4	5.8	5.8	18.7	41.4
CWS Station	4.4	3.6	3.6	3.6	3.6
Information Staff House	(4.4)	(3.6)	(3.6)	(7.2)	(14.4)
Information Centre	-	(5.1)	(5.1)	(12.5)	(29.0)
Total Info. Station	4.4	8.7	8.7	19.7	43.4
Isolation Station	12.5	-	3.6	7.2	14.4
North Gate Station	-	-	-	3.6	7.2
Tawayik Lake Campground	-	-	-	4.5	9.0
Flyingshot Lake Campground	-	-	-	11.5	27.0
Mud Lake Corrals	4.4	0.6	0.6	0.6	0.6
Isolation Corrals	4.4	0.9	0.9	0.9	0.9
Horse Barn Well	12.5	0.2	0.2	0.4	0.8
North Point Well	4.4	0.4	-	-	-

Water system upgrading to provide increased storage to meet projected peak demands is required at:

- low, medium and high growth conditions (new source needed under high growth conditions)
  - Information Station well
  - Oster Station well
- high growth conditions only
  - Astotin Lake Administration Headquarters plant
  - Astotin Lake Campground plant
  - Isolation Station well

The water quality of existing individual water sources within Elk Island National Park is summarized and evaluated in table 8.2. None of the existing sources can be considered of totally adequate quality for their current or projected uses. The following sources are of marginal quality:

- Astotin Lake Campground plant
- Astotin Lake Administration Headquarters plant
- Mud Lake corrals well
- Isolation corrals well
- Horse barn well

The following sources are of inadequate quality:

- Oster Station well
- CWS Station well
- Information Station well
- Isolation Station well
- North Point well

TABLE 8.2

Evaluation of Water Quality of Existing Sources

Source	Use	Quality for Use	Problems
Astotin Lake Campground Plant	Human Consump. Domestic Use	Marginal	Hardness, taste, odor, color
Astotin Lake Admin. Headquarters Plant	Human Consump. Domestic Use	Marginal	Taste, Odor, Color
Oster Station Well	Human Consump. Domestic Use	Inadequate	TDS, alkalinity, sodium, bicarbonate
CWS Station Well	Human Consump. Domestic Use	Inadequate	TDS, (hardness), alkalinity, sodium, bicarbonate
Information Station Well	Human Consump. Domestic Use	Inadequate	TDS, alkalinity, sodium, bicarbonate H_2S
Isolation Station Well	Human Consump. Domestic Use (currently not used)	Inadequate	TDS, alkalinity, sodium, bicarbonate (hardness)
Mud Lake Corrals Well	Livestock	Marginal	Total dissolved solids, alkalinity
Isolation Corrals Well	Livestock	Marginal	Total dissolved solids, alkalinity
Horse Barn Well	Livestock	Marginal	Total dissolved solids, alkalinity
North Point Well	Human Consump.	Inadequate	TDS, hardness, alkalinity, sodium sulphate, bicarbonate

9. POTENTIAL WATER SOURCES

There are a wide variety of potential water sources available for use at Elk Island National Park. Some of these sources are currently developed and utilized, but require upgrading to improve water quality and, in some cases, increase capacity. Other potential sources are available both within and beyond Park boundaries, but require evaluation to determine the feasibility of development.

9.1 Improved Lake Treatment Plants

The chemical quality of water produced at both lake treatment plants is acceptable for human consumption and domestic use. Fluctuating raw and treated water hardness, at times slightly in excess of desireable limits, is best removed by using individual ion-exchange water softeners in those houses and buildings where the hardness is deemed undesireable. A full discussion of ion-exchange softening is contained in section 9.3

The bacteriological water quality from both plants is generally acceptable, but more precise (post) chlorination is required at the campground plant to control general bacterial growth in the distribution system.

The physical water quality from both plants is inadequate, since the treated water contains undesirable taste, odor and color. Substances causing taste, odor and color in water are usually organic, although there are numerous organic substances that can cause such problems. Generally, the organic substances can be classified as being either artificially-present or naturally-present. The former classification includes industrial, urban and domestic wastes, while the latter classification includes algae, actinomycetes, nematodes and amoebae (AWWA, 1971). It is unlikely that industrial, urban or domestic waste is a significant source of organic substances in Astotin Lake. Like most other lakes in the Cooking Lake Moraine, Astotin Lake is shallow and eutrophic and contains an abundance of naturally present organic substances (Alberta Environment, 1976. Hickman, 1979).

Taste and odor control is a complex treatment process; color removal is often a separate process that may involve different techniques. Techniques that may be employed include the use of chlorine, ozone or potassium permanganate. Pretreatment with aeration is sometimes used, and complete color removal often requires coagulation and flocculation with aluminum sulphate (AWWA, 1971).

Chlorination practices include combined residual chlorination (chlorine-ammonia treatment), free-residual chlorination (breakpoint process), superchlorination and dechlorination, and chlorine dioxide treatment. Because of the concern with trihalomethane production when aquatic humus is chlorinated, chlorination without post filtration with granular activated carbon is not recommended (Vik, 1985). Superchlorination with chlorine dioxide during spring in the City of Edmonton water treatment plants is effective in controlling tastes and odors produced by naturally occuring organic substances, but is not effective in controlling tastes and odors produced by artificially present (ie: urban & industrial) organic substances (Walker, 1986). With any chlorination practice, it is essential to add sufficient chlorine to ensure complete oxidation, otherwise intermediate chlorinated compounds may be produced which can intensify any existing tastes and odors (AWWA, 1971).

Ozonation is also used to oxidize taste and odor causing organic substances, with a normal dosage range of 0.8 - 5.0 kg of ozone per 1,000 m^3 of water. Extensive use in France and increasingly in the United States for both disinfection and taste and odor control has been generally effective. Ozone is considered as being most effective for the control of tastes and odors produced by naturally-present organic substances (AWWA, 1971). Laboratory simulations are recommended prior to the installation of ozone generators, since water quality can effect oxidation chemistry and the volatility of organic compounds (Gurol, 1985). Ozone does not leave a residual in the treated water, so post chlorination is required to protect the distribution system from bacterial regrowth.

Potassium permanganate is reported to be an effective oxidizing agent used in the removal of tastes and odors. Normally, it is added as a pretreatment in a dosage range of 1-5 mg/L, and requires post filtration to remove insoluble manganese oxide hydrates that are formed. Post chlorination is required to maintain an effective chlorine residual in the distribution system (AWWA, 1971).

Coagulation and flocculation are used for color removal, in addition to removal of suspended solids and colloidal matter. Coagulation and flocculation is also effective in removing some tastes and odors from water. Aluminum sulphate is the most common and effective coagulant used; rapid mixing is required after addition of the coagulant to ensure uniform dispersal. Following rapid mixing, gentle agitation is required to encourage floc formation. Flocs remove some taste and odor and most color producing substances by adsorption or encapsulation. Settling in a sedimentation basin is required to remove the flocs from the water. After settling, filtration is required, normally using slow or rapid sand filters. Post treatment with either powdered activated carbon or granular activated carbon is sometimes required to adsorb the remaining taste and odor causing substances (AWWA, 1971).

The following steps are recommended to be investigated as an effective treatment process to remove taste, odor and color at both lake treatment plants at the Park:

1. Improvement of the lake quality adjacent (see section 9.2) to the intakes, and a more efficient intake system.
2. Pretreatment of the raw water with ozone, by using an ozone generator.
3. Coagulant feed using aluminum sulphate in a rapid or flash-mixing basin.
4. Monitoring of the pH for optimal color removal (pH 4.0-6.0).
5. Flocculation in a mixing basin; either a conduit-type or mechanical-type.
6. Sedimentation of flocs in a gravity sedimentation basin.
7. pH adjustment to a neutral range.
8. Prechlorination with chlorine gas.
9. Rapid sand filtration with pressure sand filters, operating at a filtration rate of approximately 90-100 L/m^2.
10. Adsorption with granular activated carbon, contained in filter pressure vessels.

11. Post chlorination with chlorine gas to maintain a free residual of at least 0.2 mg/L in the storage and distribution system. An automatic chlorine residual indicator and recorder is recommended.

A full time, trained water treatment plant operator is strongly recommended to operate and maintain the treatment systems.

The Administration Headquarters plant has sufficient gross capacity to meet all projected water demands until 2016. However, additional storage of approximately 550 m^3 is predicted to meet peak weekend demands under high growth conditions by 2016. The campground plant requires additional capacity to meet projected water demands by 2016 under high growth conditions, unless the plant is operated for longer than 16 hours per day by this time. A doubling of plant capacity to 454 L/minute is an alternative. Additional storage is required to meet peak weekend demands by 2016 under high growth conditions. It is estimated that 730 m^3 of peak storage is required for high growth conditions at the Campground plant.

9.2 Improved Lake quality

Eutrophication is a natural aging process that affects every body of water from the time of its formation. Most shallow eutropic lakes in central Alberta are well-mixed, with little change in vegetative standing crop with depth (Hickman, 1979). However, decomposing algae and aquatic weeds, the primary source of taste, odor and color problems, tend to accumulate at the bottom of the lake. Raising the existing plant intakes from their present position near the bottom of the lake to a point near the lake surface should reduce the inflow of decomposing organic matter in with the raw plant water. A floating intake to draw water from approximately 300 - 450 mm below surface, with an adjustable anchor system so that the intake can be positioned below anticipated winter ice level in late fall appears to be successful (EPA, 1973).

Algae control in water bodies and raw water reservoirs is traditionally accomplished with an algaecide such as copper sulphate. Where used, the copper sulphate is effective if applied in the correct dosage, although it is not very effective in waters containing significant alkalinity (AWWA, 1971). Copper sulphate treatment adjacent to the plant intakes was performed by Parks Canada from approximately 1960 to 1967, without any apparent improvement in plant raw water quality. Algaecides including copper sulphate do kill algae, but the dead algae accumulate at the bottom of the lake and decompose as they would eventually do without the application of any algaecide. It should be noted that blue green algae may bloom infrequently on the lake. Some toxins contained in blue green algae are extremely poisonous, and it appears that poisoning will occur when large amounts of the actual algae are ingested. For this reason, algaecide application may be required at some times.

Aeration is not generally effective in removing taste and odor associated with decomposing algae, since the offending substances released when algae decompose are not highly volatile (AWWA, 1971). However, when decomposition is anaerobic, byproducts such as hydrogen sulphide are produced which cause additional taste and odor problems. Studies on shallow lakes in central Alberta indicate that as macrophytes and plant material decompose, sulphur bacteria become established and anaerobic decomposition is initiated. Formation of an ice cover over the lake in winter reinforces the anaerobic decomposition and additional decomposing plants adds to the process. Cooking, Ministik and Oliver Lakes have been observed to become totally anaerobic sometime after ice formation, and remain so until spring breakup (Gallup, 1975). In summer, shallow lake water in central Alberta tends to have saturated or near-saturated dissolved oxygen conditions within 1 - 2 metres of surface, but are generally only 20-70% saturated below that depth (Hickman, 1979). Raw water influent dissolved oxygen at both plants was measured in summer 1986 using a Hach OX-2P test kit and the results indicate approximately 50% saturation with dissolved oxygen in the water at present intake depth (see table 9.1).

Table 9.1

DISSOLVED OXYGEN CONTENT
ASTOTIN LAKE TREATMENT PLANTS

July, 1986

Campground Plant	
Lake at 300 mm depth	8.5 mg/L
Raw influent (depth 2.1 m)	4.5 mg/L
Administration Plant	
Lake at 300 mm depth	8.0 mg/L
Raw influent (depth 2m±)	4.0 mg/L

Water Temperature 17.0°C
Atmospheric Pressure 27.6 inches of mercury
Dissolved Oxygen Saturation (Calculated) 8.6 mg/L

Source: Author

Artificial aeration with compressed air has been established as being a suitable technique for improving the physical quality of water in small surface water reservoirs. Hydrogen sulphide can be eliminated by causing the organic matter decomposition to become aerobic. Summer dissolved oxygen content can be maintained between 60 and 70% saturation, with 80-95% saturation over winter (Livingstone, 1983). However, in larger lakes, artificial aeration is not practical, except as zone aeration adjacent to the intake. The periodic inflow of poorer quality water into the aerated intake zone would counteract the beneficial effects of aeration. It would be best to construct a reservoir adjacent to the lake, pump it full of lake water, and aerate the reservoir water instead. The concept of a lakeside storage was suggested at the Park in 1967 (Parks Canada), but the recommendation was not implemented.

The following steps are recommended for consideration as being potentially effective in improving the physical quality of raw water withdrawn from Astotin Lake:

1. Install a floating intake at the Administration Headquaters plant.
2. Install zone aeration, for use primarily in winter, adjacent to the floating intake at the Administration Headquarters plant.
3. Construct a lined earthern storage reservoir adjacent to the Campground plant to hold one year's supply of water. The reservoir to be filled from the lake when physical analysis indicates the lake water is of optimum quality. Aerate the reservoir water.
4. Implement a spot algaecide application program to control the growth of blue green algae on all major lakes.

9.3 Improved treatment of existing utilized wells

The four Station wells all require treatment of the water for human consumption to remove excess total dissolved solids. Treatment of the water for domestic use is not required at Oster Station, but is required for the control of iron bacteria at the other three Stations. In addition, hardness removal is desireable at CWS and Isolation Stations. Increased system storage to meet projected peak demands is required at Information Station under low and medium growth conditions, and at Oster Station under low and medium growth conditions, and at Isolation Station under high growth conditions. New sources of supply are required by 2016 under high growth conditions at Information and Oster Stations.

Removal of total dissolved solids from water for human consumption can be accomplished by electrodialysis, ion-exchange, distillation or reverse-osmosis.

Electrodialysis has been successfully used to remove total dissolved solids in the range of 1,000 to 5,000 mg/L, and is one of the most common large-scale methods used at present in the world (AWWA, 1971). Pretreatment to remove iron, manganese, turbidity and organic matter is required. Design of electrodialysis equipment for specific applications is required to ensure optimum operation. Approximately 30% of the feed water to an elecrodialysis unit is used for membrane flushing and is a waste product.

Ion-exchange processes for demineralization of water have been developed, and usually involve mixed beds of both cation and anion exchange resin media. The normal application is for waters containing 500 to 1,500 mg/L total dissolved solids. Regeneration of the resins with acid and alkali is required, and tends to be a complicated process. Operational control is also complex, requiring monitoring of feed and product water (AWWA, 1971).

Distillation for small water systems usually employs an evaporation tank and condensing coil, with distilled water storage in a small tank. The technique is simple and relatively trouble-free, the main input being electrical energy to boil the water. Routine maintenance is required to remove encrustations from the evaporation tank to maintain equipment efficiency. There is no limit to the range of total dissolved solids removed by distillation; sea water with an average of 35,000 mg/L total dissolved solids is distilled in many parts of the world (AWWA, 1971).

Reverse osmosis is normally used to remove total dissolved solids in the range of 500 - 2,000 mg/L. Small reverse osmosis units are available that operate on line pressure (140 - 280 kPa) and produce 5-15 L/day; larger units producing 200 - 1200 L/day require pressures inside the reverse osmosis unit of 1,200 - 1,400 kPa. Normal treatment range from reverse osmosis is 70 to 90% removal of total dissolved solids. Pretreatment to remove iron, maganese, hardness and turbidity is required, and excess chlorine may be deleterious to the membranes. Membrane flushing produces waste of 50 - 500% of the feed water, with higher waste from the smaller reverse osmosis units (AWWA, 1971, Alberta Agriculture, 1979).

Iron bacteria are a common occurrence in well water in Alberta (Alberta Agriculture, 1978). They cause deterioration of the water supply system by a combination of corrosion and slime encrustation; they produce unpleasant tastes and odors and cause discoloration of the water, and cause staining of laundry and plumbing fixtures. High concentrations (>0.3 mg/L) of inorganic iron in the well water are not neccessary to support iron bacteria growth, since they can derive sufficient iron for metabolism from iron well casing, iron pipes, etc. The only practical treatment to control iron bacteria is shock chlorination. A large volume of superchlorinated water containing 500 - 2,000 mg/L chlorine is introduced into the well. The chlorine solution is pumped throughout the water system, retained in the water system for 8-12 hours, then flushed to waste. Since shock chlorination is a control technique, repeat treatments are required when iron bacteria regrowth occurs. Treatments every 6 months are recommended (AWWA, 1971, Alberta Agriculture, 1978, EPA, 1973).

Continuous chlorination for the control and prevention of regrowth of iron bacteria is usually accomplished by injection of chlorine directly down the well. Normally a chlorine dosage is calculated to provide a free residual of 3-5 mg/L in the well and water system. Dechlorination with granular activated carbon is required before human consumption or domestic water use. Chlorine liquid injection using a chemical feed pump, or chlorine solid injection using a volumetric feeder is employed. Solid calcium hypochlorite pellet feeders have been developed recently that have been successful in a number of small water systems. Agitation of the well water with compressed air is beneficial in promoting mixing of the chlorine feed (EPA, 1973, AWWA, 1971).

Water softening is usually accomplished by either the Lime-Soda Process, or by ion-exchange. The Lime-Soda Process is usually employed in larger municipal scale plants and essentially consists of feeding lime (calcium hydroxide) to precipitate magnesium hydroxide and calcium carbonate, then feeding soda (sodium carbonate) to precipitate the remaining noncarbonate hardness (AWWA, 1971). Due to the complexity of the process, it is not recommended for small water systems (EPA, 1973).

Water softening using the ion-exchange process is well-suited for small water systems. A cation exchange resin, usually synthetic, is charged with sodium cations from regeneration with salt. These sodium cations are exchanged for calcium and magnesium cations in the hard (raw) water. Periodic regeneration of the resin is required; regeneration wastes can be deleterious to the operation of sewage disposals weeping tile fields so disposal in a separate system is recommended (see section 6.2). Water softened by the ion-exchange process contains more sodium that the raw water; 46 mg/L of sodium are added for each 100 mg/L of hardness removed. Ion-exchange water softeners will remove small amounts of iron from raw water by direct filtration, but a resin cleaning compound such as sodium hydrosulphite should be used frequently to clean accumulated iron from the resin. Iron bacteria will foul resin rapidly, significantly reducing its ion-exchange capacity. Excess amounts of chlorine (>0.5 mg/L free residual) are deleterious to the resin and should be avoided (AWWA, 1971, EPA, 1973).

The following recommendations are suggested as appropriate treatment processes at the four Stations. In addition, storage and water supply recommendations are suggested where appropriate:

- Oster Station

1. Installation of a distiller or reverse-osmosis system to treat the water for human consumption at the staff house and for campers.
2. Peak storage is required to meet weekend demands on the well system of approximately 30 m^3 (medium growth conditions).
3. A new water source capable of producing approximately 2,500 m^3/year is required (high growth conditions).

- CWS & Isolation Stations

1. Treatment with shock chlorination for the control of iron bacteria.
2. Installation of a continuous chlorination system for in-well control of iron bacteria, followed by dechlorination with granular activated carbon contained in a filter pressure vessel.
3. Ion-exchange water softening using the existing equipment. The water softener to be installed after the dechlorination point.
4. Installation of a distiller or reverse osmosis system to treat the water for human consumption. The feed line to the system should be after the dechlorination point, but before the softening point.

5. At Isolation Station only, peak storage of approximately 2 m^3 is required to meet demands under high growth conditions.

- Information Station

1. Installation of a distiller or reverse-osmosis system to treat the water for human consumption at the staff house and Information Centre.
2. Treatment with shock chlorination for the control of iron bacteria.
3. Installation of a continuous chlorination system for in-well control of hydrogen sulphide and iron bacteria, followed by dechlorination with granular activated carbon contained in a filter pressure vessel.
4. Peak storage is required to meet weekend demands on the well system of approximately 13 m^3 (low growth) and 46 m^3 (medium growth).
5. A new water source capable of producing approximately 2500 m^3/year is required under high growth conditions.

9.4 Conjunctive use of groundwater and surface water.

Conjunctive use of groundwater and surface water is an alternative to be considered when one available water supply is of high quality but limited quantity, and the other available supply is of relatively unlimited quantity but poorer quality. Also, conjunctive use to supplement seasonal surface water supplies with stored groundwater may be an alternative. Conjunctive use may take the form of one supply for human consumption and another supply for all other domestic uses.

Another variation is the use of a soft water supply for washing and laundering, and a hard water supply for human consumption, toilet flushing and lawn watering. An example of conjunctive use common on southern Alberta farms is the use of a low-yielding water well for human consumption, cooking, washing and laundering, and the use of lower quality dugout water for toilet flushing and lawn watering.

Groundwater within Elk Island National Park requires treatment for human consumption and, with the exception of Oster Station, for domestic use. Surface water, although suitable for lawn watering, requires some treatment for domestic use and considerable treatment for human consumption. Availability of supply relative to demand is adequate at all points at present and under low and medium growth conditions. Treatment of one water supply system at each water point is more feasible than the treatment of two supply systems at each water point when water availability is not a limiting factor. Under high growth conditions it may be feasible to consider conjunctive use at the Astotin Campground area, and Information Station, where increasing the capacity of existing sources or developing new sources is predicted.

9.5 Outwash Aquifer Northwest of Park Boundaries

An outwash sand and gravel aquifer with a calculated 20 year individual well safe yield of 5-25 ig/minute (22.5-114 L/minute) is located northwest of Astotin Lake (Stein, 1976). A small lobe extends just into the Park adjacent to the northwest gate. The closest distance from the edge of the aquifer to the Administration Headquarters area is approximately 500 m, and about 6,500 m to the Astotin Campground area. Another portion of the outwash aquifer is approximately 1,000 m west northwest from Oster Station (see Figure 9.1).

Logs from wells completed in the outwash aquifer (Alberta Research Council) for sections 16, 17, 20, 21, 28, 29, 32, 33, Township 54, Range 20, west of the Fourth Meridian adjacent to Astotin Lake were examined. The total number of well logs available for this area of the aquifer is sixteen, of which five provide enough information for evaluation:

log SW28 - well depth 42.7 m
- gravel 40.9 m to 42.7 m
- yield 54.5 L/minute

log SW33 - well depth 19.5 m
- sand 9.1 m to 10.1 m
- yield 20.4 L/minute

log NE32 - well depth 7.9 m
- coarse gravel 2.4 m to 3.0 m
- sand 6.1 m to 7.9 m
- yield 90.8 L/minute

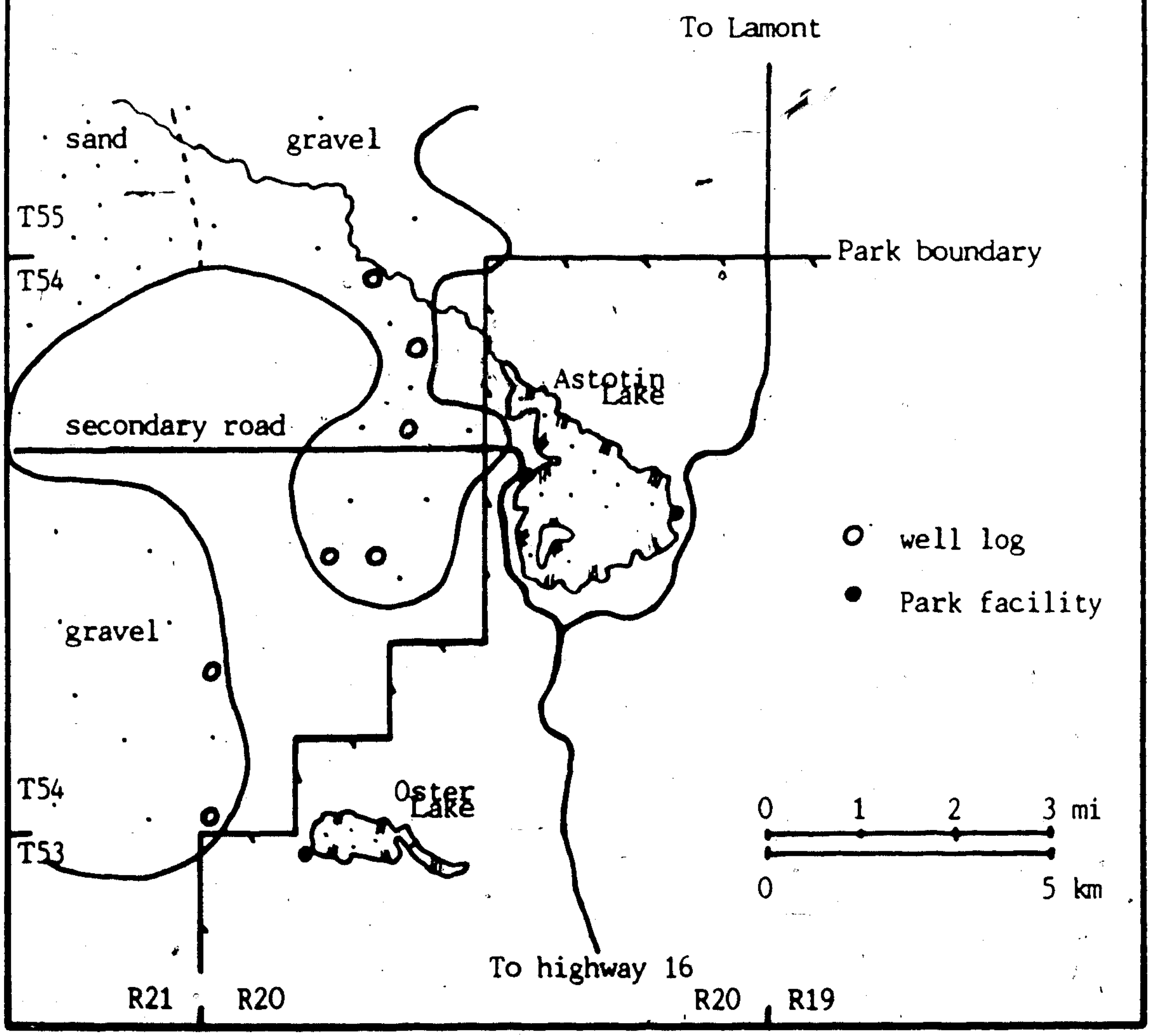
log NE17 - well depth 45.7 m
- gravel 44.2 m to 45.7 m
- yield 36.3 L/minute

log NW17 - well depth 14.6 m
- sand 4.9 m to 7.0 m
- sand 7.6 m to 9.8 m
- yield 45.4 L/minute

Figure 9.1

Northwest outwash aquifer

(source: Stein. 1976)



Logs from wells completed in the outwash aquifer for sections 6 and 7, Township 54, Range 20, west of the Fourth Meridian adjacent to Oster Station were examined, and two provided enough information for evaluation:

log SW6 - well depth 18.3 m
- gravel (depth not recorded)
- yield 90.8 L/minute

log NW7 - well depth 23.8 m
- coarse sand at 23.8 m
- yield 227 L/minute

The projected flows to meet maximum daily demands at the Park, based upon a maximum of 16 hours per day system operation are:

- Administration Headquarters

1986 estimate	24.3 L/minute
2016 low growth	25.7
2016 medium growth	58.5
2016 high growth	139.6

- Astotin Campground

1986 estimate	24.3 L/minute
2016 low growth	27.6
2016 medium growth	75.0
2016 high growth	242.4

- Oster Station (for summer peak period)

1986 estimate	3.2 L/minute
2016 low growth	3.2
2016 medium growth	13.6

2016 high growth 31.9 L/minute

Chemical water quality in the outwash aquifer is variable, being generally good in the recharge areas (total dissolved solids §1,000 mg/L) but poorer in the discharge areas (total dissolved solids (1,000 - 2,000 mg/l). The major cations are calcium and magnesium, with carbonate and bicarbonate anions predominant in the recharge areas and sulphate anions predominant in the discharge areas (Stein, 1976). Chemical water analysis data are not recorded on many of the well logs examined, but the results are summarized on table 9.2. The data indicate that the chemical water quality in the outwash aquifer adjacent to the Astotin Lake Administration area is potentially good, but contains excess hardness; the chemical water quality in the outwash aquifer adjacent to Oster Station is potentially poor, containing excess total dissolved solids, hardness, sodium, sulphate and iron.

Test drilling is required to locate zones within the outwash aquifer that have high permeabilities and thicknesses to optimize well yield. Coarse sands, gravels and mixtures of coarse sand and gravel will generally provide maximum yields, depending upon the cleanness of the deposits (Stein, 1976). Proximity to the intended point(s) of use is an important economic consideration. Once a potential high yielding zone within the outwash aquifer is located, several other factors have a major effect upon potential well yield; the depth of penetration and the designed well efficiency. Full penetration and full screening of the aquifer is usually necessary to minimize head loss within the aquifer as it is pumped. However, for thin aquifers (less than approximately 6m), a large diameter well can reduce the percentage of aquifer that requires

TABLE 9.2

SUMMARY OF CHEMICAL ANALYSES

NORTHWEST OUTWASH AQUIFER

	NE32	SW6	NW7
Total Dissolved Solids	752	1,888	1,445
Hardness	597	952	781
Alkalinity	352	nv	nv
Sulphate	270	1,000	850
Sodium	15	nv	306
Bicarbonate	352	nv	666
Iron	nv	nv	1.9

nv = no value

values in mg/L

Source: Alberta Research Council

screening (Johnson Division, 1975). Well design is critical in obtaining maximum well efficiency. A properly sized well screen with a maximum of open area, with a properly graded filter sand pack if necessary, will result in a high well efficiency. Correct screen placement and well development after construction will maximize well efficiency (Johnson Divison, 1975).

The use of large diameter wells equipped with large diameter spirally-wound, continuous slot-type screens is gaining popularity in Alberta, after being successfully used in Saskatchewan and Manitoba. A typical well diameter is 600 - 750 mm and depths up to 40 m are feasible." There are several water well contractors in central Alberta who have experience with this technique (Livingstone, 1982).

The following steps are recommended for consideration to assess the feasibiity of utilizing the northwest outwash aquifer as a water source for the Administration Headquarters and Astotin Campground areas:

1. Test drilling to locate highly permeable zones in the portion of the aquifer that lies within the Park adjacent to the northwest gate.
2. Test drilling in the aquifer in sections 16, 17, 20, 21, 28, 29, 32, 33. Township 54, Range 20, west of the Fourth Meridian.
3. Aquifer testing and water analysis of potentially high yielding zones.
4. If a high yielding well or well field can be developed, then perform an economic analysis to determine the costs and benefits associated with:
   - using the outwash aquifer as a replacement water source
   - using the outwash aquifer as a conjunctive (supplementary) water source
   - not using the outwash aquifer

The following steps are recommended for consideration to assess the feasibility of utilizing the northwest outwash aquifer as a water source for the Oster Station:

1. Test drilling to locate permeable zones in the aquifer in sections 6, Township 54, Range 20 and in Section 1, Township

54, Range 21 and in Section 36, Township 53, Range 21, west of the Fourth Meridian.

2. Testhole pumping for water analysis sampling. If a source of significantly better quality than that currently used at Oster Station is found, then proceed with aquifer testing.

3. If a well of adequate yield and acceptable quality can be developed, then perform an economic analysis to determine the costs and benefits associated with:

   - using the outwash aquifer as a replacement water source
   - using the outwash aquifer as a conjunctive source
   - not using the outwash aquifer.

A discussion of the legal and administrative considerations in utilizing out-of-Park water sources is contained in Section 10.3.

9.6 Aquifers in the south of the Park

There are three potentially higher yielding aquifers in the south of the Park: a more permeable zone of the Horseshoe Canyon Formation; permeable surficial sediments contained in buried preglacial channels; outwash sand and gravel (see Figure 4.1).

In the southwest of the Park, the probable 20 year safe yield of the Horseshoe Canyon Formation ranges from 5 - 100 ig/minute (22.7 - 454 L/minute). This higher rated yield is due to the presence of numerous highly fractured coal seams interbedded with sandstone and shale (Stein, 1976). The CWS and Isolation Station wells are constructed into a less permeable zone of the Horseshoe Canyon Formation, with estimated safe yields of 1 and 3 ig/minute (4.5 and 13 L/minute) respectively (see section 4.3). The higher yielding zone can be accessed within Park boundaries, 800 m west of CWS Station and 4,000 m northwest of Isolation Station. Outside of Park boundaries, the zone is 400 m west of CWS Station and 1,500 m south of Isolation Station. Flyingshot Lake is over 5,000 m east of the zone. The chemical water quality from the formation is poor with total dissolved solids ranging from 1,000 to 2,000 mg/L. The total dissolved solids at CWS Station is 1,223 mg/L (1986) and 1,703 mg/L (1986) at Isolation Station. The water contains excess hardness, alkalinity, sodium and bicarbonate (see appendix). Iron bacteria is also present in both station wells.

The surficial sediments contained in buried preglacial channels are classified as Saskatchewan Gravels and Sands. The probable 20 year safe yield ranges from 5 to 25 ig/minute (22.7 - 114 L/minute) in the small tributary channels found within the Park (Stein, 1976). Preglacial channels are located within 1,000 m (north) of CWS Station, 1,200 m (north) of Isolation Station, and on the west, south and southeast side of Flyingshot Lake.

Hydraulic connections exist between sediments contained in preglacial channels, and the overlying and adjacent surficial deposits, the underlying and adjacent bedrock, and any surface water bodies (Alberta Research Council, 1978). For these reasons, flow within preglacial channel sediments is extremely complex. Chemical water quality in the preglacial channel sediments is related to the flow patterns within the sediments. Generally, highly permeable preglacial channel sediments, with recharge predominantly from surficial deposits and/or surface water bodies, have good chemical water quality.

Conversely, less permeable preglacial channel sediments, with recharge predominantly from adjacent and underlying bedrock, have poor chemical water quality. Within the Edmonton region, total dissolved solids in preglacial sediments ranges form 500 to 4,000 mg/L, but is usually less than 1,000 mg/L (Alberta Research Council, 1978).

In the extreme southwest of the Park, an outwash sand and gravel aquifer has a probable 20 year safe yield of 5-25 ig/minute (22.7 - 114 L/minute) (Stein, 1976). It is located approximately 1,600 m southeast of the south end of Flyingshot Lake, within park boundaries. Blackfoot Lake within the outwash zone appears to be in part a groundwater discharge feature of this aquifer. A buried preglacial channel from the northwest passes through the outwash zone, so some degree of hydraulic connection is probable. Groundwater flow within the outwash aquifer is complex, so prediction of chemical water quality is difficult.

The following recommendations are given regarding the potential feasibility of utilizing the aquifers in the south of the Park:

1. Due to the inherent poor chemical water quality, the more permeable zone of the Horseshoe Canyon Formation is not recommended for development as a potable water source.
2. Test drilling and water sampling might be conducted to determine if permeable zones with good quality water exist within the buried preglacial channels.
3. Test drilling and water sampling might be conducted to determine if permeable zones with good quality water exist within the southeast outwash sand and gravel aquifer.

4. If a well or wells of acceptable yield and quality can be developed, then perform an economic analysis to determine the costs and benefits associated with:
   - using the well(s) as a replacement source for CWS and Isolation Stations
   - using the well(s) as a new source for Flyingshot Lake campground under medium and high growth conditions
   - not using the well(s).

9.7 Bedrock aquifer west of the Information Centre.

A small, more permeable zone within the bedrock aquifer is located approximately 500 m west of the Information Centre. The increased permeability is due to the presence of numerous, fractured coal seams in this approximately 0.3 km^2 area (Stein, 1976). The zone is within a subcrop of the Horseshoe Canyon Formation, and as such will contain poor quality water (see section 9.6). Recharge from adjacent Little Tawayik Lake is improbable, due to the relatively impermeable till overlying the bedrock.

Recommendation:

1. Due to the inherent poor chemical water quality, the small, more permeable zone of the Horseshoe Canyon Formation west of the Information Centre is not recommended for development as a potable water source.

9.8 Vegreville Corridor Regional Water Supply System (VCRWSS) pipeline

The VCRWSS was constructed in 1981 and 1982 to serve the urban municipalities of Bruderheim, Lamont, Chipman, Mundare and Vegreville with potable water from the City of Edmonton. Rural municipalities along the corridor are also served, but constitute a minor use at present. The pipeline starts with on-line storage and pumping facilities near Fort Saskatchewan, connecting to the North East Water Board pipeline. The maximum des n flow of the pipeline is 19,658 L/minute, based upon a projected 2005 design population of 37,000 people served (5.85% population growth projection). Design flow capacity immediately before Lamont is approximately 13,000 L/minute, at an average operating pressure of approximately 300 psi (2,100 kPa). Due to a lower population growth rate than projected, the pipeline has excess capacity, and at present is is operated at approximately 60% of design capacity (Associated Engineering Alberta Ltd., 1980).

The VCRWSS pipeline is administered by the Vegreville Corridor Water Services Commission. The Commission is agreeable to sell excess capacity from the pipeline to additional municipal customers. The connection requirements include provision of a minimum of 2 days storage of customer's water off of the pipeline, and a variety of flow and pressure control and monitoring equipment. The total cost of connection is borne by the customer, but does not include an administrative connection fee. The cost of water in 1986 is approximately $4.50/1,000 ig for municipal customers.

The closest point that the VCRWSS pipeline approaches Elk Island National Park is approximately 5 km northwest of Lamont on the north side of highway 15. If a connection was made on the southeast of section 25, Township 55, Range 20, west of the Fourth Meridian in the County of Lamont, the distance due south to the Astotin Lake Campground area is approximately 11.2 km. Other routes are available but would involve longer lengths of Park supply pipeline to avoid crossing private land. The elevation difference between the potential connection point and Astotin Lake Campground area is approximately 53 m, with the Park being the higher point.

Assuming that the supply pipeline was installed to supply all of the water demand in the Park, an average daily flow in the pipeline would be 28, 68 and 177 L/minute to meet low, medium and high growth conditions by 2016. If the supply pipeline was sized to accomodate twice mean daily flow, then suitable pipe diameters would be 75, 100 and 150 mm polyvinylchloride respectively (Linsley and Franzini, 1972). Peak storage could be provided at the Campground area in reservoirs of 80 m^3, 200 m^3 and 500 m^3 capacity respectively. Distribution from the reservoir to the Administration Headquarters area would require pumping and a 200 - 250 mm diameter main. A tank-loading station could be provided at the reservoir for transport of water to remote stations, campgrounds and day use areas.

The following steps are recommended to assess the feasibility of connection to the VCRWSS pipeline and installation of a supply pipeline to the Park:

1. Engage a professional engineering consultant to prepare preliminary designs and order of magnitude cost estimates for supply systems from the VCRWSS pipeline for low, medium and

high growth conditions, and

2. Perform an economic analysis to determine the costs and h fits associated with installing a supply system from the SS pipeline, as compared to implementing other water source development projects.

A preliminary economic analysis is contained in Chapter 10, and includes a comparison with other options discussed in this chapter.

9.9 Surface water in the south of the Park

There are six borrow pits located adjacent to the south side of highway 16, with a combined storage capacity of approxiately 150,000 m^3. Several of the borrow pits are in excess of 6 m deep, and are filled with a combination of surface runoff and groundwater seepage. Some surface runoff originates from the northwest and from the highway 16 ditch, but a considerable amount originates from the south and southeast. One of the deeper borrow pits is approximately 1,000 m southeast of the Information Centre, and another deep one is approximately 1,600 m due north of the north end of Flyingshot Lake.

Surface water reservoirs where inflow can be controlled can potentially be excellent water sources. Many small municipalities in Alberta utilize controlled catchment surface water reservoirs for potable use, after treatment. Earthwork would be required to divert potentially contaminated runoff originating from the highway 16 ditch, and additional earthwork may be required to enhance surface runoff yield from the south and east. Algae and aquatic weed control and prevention is simplified when reservoir inflow is controlled. The reservoir depth, combined with artificial aeration, would allow high saturations of dissolved oxygen to be maintained in the reservoir water. A floating intake would allow for the withdrawal of optimum physical quality water. Treatment for human consumption and domestic use could conceivably consist of pre chlorination, detention, sand filtration, adsorption with granular activated carbon, and post chlorination (EPA, 1973).

The following recommendations are given regarding the potential feasibility of using surface water in the south of the Park:

1. Monitor the origins and quality of surface runoff into the borrow pits for a one year period.
2. Monitor the physical, chemical and bacteriological quality of the water stored in the borrow pits for a one year period.
3. If the surface runoff and stored water quality is potentially adequate, perform an economic analysis to determine the costs and benefits associated with:
   - using a borrow pit as a replacement water source for the Information Centre,
   - using a borrow pit as a conjunctive water source for the Information Centre,
   - using a borrow pit as a water source for the Flyingshot Lake Campground under medium and high growth conditions,
   - not using the borrow pit.

10. COST COMPARISON OF DEVELOPING POTENTIAL WATER SOURCES

Order of magnitude capital cost estimates, and operation and maintenance cost estimates are necessary to allow comparison and evaluation of alternatives. Legal and administrative considerations associated with implementing alternatives must also be examined. The potential benefits realized from implementing various alternatives need to be identified and, where possible, quantified.

10.1 Capital Costs

Order of magnitude capital cost estimates (1986 Dollars) can be derived for each alternative identified in Section 9 and preceding sections. However, without preliminary engineering assessment and design, the cost estimates derived are useful for comparative purposes only. Comparison of capital costs will allow some order of priority to be established for each alternative by the Park Administration. Detailed cost breakdowns are contained in the appendix (2.1 - 2.15)

The capital cost estimates are based upon average costs for constructing similar water systems in central Alberta during 1986. Costs were obtained from Alberta Utilities, Municipal Utilities Division, from both municipal and rural water supply staff. The two major variables contained in the cost estimates are labor and materials, both of which are subject to seasonal variations and variations caused by supply and demand factors.

- Improvement of Administration Headquarters water treatment plant:

low/medium/high growth	$ 90,000
high growth peak storage	120,000

- Improvement of Astotin Lake Campground water treatment plant:

low/medium growth	$110,000
high growth (increased capacity)	300,000
high growth peak storage	160,000

- Improved lake quality:

(Administration plant) low/medium/high growth	$ 20,000
(Campground plant) low growth raw storage reservoir	15,000
medium growth raw storage reservoir	25,000
high growth raw storage reservoir	55,000

- Improvement of Oster Station system:

potable treatment (low growth)	$ 6,000
potable treatment (medium growth)	13,000
potable treatment (high growth)	new source needed
peak storage (low growth)	2,000
peak storage (medium growth)	7,000
new source (high growth)	see other alternatives

- Improvement of CWS Station system:

low/medium/high growth	
potable treatment	$ 1,000
domestic treatment	5,000

- Improvement of Isolation Station system:

potable treatment (low growth)	$ 1,000
potable treatment (medium growth)	1,500
potable treatment (high growth)	2,000
domestic treatment (low growth)	5,000

domestic treatment (medium growth)	5,000
domestic treatment (high growth)	10,000
peak storage (high growth)	1,000

- Improvement of Information Station system:

potable treatment (low growth)	$ 10,000
potable treatment (medium growth)	22,000
potable treatment (high growth)	new source needed
domestic treatment (low growth)	5,000
domestic treatment (medium growth)	10,000
domestic treatment (high growth)	new source needed
peak storage (low growth)	3,000
peak storage (medium growth)	10,000
new source (high growth)	see other alternatives

- Northwest Outwash aquifer supply for the Administration Headquarters area:

low growth	$116,000
medium growth	147,000
high growth	270,000

- Northwest Outwash aquifer supply for the Astotin Campground area:

low growth	$171,000
medium growth	235,000
high growth	460,000

- Northwest Outwash aquifer supply for Oster Station:

low growth	$110,000
medium growth	111,000
high growth	129,000

- Southern buried preglacial channel aquifer supply for CWS Station, Isolation Station and Flyingshot Campground:

CWS (low/medium/high growth)	$ 60,000
Isolation (low, medium/high growth)	63,000
Flyingshot Campground (medium/high growth)	71,000

- Southeast Outwash aquifer optional supply for Flyingshot Campground:

medium/high growth	$181,000

- VCRWSS supply for all Park uses:

low growth	$735,000
medium growth	887,000
high growth	1,215,000

- Surface water supply for Information Station and option for Flyingshot Campground:

Information (low/medium/high growth)	$ 69,000
Flyingshot Campground (medium/high growth)	81,000

- New additional sources required:

North Gate Station (medium/high growth)	$ 31,000
Tawayik Campground (medium/high growth)	55,000

The range of capital cost estimates for alternatives under each growth scenario can be summarized:

	$
- Low Growth	
- Improve all existing supplies	273,000
- Replace all existing supplies with better individual sources	589,000
- Replace all existing supplies with VCRWSS pipeline	735,000
- Medium Growth	
- Improve all existing supplies*	476,000
- Replace all existing supplies** with better individual sources	842,000
- Replace all existing supplies with VCRWSS pipeline	887,000
- High Growth	
- Improve all existing supplies***	$1,119,000
- Replace all existing supplies**** with better individual sources	1,208,000
- Replace all existing supplies with VCRWSS pipeline	1,215,000

An evaluation of the alternatives is contained in Chapter 12.

* Includes new supplies for Flyingshot and Tawayik Lake Campgrounds and North Gate Station ($157,000) (see below)

**Assumes new well supply for Flyingshot Lake campground ($71,000), and new on-site well supplies for Tawayik Lake Campground and North Gate Station ($86,000).

***Includes new supplies for Flyingshot and Tawayik Lake Campgrounds and North Gate Station ($157,000) and replacement supplies at Oster Station and Information Station ($198,000) (see below)

****Assumes new well supply for Flyingshot Lake Campground ($71,000), new on-site well supplies for Tawayik Lake Campground and North Gate Station ($86,000), and a replacement well supply for Oster Station ($129,000) and a replacement surface water supply for Information Station ($69,000)

10.2 Operation and maintenance cost

Estimated operation and maintenance costs are necessary to further evaluate and compare capital cost estimates. However, without preliminary engineering assessment and design, the estimates derived are useful for comparative purposes only. The estimated operation and maintenance costs are summarized in table 10.1. It is assumed that the maintenance required is higher for older systems than for newer ones, due primarily to design and efficiency factors. No allowance has been made for depreciation, financing or interest charges, opportunity cost, etc. Detailed cost breakdowns are contained in the appendix (3.1 - 3.6)

TABLE 10.1

SUMMARY OF OPERATION & MAINTENANCE COSTS ($/y)

		Low	Medium	High
Administration HQ plant		15,400	35,900	83,900
Astotin Campground plant		6,900	18,800	38,800
Existing Station wells		10,150	20,500	40,900
TOTAL	$	32,450	75,200	163,600
Administration NW Outwash well		5,700	12,000	27,200
Astotin Campground NW outwash well		3,700	7,900	22,100
Oster NW outwash well		1,300	1,700	2,500
CWS/Isolation/Flyingshot new wells		1,650	2,750	3,550
Information Station surface water supply		1,150	1,600	2,500
Tawayik/North Gate wells		-	1,350	1,800
TOTAL	$	13,500	27,300	59,650
VCRWSS Pipeline		24,300	49,500	116,800
Water hauling to Oster/CWS/Isolation Flyingshot/Information/Tawayik/North Gate		8,450	19,150	37,800
TOTAL	$	32,750	68,650	154,600

Source: Estimate by Author

10.3 Legal and Administrative Considerations

A brief review of the major legal and administrative considerations for various alternatives is necessary, to aid in the decision-making process.

Water sources within Federal land are not subject to Provincial jurisdiction. This extends to withdrawal water rights within Elk Island National Park. Under Provincial legislation, water withdrawals in excess of 5 acre feet/year from surface water sources require licensing. The estimated annual withdrawal by the Park from Astotin Lake is approximately 10 acre feet (1986) and will rise to approximately 68 acre feet/year by 2016 under high growth conditions. This does not include withdrawals for irrigation, which are substantial. Groundwater withdrawals in excess of 100 m^3/week from individual wells or well fields also require licensing under Provincial legislation. At present, no wells within the Park are used for withdrawals of such magnitude. The Information Centre/Station well has the largest withdrawal, estimated as a peak of 8.7 m^3/day or an approximate weekly maximum of 35 m^3.

However, if wells are developed outside of Park boundaries, they will be subject to Provincial legislation. A well in the northwest outwash aquifer for the Administration Headquarters area is estimated to have an average weekly withdrawal of 175 m^3 to 940 m^3 under low to high growth conditions. A well or well field for the Astotin Campground area is estimated to have an average weekly withdrawal of 185 m^3 to 1630 m^3. If either or both sources are outside of Park boundaries, licensing by Alberta Environment will be required. The withdrawal by the Park will have lower priority than domestic use, and will be subject to regulation such that it does not unduly alter or impair adjacent licensed groundwater withdrawals (Percy, 1976). Test drilling outside of Park boundaries requires an exploration permit prior to the commencement of work.

Construction of a well water supply system outside of Park boundaries will entail other legal and administrative requirements. The well site and pipeline will require either the purchase of land or, more usually, the obtaining of easements to construct, operate and maintain the system. Aquisition of easements from private landowners is a delicate process, that may have some costs associated with it. It may be possible to route most of the pipeline along municipal road allowances, but permission from the County of Strathcona is required. The County also would have to be contacted regarding the crossing of municipal roads and road allowances, and possibly for the purpose of obtaining a development permit. Crossing agreements are also required from any utility companies already holding easements that have to be crossed by the water supply pipeline such as when crossing gas, oil and telephone lines. Municipal scale systems constructed in Alberta require a permit from Alberta Environment, to ensure compliance with certain design standards and water quality standards. Federal government agencies constructing water supply pipelines on Federal Land in Alberta are not required to obtain a Permit to Construct.

Construction of a water supply system from the VCRWSS pipeline would entail similar legal and administrative requirements. The County of Lamont would be the rural municipality to grant permission concerning effecting municipal roads and road allowances. In addition, a formal agreement with the Vegreville Corridor Water Services Commission would be required for connection and the supply of water. Permission to cross highway 15 would be required from Alberta Transportation. A similar crossing permit is required for highway 16, if a surface water source is constructed for the Information Station.

The question of liability arises when a municipal water supply system is installed. Liability during constuction is usually the responsiblity of the contractor. After completion, liability is assumed by the owner, and included under the general liability insurance that the owner has for other structures and facilities under the owner's control. Unless otherwise indicated, it is assumed that the owner will supply safe, potable water through the system for use by the public. Careful and frequent monitoring of water quality is required to ensure that the water does in fact remain safe to drink, and meets all applicable standards.

Water conservation, and operating and maintenance cost reductions, can be achieved by judicious pricing of the water used (White, 1969). It may be considered desireable for the Park to adopt a modified user-pay philosophy and either charge for staff domestic water use, or include it as a benefit within overall staff remuneration packages. The value of water used in Park operation and maintenance activities can be calculated and assigned to the appropriate account. A portion of the registration fee collected from campers could be applied to the cost of supplying water at the campgrounds. It would be difficult to charge for water withdrawn by day users.

10.4 Benefits

Some of the benefits associated with implementing various alternatives can be readily identified. Others can only be identified after evaluation of the alternatives by Park staff. No attempt is made to quantify the following benefits, since they are largely intangible.

- Improve all existing supplies:
  - all existing supplies are within the Park boundaries, which simplifies the implementation of improvement projects.
  - can be readily broken down into many small projects, allowing phased implementation.
  - would improve the quality of life for staff, and may also increase public visitation.
  - provides employment for a water treatment plant operator, and potentially for maintenance personnel.
  - self-sufficiency may allow greater control over water resources by the Park.
- Replace all existing supplies with better individual sources:
  - allows for the selection of better quality raw water supplies, reducing maintenance requirements.
  - can be readily broke wn into several small and several larger projects, allowing phased implementation.
  - would improve the quality of life for staff, and may also increase public visitation.
  - provides employment for water treatment maintenance personnel.
  - reduces the pressure on Astotin Lake as a water source for human consumption and domestic use.

- Replace all existing supplies with the VCRWSS pipeline:
  - Supplies high quality treated water, eliminating the need for water treatment maintenance in the Park.
  - one large project, so it could be implemented in a short time period, with readily apparent effect.
  - would improve the quality of life for staff, and may also increase public visitation.
  - provides employment for a water hauler.

11. RECOMMENDATIONS FOR FURTHER STUDY

Several topics related to surface and groundwater withdrawal management at Elk Island National Park should be studied, to compliment this study and to aid in decision making at the Park.

The current and potential future impact of Park sewage disposal facilities should be examined. This is of particular importance, since most of the groundwater flow within the Park is local and confined to surficial deposits, the more permeable of which are potentially useful aquifers.

Rainfall catchment for water supply upon natural and artificial (paved) surfaces and upon building roofs should be studied to determine potential yields and water quality. Interrelationships between airborne contaminants and precipitation quality should be established to assess the feasibility of this potential supply.

Water balance studies, such as one currently begin conducted by A. Patrick, should be continued to determine surface and groundwater replacement and discharge. With predictions of a future warmer climate caused by the Greenhouse effect, with resultant increases in evapotranspiration and only partial balancing by increased spring and winter preciptation, a major reduction in lake and wetland presence is probable (EPA, 1984). A better understanding of present water balance within the Park would greatly aid in prediction of any future hydrologic changes.

A comprehensive study would be useful to determine the extent and frequency of natural flushing that occurs in Astotin Lake. The beneficial effects of flushing should be established, and if warranted, artificial enhancement of flushing through surface water diversion should be examined for feasibility.

Recharge of the outwash aquifers both inside and outside of Park boundaries could be enhanced by better cover management and surface drainage onto the aquifer. The feasibility of recharge enhancement and the improvement of aquifer water quality should be examined.

The precise causes of the taste, odor and color problems in Astotin Lake water should be determined and feasible solutions proposed. The impact of these solutions upon lake and wetland ecology should be fully explored.

A comprehensive park visitation survey would be useful to determine why people visit the Park, and what changes they wouldlike to see implemented. Also of benefit would be a survey to determine why visitation to the Park has not increased significantly in the past 10 years.

The feasibility of centralizing or relocating Park Administrative facilities into one area of the Park should be examined, with respect to reducing the water supply infrastructure requirements.

12. SUMMARY AND CONCLUSIONS

The estimated surface and groundwater withdrawal at Elk Island National park for human consumption and domestic use in 1986 is 13,448 m^3, of which 89% (12,022 m^3) is surface water and 11% (1,426 m^3) is groundwater. Surface water withdrawal is through two plants located on Astotin Lake, which supply the Administration Headquarters area and the Astotin Campground area. Groundwater withdrawal is from a total of eight individual wells, located at staff Stations (4) livestock handling or housing facilities (3), and at a day use area (1). The greatest single demand for surface water is at the Administration Headquarters area (8,522 m^3/y); the highest demand for groundwater is at the Information Centre and Station (535 m^3/y). The estimates are based upon a combination of operating records, park use data, and assumed per capita demands for various uses. Without metering, more accurate water withdrawal volumes cannot be estimated.

The chemical and bacteriological quality of the treated surface water is generally acceptable for human consumption and domestic use, but the physical water quality is poor. Objectionable taste, odor and color are the major problems, and a variety of lake and process treatment techniques have been tried to rectify these problems. Considering the water source is a shallow, eutrophic lake, the two water treatment plants are performing reasonably well, but improvements are possible. The physical water quality of the raw groundwater is acceptable for human consumption and domestic use, but the chemical quality is unacceptable for human consumption (high total dissolved solids, especially sodium, bicarbonate and alkalinity). Groundwater chemical quality for domestic use is more variable, being hard at some locations (CWS, Isolation Stations and North Point well) and containing hydrogen sulphide at the Information Centre and Station. All of the groundwater used is bacteriologically safe for human consumption, but non-pathogenic iron bacteria are present in wells at CWS, Isolation and Information Stations. Groundwater withdrawn for livestock consumption is of satisfactory quality, although better quality sources would be desireable if economically feasible.

Water source yields are at present adequate at all locations of water withdrawal within the Park. The Astotin Lake plants' capacities are well in excess of demand at present, and all of the wells have adequate yields. Water supply system deficiencies of a technical nature are probable at the Information Centre and Station, and at the Oster Station and Campground. Both systems would benefit from additional storage to meet peak demands.

A variety of presently non-utilized water sources exist within the Park, consisting of abandoned wells, test holes drilled, and springs. They tend to be typical of the groundwater already developed at the park (ie: poor quality) and some of the springs especially are very low yielding. Many potential water sources are available for use in the Park; the more promising ones are groundwater sources of potentially better quality, consisting of outwash sand and gravel northwest of the Park and buried preglacial channels in the south of the Park. Potentially better quality surface water is available within a reasonable distance of the Information Centre and Station, contained in borrow pits adjacent to highway 16. High quality treated water is available for purchase from the VCRWSS pipeline, located approximately 11 kilometres north of Astotin Lake.

Management alternatives for surface and groundwater withdrawal at the Park are modified by potential growth in Park use. Three growth scenarios are developed to examine the range of possible future water withdrawal demands. In the low growth scenario it is assumed no real growth in Park use up to 2016, which is essentially the documented pattern of Park use from 1976 until the present. In the medium growth scenario it is assumed that Park use will increase by 3% annually up to 2016, as it did in the period prior to 1976. In the high growth scenario it is assumed a 6% annual increase in Park use up to 2016, which reflects a 6% annual population growth rate of the Edmonton region used in planning prior to the mid 1980s. Under the three alternative growth rates, total water withdrawal for human consumption and domestic use at Elk Island National Park is predicted as being low 14,716, medium 35,730 and high 92,797 m^3/y respectively by 2016. The percentage of use at various points within the Park remains relatively constant (ie: 87-90% of demand adjacent to Astotin Lake). Increased Park use will require expansion of existing facilities and development of new facilities; likewise, facility expansion and development, to a major extent, will be a factor in promoting increased Park use.

Under various future growth alternatives, water quantity shortfalls occur at existing withdrawal points, and the eed for water sources is created at newly developed facilities. The capacities of present water sources are inadequate at Oster Station/Campground and at Information Station/Centre under high growth conditions, and the capacity of the

Astotin Campground plant is inadequate. New water sources are required at the projected North Gate Station and at Flyingshot Lake and Tawayik Lake campgrounds under medium and high growth conditions. Technical problems resulting in temporary water shortages at the Administration Headquarters plant and at Isolation Station can be corrected by the installation of increased peak storage.

Three general courses of action are possible at the Park to adequately meet present and projected water withdrawal demands for human consumption and domestic use. The three wells used for livestock water supply are not considered as requiring any significant rehabilitation or upgrading.

One course of action emphasises rehabilitation of existing water supplies to improve water quality and, where applicable, improve peak supply. This course of action will meet most of the projected water demands, but does not provide new sources for use at North Gate Station, and Flyingshot Lake and Tawayik Lake Campgrounds, or for supplemental sources at Oster Station/Campground and Information Station/Centre, when required by growth in Park use. These needs would presumably be met by utilizing appropriate new sources adjacent to the points of use.

The second course of action emphasises the replacement of all existing supplies with better quality (primarily groundwater) individual sources. The major water demand at the Park is met by installing a supply from wells in the outwash aquifer northwest of Park boundaries. Oster Station/Campground is supplied from a similar, but separate system. Replacement, better quality wells constructed in buried preglacial channel aquifers are used to supply CWS and Isolation

Stations, and Flyingshot Lake Campground. The source for the Information Station/Centre becomes the better quality surface water south of the station, and on-site wells are provided at North Gate Station and Tawayik Lake Campground.

The third course of action emphasises the replacement of all existing supplies with high quality treated water from the VCRWSS pipeline near Lamont. The major water demand at the Park is met by installing a reservoir and distribution system near Astotin Lake. The water demands at the remote Station and Campgrounds are met by hauling water into cisterns from a tank-loading facility at the main reservoir.

In terms of capital cost, the least expensive course of action to implement under low and medium growth conditions is the rehabilitation of existing water supplies ($273,000 and $476,500). Under high growth conditions, the capital cost ($1,119,000) is approximately equal to the capital costs of each of the other two major options. The rehabilitation of existing water supplies has associated operation and maintenance costs approximately equal to those associated with the VCRWSS pipeline option, and are approximately two and half times higher than the operation and maintenance costs associated with the option of replacing all existing supplies with better quality individual sources. In terms of capital cost, it is less expensive to implement the replacement source option than the VCRWSS option under low growth conditions ($589,000 versus $735,000), but the capital costs are approximately equal for these two options under medium and high growth conditions (average $865,000 and $1,212,000 approximately). The majority of the operation and maintenance costs associated with the

VCRWSS option are for the purchase of water (45-60%) and for the hauling of water (25-28%). The quality of water from the VCRWSS pipeline is excellent and requires no treatment, and therefore is a very attractive option.

An overview of the current water supplies utilized for human consumption and domestic use at Elk Island Park brings to mind a verse by Coleridge:

> "Water, water, everywhere,
> nor any drop to drink."

Rehabilitation of existing sources and supplies, while being technically feasible and having a relatively low present capital cost, creates a high recurrent cost; for operation and especially for maintenance. It may also preclude the implementation of other source and supply options, which offer attractive long term solutions to the water withdrawal needs at the Park, especially at higher growth rates in park use.

The key factor in deciding which course of action to implement is the future growth in Park use, and subsequent water demand. Growth in Park use, while governed by population growth in the surrounding region to some extent, is largely determined by the quality of the recreational experience obtained from the Park. Promoting Park use by developing better facilities and opportunities for recreation is not inconsistent with environmental protection.

Short term or immediate steps can be implemented, such as improving the treatment at both lake plants, to provide better quality water for the majority of the visitors and the staff. Hauling this improved quality surface water to remote stations, campgrounds and day use areas could be implemented at a reasonable cost. This would allow future flexibility in deciding whether to rehabilitate all other existing supplies, or whether to seek a replacement source or sources for some or all existing supplies, based upon the actual future growth in Park use and water demand.

* * *

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APPENDIX

.1 Chemical Water Analysis 1986

1.1 - Astotin Lake Campground Plant (raw)

1.2 - Astotin Lake Campground Plant (treated)

1.3 - Astotin Lake Administration H.Q. Plant (raw)

1.4 - Astotin Lake Administration H.Q. Plant (treated)

1.5 - Oster Station Well

1.6 - CWS Station Well (raw)

1.7 - CWS Station Well (treated)

1.8 - Information Station Well (raw)

1.9 - Isolation Station Well (treated)

1.10 - Isolation Station Well (raw)

1.11 - Mud Lake Corrals Well

1.12 - Isolation Corrals Well

1.13 - Horse Barn Well

1.14 - North Point Well

1.15 - Astotin Lake Adjacent to North Point Well

1.16 - North Gate Abandoned Well (W12)

1.17 - Oster Campground Abandoned Well (W7)

1.18 - North Tawayik Abandoned Well (W9)

1.19 - Abandoned Abattoir Drilled Well (W5)

Source: Samples submitted by Author.
Analysis by Alberta Agriculture, Lethbridge

.1.1

Chemical Water Analysis Report

SAMPLE SUBMITTED: June 6/86

ANALYSIS COMPLETED: July 15/86

ORIGIN: Astotin Lake Campground Plant (RAW)

pH	7.2	EC	0.42
		SAR	0.52
CALCIUM	66.1	IRON	0.1
MAGNESIUM	18.2	FLUORIDE	0.06
HARDNESS, TOTAL	240 $CaCO_3$	SULPHATE	87.8
SODIUM	18.4	CHLORIDE	3.6
POTASSIUM	12.9	NO_2+NO_3	0.2 N
CARBONATE	0	TDS	451.4
BICARBONATE	244.0		
ALKALINITY, TOTAL	200 $CaCO_3$		

.1.2

Chemical Water Analysis Report

SAMPLE SUBMITTED: June 6/86

ANALYSIS COMPLETED: July 15/86

ORIGIN: Astotin Lake Campground Plant (Treated)

pH	7.4	EC	0.31
		SAR	0.67

CALCIUM	30.1	IRON	< 0.1
MAGNESIUM	17.0	FLUORIDE	0.05
HARDNESS, TOTAL	145 $CaCO_3$	SULPHATE	34.1
SODIUM	18.4	CHLORIDE	1.8
POTASSIUM	14.1	NO_2+NO_3	0.1 N
CARBONATE	0	TDS	317.0
BICARBONATE	201.3		
ALKALINITY, TOTAL	165 $CaCO_3$		

.1.3

Chemical Water Analysis Report

SAMPLE SUBMITTED: June 6/86

ANALYSIS COMPLETED: July 15/86

ORIGIN: Astotin Lake Administration H.Q. Plant (RAW)

pH 7.3 EC 0.32

SAR 0.69

CALCIUM	28.1	IRON	
MAGNESIUM	15.8	FLUORIDE	.05
HARDNESS, TOTAL	135 $CaCO_3$	SULPHATE	28.8
SODIUM	18.4	CHLORIDE	1.8
POTASSIUM	13.7	NO_2+NO_3	0.8 N
CARBONATE	0	TDS	302.7
BICARBONATE	195.2		
ALKALINITY, TOTAL	160 $CaCO_3$		

.1.4

Chemical Water Analysis Report

SAMPLE SUBMITTED: June 6/86

ANALYSIS COMPLETED: July 15/86

ORIGIN: Astotin Lake Administration H.Q. Plant (Treated)

pH	7.25	EC	0.31
		SAR	0.69
CALCIUM	28.1	IRON	< 0.1
MAGNESIUM	15.8	FLUORIDE	0.05
HARDNESS, TOTAL	135 $CaCO_3$	SULPHATE	26.9
SODIUM	18.4	CHLORIDE	14.2
POTASSIUM	14.1	NO_2+NO_3	0.1 N
CARBONATE	0	TDS	294.6
BICARBONATE	176.9		
ALKALINITY, TOTAL	145 $CaCO_3$		

.1.5

Chemical Water Analysis Report

SAMPLE SUBMITTED: June 6/86

ANALYSIS COMPLETED: July 15/86

ORIGIN: Oster Station Well

pH	7.75	EC	2.74
		SAR	46.48

CALCIUM	12.0	IRON	0.1
MAGNESIUM	2.4	FLUORIDE	0.12
HARDNESS, TOTAL	40 $CaCO_3$	SULPHATE	165.1
SODIUM	676.2	CHLORIDE	186.4
POTASSIUM	3.5	NO_2 + NO_3	0.1 N
CARBONATE	0	TDS	2363.4
BICARBONATE	1317.6		
ALKALINITY, TOTAL	1080 $CaCO_3$		

.1.6

Chemical Water Analysis Report

SAMPLE SUBMITTED: June 6/86

ANALYSIS COMPLETED: July 15/86

ORIGIN: CWS Station Well (Raw)

pH	7.0	EC	1.38
		SAR	4.68

CALCIUM	104.2	IRON	0.3
MAGNESIUM	20.7	FLUORIDE	0.05
HARDNESS, TOTAL	34.5 $CaCO_3$	SULPHATE	236.2
SODIUM	200.1	CHLORIDE	3.6
POTASSIUM	4.7	NO_2+NO_3	0.2 N
CARBONATE	θ	TDS	1222.8
BICARBONATE	652.7		
ALKALINITY, TOTAL	535 $CaCO_3$		

.1.7

Chemical Water Analysis R[illegible]

SAMPLE SUBMITTED: June 6/86

ANALYSIS COMPLETED: July 15/86

ORIGIN: CWS Station Well (Treated)

pH	7.0	EC	1.50
		SAR	26.7

CALCIUM	8.0	IRON	0.1
MAGNESIUM	3.7	FLUORIDE	0.05
HARDNESS, TOTAL	35 $CaCO_3$	SULPHATE	241.4
SODIUM	363.4	CHLORIDE	3.6
POTASSIUM	9.0	NO_2+NO_3	0.1 N
CARBONATE	0	TDS	1337.0
BICARBONATE	707.6		
ALKALINITY, TOTAL	580 $CaCO_3$		

.1.8

Chemical Water Analysis Report

SAMPLE SUBMITTED: June 12/86

ANALYSIS COMPLETED: July 15/86

ORIGIN: Information Centre Well (Raw)

pH 7.8 EC 2.67

SAR 40.30

CALCIUM	14.0	IRON	< 0.1
MAGNESIUM	3.7	FLUORIDE	0.22
HARDNESS, TOTAL	50 $CaCO_3$	SULPHATE	451.2
SODIUM	655.5	CHLORIDE	37.3
POTASSIUM	3.9	NO_2+NO_3	0.2 N
CARBONATE	0	TDS	2337.2
BICARBONATE	1171.2		
ALKALINITY, TOTAL	960 $CaCO_3$		

.1.9

Chemical Water Analysis Report

SAMPLE SUBMITTED: June 6/86

ANALYSIS COMPLETED: July 15/86

ORIGIN: Information Centre Well (Treated)

pH	7.8	EC	2.62
		SAR	38.96
CALCIUM	16.0	IRON	< 0.1
MAGNESIUM	3.7	FLUORIDE	0.12
HARDNESS, TOTAL	55 $CaCO_3$	SULPHATE	434.9
SODIUM	664.7	CHLORIDE	33.7
POTASSIUM	4.3	NO_2+NO_3	0.1 N
CARBONATE	0	TDS	2383.6
BICARBONATE	1226.1		
ALKALINITY, TOTAL	1005 $CaCO_3$		

.1.10

Chemical Water Analysis Report

SAMPLE SUBMITTED: June 6/86

ANALYSIS COMPLETED: July 15/86

ORIGIN: Isolation Station Well (Raw)

pH	8.5	EC	2.02
		SAR	19.23

CALCIUM	24.1	IRON	< 0.1
MAGNESIUM	10.9	FLUORIDE	0.05
HARDNESS, TOTAL	105 $CaCO_3$	SULPHATE	410.9
SODIUM	453.1	CHLORIDE	10.7
POTASSIUM	6.3	NO_2+NO_3	0.1 N
CARBONATE	12.0	TDS	1702.9
BICARBONATE	774.7		
ALKALINITY, TOTAL	655 $CaCO_3$		

.1.11

Chemical Water Analysis Report

SAMPLE SUBMITTED: June 6/86

ANALYSIS COMPLETED: July 15/86

ORIGIN: Mud Lake Corrals Well

pH	7.6	EC	1.64
		SAR	12.10

CALCIUM	46.1	IRON	0.6
MAGNESIUM	10.9	FLUORIDE	0.05
HARDNESS, TOTAL	160 $CaCO_3$	SULPHATE	243.8
SODIUM	351.9	CHLORIDE	24.9
POTASSIUM	11.0	NO_2+NO_3	0.1 N
CARBONATE	θ	TDS	1482.4
BICARBONATE	793.0		
ALKALINITY, TOTAL	650 $CaCO_3$		

.1.12

Chemical Water Analysis Report

SAMPLE SUBMITTED: June 6/86

ANALYSIS COMPLETED: July 15/86

ORIGIN: Isolation Corrals Well

pH	7.85	EC	2.56
		SAR	38.89
CALCIUM	14.0	IRON	<0.1
MAGNESIUM	3.7	FLUORIDE	0.08
HARDNESS, TOTAL	50 $CaCO_3$	SULPHATE	453.6
SODIUM	632.5	CHLORIDE	58.6
POTASSIUM	3.9	NO_2+NO_3	0.1 N
CARBONATE	θ	TDS	2234.0
BICARBONATE	1067.5		
ALKALINITY, TOTAL	875 $CaCO_3$		

.1.13

Chemical Water Analysis Report

SAMPLE SUBMITTED: June 6/86

ANALYSIS COMPLETED: July 15/86

ORIGIN: Horse Barn Well

pH 7.85 EC 2.48

SAR 46.31

CALCIUM	8.0	IRON	<0.1
MAGNESIUM	3.7	FLUORIDE	0.10
HARDNESS, TOTAL	35 $CaCO_3$	SULPHATE	272.6
SODIUM	630.2	CHLORIDE	63.9
POTASSIUM	3.1	NO_2+NO_3	0.1 N
CARBONATE	0	TDS	2244.4
BICARBONATE	1262.7		
ALKALINITY, TOTAL	1035 $CaCO_3$		

.1.14

Chemical Water Analysis Report

SAMPLE SUBMITTED: June 6/86

ANALYSIS COMPLETED: July 15/86

ORIGIN: North Point Well

pH 7.15 EC 2.24

SAR 3.58

CALCIUM	216.4	IRON	0.1
MAGNESIUM	74.1	FLUORIDE	0.11
HARDNESS, TOTAL	845 $CaCO_3$	SULPHATE	590.4
SODIUM	239.2	CHLORIDE	19.5
POTASSIUM	9.8	NO_2+NO_3	0.5 N
CARBONATE	0	TDS	2046.8
BICARBONATE	896.7		
ALKALINITY, TOTAL	735 $CaCO_3$		

.1.15

Chemical Water Analysis Report

SAMPLE SUBMITTED: June 6/86

ANALYSIS COMPLETED: July 15/86

ORIGIN: Astotin Lake Adjacent to North Point Well

pH 7.35 EC 0.32

SAR 0.70

CALCIUM	26.1	IRON	< 0.1
MAGNESIUM	15.8	FLUORIDE	0.05
HARDNESS, TOTAL	130 $CaCO_3$	SULPHATE	19.2
SODIUM	18.4	CHLORIDE	5.3
POTASSIUM	13.7	NO_2+NO_3	0.1 N
CARBONATE	θ	TDS	293.9
BICARBONATE	195.2		
ALKALINITY, TOTAL	160 $CaCO_3$		

.1.16

Chemical Water Analysis Report

SAMPLE SUBMITTED: June 6/86

ANALYSIS COMPLETED: July 15/86

ORIGIN: North Gate Abandoned Well (W12)

pH	7.3	EC	0.24
		SAR	0.50

CALCIUM	26.1	IRON	< 0.1
MAGNESIUM	8.5	FLUORIDE	0.04
HARDNESS, TOTAL	100 $CaCO_3$	SULPHATE	< 4.8
SODIUM	11.5	CHLORIDE	8.9
POTASSIUM	10.2	NO_2+NO_3	0.1 N
CARBONATE	0	TDS	217.9
BICARBONATE	152.5		
ALKALINITY, TOTAL	135 $CaCO_3$		

.1.17

Chemical Water Analysis Report

SAMPLE SUBMITTED: June 6/86

ANALYSIS COMPLETED: July 15/86

ORIGIN: Oster Campground Abandoned Well (W7)

pH	7.3	EC	1.63
		SAR	15.48

CALCIUM	36.1	IRON	0.1
MAGNESIUM	6.1	FLUORIDE	0.05
HARDNESS, TOTAL	115 $CaCO_3$	SULPHATE	211.2
SODIUM	381.8	CHLORIDE	3.6
POTASSIUM	3.9	NO_2+NO_3	1.5 N
CARBONATE	θ	TDS	1528.8
BICARBONATE	884.5		
ALKALINITY, TOTAL	725 $CaCO_3$		

.1.18

Chemical Water Analysis Report

SAMPLE SUBMITTED: June 6/86

ANALYSIS COMPLETED: July 15/86

ORIGIN: North Tawayik Abandoned Well

pH 7.2 EC 1.51

SAR 1.92

CALCIUM	170.3	IRON	< 0.1
MAGNESIUM	42.5	FLUORIDE	0.25
HARDNESS, TOTAL	600 $CaCO_3$	SULPHATE	370.1
SODIUM	108.1	CHLORIDE	8.9
POTASSIUM	10.2	NO_2+NO_3	7.6 N
CARBONATE	θ	TDS	1267.0
BICARBONATE	549.0		
ALKALINITY, TOTAL	450 $CaCO_3$		

1.19

Chemical Water Analysis Report

SAMPLE SUBMITTED: June 6/86

ANALYSIS COMPLETED: July 15/86

ORIGIN: Abandoned Abbattoir Drilled Well (V5)

pH	8.05	EC	3.07
		SAR	26.25

CALCIUM	28.1	IRON	0.2
MAGNESIUM	8.5	FLUORIDE	0.08
HARDNESS, TOTAL	105 $CaCO_3$	SULPHATE	327.4
SODIUM	618.7	CHLORIDE	26.6
POTASSIUM	22.3	NO_2+NO_3	0.1 N
CARBONATE	0	TDS	2373.9
BICARBONATE	1342.0		
ALKALINITY, TOTAL	1100 $CaCO_3$		

.2 **Summary of Capital Cost Calculations**

2.1 – Improvement of Admin. H.Q. water treatment plant

2.2 – Improvement of Astotin Campground water treatment plant

2.3 – Improved Lake Quality

2.4 – Improvement of Oster Station system

2.5 – Improvement of CWS Station system

2.6 – Improvement of Isolation Station system

2.7 – Improvement of Information Station system

2.8 – Northwest Outwash aquifer (Administration)

2.9 – Northwest Outwash aquifer (Astotin Campground)

2.10 – Northwest Outwash aquifer (Oster Station)

2.11 – Southern Buried Preglacial Channel aquifer supplies

2.12 – Southeast Outwash aquifer (Flyingshot Campground)

2.1[illegible] – VCRWSS (for all Park areas)

2.14 – Surface water (Information Station, Flyingshot Campground)

2.15 – New additional sources

Source: Author

.2.1

Improvement of Administration Headquarters Water Treatment Plant

- low/medium/high growth

	$
Ozone pretreatment	10,000
Flash mixing basin	5,000
Sedimentation chamber	30,000
Rapid sand filtration	20,000
GAC adsorption	20,000
Chlorine residual monitoring	5,000
	90,000

- 550 m^3 (3d) Peak storage (high growth) 120,000

.2.2

Improvement of Astotin Lake Campground water treatment plant

- low/medium growth

	$
Ozone pretreatment	10,000
Coagulant feed	5,000
Flash mixing basin	5,000
Mixing basin	10,000
Sedimentation chamber	30,000
pH adjustment	5,000
Rapid sand filtration	20,000
GAC adsorption	20,000
Chlorine residual monitoring	5,000
	110,000

- high growth

Rehabilitating plant to double capacity	300,000

- peak storage (if plant capacity not increased)

730 m^3 high growth	160,000

.2.3

Improved Lake Quality

- low/medium/high growth

	$
Administration Plant	
Zone aeration	10,000
Floating intake	10,000
	20,000
Campground Plant	
Reservoir storage for raw water*	
4,000 m^3 low growth	15,000
11,000 m^3 medium growth	25,000
35,000 m^3 high growth	55,000

* includes reservoir and portable filling equipment

.2.4

Improvement of Oster Station System

- Distiller or reverse-osmosis treatment for water for human consumption at the staff house(s) and campground

low growth (300 L/d capacity)	$ 6,000
medium growth (650 L/d capacity)	13,000
high growth (1600 L/d capacity)	32,000

- Peak storage

4 m^3 (low growth	2,000
30 m^3 (medium growth)	7,000

- new source for high growth

  (see .2.10)

.2.5

Improvement of CWS Station System

- low/medium/high growth

- Distiller or reverse osmosis treatment for water for human consumption at the staff house

	$
20 L/d capacity	1,00[illegible]

- Treatment for water for domestic use at the [illegible] house

Shock chlorination (mai[illegible]	-
continuous chlorination/[illegible]sorption	5,000
Water softener (existing)	-
	5,000

.2.6

Improvement of Isolation Station System

- Distiller or reverse-osmosis treatment for water for human consumption at staff house(s)

	$
low growth (20 L/d capacity)	1,000
medium growth (40 L/d capacity)	1,500
high growth (80 L/d capacity)	2,000

- Treatment for water for domestic use at staff house(s)

	Low	Medium	High
Shock chlorination (maintenance)	-	-	-
Continuous chlorination/GAC adsorption	5,000	5,000	10,000
Water softener	existing	existing	5,000
TOTAL $	5,000	5,000	15,000

- peak storage

high growth 2 m^3 $1,000

.2.7

Improvement of Information Station System

- Distiller or reverse-osmosis treatment for water for human consumption at the staff house(s) and at the Information Centre

	$
low growth (460 L/d capacity)	10,000
medium growth (1100 L/d capacity)	22,000
high growth (2580 L/d capacity)	50,000

- Treatment for water for domestic use at the staff house(s) and at the Information Centre

	Low	Medium	High
Shock chlorination	-	-	-
Continuous chlorination/GAC adsorption	5,000	10,000	20,000
TOTAL $	5,000	10,000	20,000

- Peak storage

	$
low growth 13 m^3	3,000
medium growth 46 m^3	10,000

- new source for high growth (see .2.13/14)

.2.8

Northwest Outwash aquifer (Administration)

	Low	Medium	High
Test drilling, aquifer testing	5,000	5,000	10,000
Production well	15,000	15,000	20,000
Pipeline (2400 m)	40,000	40,000	50,000
Pump, controls, etc.	5,000	5,000	10,000
Electrification, wiring	10,000	10,000	15,000
Storage (2d)	22,000	48,000	120,000
Chlorination	2,000	2,000	5,000
Rapid sand filtration	5,000	5,000	10,000
GAC adsorption	5,000	5,000	10,000
Booster pump	2,000	2,000	5,000
Softening (for houses)	5,000	10,000	15,000
Post chlorination (existing equipment)	-	-	-
TOTAL $	116,000	147,000	270,000

* low growth system supply 25 m^3/d

medium growth system supply 58 m^3/d

high growth system supply 134 m^3/d

.2.9

Northwest Outwash aquifer (Astotin Campground)

	Low	Medium	High
Test drilling, aquifer testing	5,000	5,000	15,000
Production well(s)	15,000	15,000	40,000(2)
Pipeline (6,400 m)	100,000	125,000	150,000
Pump(s), controls, etc.	5,000	7,000	20,000
Electrification, wiring	10,000	13,000	20,000
Storage (2d)	22,000	48,000	150,000
Chlorination	2,000	3,000	10,000
Rapid sand filtration	5,000	8,000	20,000
GAC adsorption	5,000	8,000	20,000
Booster pump	2,000	3,000	10,000
Post chlorination (extra equipment)	-	-	5,000
TOTAL $	171,000	235,000	460,000

* low growth system supply 26 m^3/d

medium growth system supply 72 m^3/d

high growth system supply 233 m^3/d

.2.10

Northwest Outwash aquifer (Oster Station)

	Low	Medium	High
Test drilling, aquifer testing	5,000	5,000	5,000
Production well	15,000	15,000	15,000
Pipeline (4,000 m)	65,000	65,000	80,000
Pump, controls, etc.	5,000	5,000	5,000
Electrification, wiring	10,000	10,000	10,000
Storage (2d)	2,000	3,000	5,000
Chlorination	2,000	2,000	2,000
Rapid sand filtration	1,000	1,000	1,000
GAC adsorption	1,000	[illegible]	1,000
Booster pump	1,000	1,000	1,000
Softening (houses only)	1,000	1,000	2,000
Postchlorination	2,000	2,000	2,000
TOTAL $	110,000	111,000	129,000

* low growth system supply 3 m^3/d

medium growth system supply 13 m^3/d

high growth system supply 31 m^3/d

.2.11

Southern Buried Preglacial Channel aquifer supplies

- low/medium/high growth (21 m^3d supply)

	CWS	Isolation
Test drilling, aquifer testing	5,000	5,000
Production well	15,000	15,000
Pipeline (1,200 m)	20,000	20,000
Pump, controls, etc.	5,000	5,000
Electrification, wiring	10,000	10,000
Storage (2d)	-	3,000
Treatment (process to be determined)	5,000	5,000
TOTAL $	60,000	63,000

- medium/high growth (21 m^3/d Supply)

	Flyingshot Campground
Test drilling, aquifer testing	5,000
Production well	15,000
Pipeline (600 m)	10,000
Pump, controls, etc.	5,000
Electrification, wiring	10,000
Storage (2d)	3,000
Treatment (process to be determined)	8,000
Treatment building	5,000
Electrification of treatment building	10,000
TOTAL $	71,000

2.12

Southeast Outwash aquifer (Flyingshot **Campground**)

- medium/high growth (21 m^3/d Supply)

Test drilling, aquifer testing	5,000
Production well	15,000
Pipeline (5,000 m)	90,000
Pump, controls, etc.	5,000
Electrification, wiring (pump)	40,000
Storage (2d)	3,000
Treatment building	5,000
Electrification of treatment building.	10,000
Treatment (process to be determined)	8,000
TOTAL $	181,000

.2.13

VCRWSS (For all Park uses)

	Low	Medium	High
Connection	50,000	60,000	70,000
Pipeline (11,200 m)	225,000	295,000	480,000
Highway #15 crossing	10,000	15,000	20,000
Rural road crossings	10,000	12,000	15,000
Other crossings	10,000	10,000	10,000
Storage (2d)	35,000	90,000	200,000
Distriubtion pumping	20,000	25,000	30,000
Distribution pipeline (6,500 m)	250,000	250,000	250,000
Tank loading facility	20,000	25,000	30,000
Post chlorination	5,000	5,000	10,000
SUB TOTAL $	635,000	787,000	1,115,000
Remote cisterns	100,000	100,000	100,000
TOTAL $	735,000	887,000	1,215,000

* low growth system Supply 80 m^3/d

medium growth system Supply 196 m^3/d

high growth system Supply 510 m^3/d

.2.14

Surface water supply for Information Station and Flyingshot Campground

– low/medium/high growth (32 m^3/d)

	Information Station
Runoff diversion/control	5,000
Intake	5,000
Compressed aeration	5,000
Pipeline (1,000 m)	17,000
Pump, controls, etc.	5,000
Electrification, wiring	10,000
Highway #16 crossing	10,000
Storage (2d)	5,000
Chlorination	2,000
Rapid sand filtration	1,000
GAC adsorption	1,000
Booster pump	1,000
Post chlorination	2,000
TOTAL $	69,000

.2.14 continued

- medium/high growth (21 m^3/d)

	Flyingshot Campground
Runoff diversion/control	5,000
Intake	5,000
Compressed aeration	5,000
Pipeline (1,600 m)	26,000
Pump, controls, etc.	5,000
Electrification, wiring	10,000
Storage (2d)	3,000
Chlorination	2,000
Rapid sand filtration	1,000
GAC adsorption	1,000
Booster pump	1,000
Post chlorination	2,000
Treatment building	5,000
Electrification of treatment building	10,000
TOTAL $	81,000

.2.15

New additional sources

- These cost estimates assume that a water well will be constructed adjacent to both North Gate Station and Tawayik Campground. Assumed maximum annual well capacity is 1,590 m^3, and assumed chemical water quality is poor.

	North Gate	Tawayik Campground
Test drilling, aquifer testing	5,000	5,000
Production well	10,000	10,000
Pump, controls, etc.	5,000	5,000
Piping	1,000	1,000
Electrical hookup	1,000	1,000
Storage (2d)	2,000	3,000
Potable treatment	2,000	5,000
Domestic treatment	5,000	-
Treatment building	-	5,000
Electrification	-*	20,000
TOTAL $	31,000	55,000

* assumes mains power on site

.3 Summary of Operation and Maintenance Cost Calculations

.3.1 Astotin Lake Plants

3.2 Existing Station Wells

3.3 Northwest Outwash Wells

3.4 Replacement Wells/Other Supplies

3.5 VCRWSS Pipeline

3.6 Water Hauling

Source: Author

.3.1

Astotin Lake Plants

- Plant operation at $15.00/hour labor
- Maintenance at 10% of operation time at $15.00/hour labor
- Operation Inputs: energy $0.25/m^3
  supplies $0.25/m^3

Administration plant	Low 9,000 m^3/y	Medium 21,000 m^3/y	High 49,000 m^3/y
Operation (@ 13.62 m^3/h)	9,900	23,100	54,000
Maintenance	1,000	2,300	5,400
Energy	2,250	5,250	12,250
Supplies	2,250	5,250	12,250
TOTAL $	15,400	35,900	83,900

Campground Plant	Low 4,000 m^3/y	Medium 11,000 m^3/y	High* 35,000 m^3/y
Operation (@13.62 m^3/h)	4,400	12,100	19,300
Maintenance	500	1,200	2,000
Energy	1,000	2,750	8,750
Supplies	1,000	2,750	8,750
TOTAL $	6,900	18,800	38,800

* high growth operation = 27.24 m^3/h

.3.2

Existing Station Wells

- maintenance at 10% of operation time at $15.00/hour labor
- inputs: energy $0.25/m^3$
  supplies $0.50/m^3$

		Low	Medium	High
Oster:	maintenance	2,200	6,000	13,200*
	energy	100	300	600
	supplies	200	600	1,200
TOTAL		2,500	6,900	15,000
CWS:	maintenance	1,800	1,800	1,800
	energy	100	100	100
	supplies	200	200	200
TOTAL		2,100	2,100	2,100
Isolation:	maintenance	1,800	3,600	7,200
	energy	100	200	400
	supplies	200	400	800
TOTAL		2,100	4,200	8,400
Information:	maintenance	3,000	6,400	13,600*
	energy	150	300	600
	supplies	300	600	1,200
TOTAL		3,450	7,300	15,400
TOTAL FOR STATIONS	$	10,150	20,500	40,900

* new source required

.3.3

Northwest Outwash Wells

- maintenance at 1% of capital cost
- inputs: energy $0.25/m^3
  supplies $0.25/m^3

		Low	Medium	High
Administration Well:	maintenance	1,200	1,500	2,700
	energy	2,250	5,250	12,250
	supplies	2,250	5,250	12,250
TOTAL		5,700	12,000	27,200
Campground Well:	maintenance	1,700	2,400	4,600
	energy	1,000	2,750	8,750
	supplies	1,000	2,750	8,750
TOTAL		3,700	7,900	22,100
Oster Well:	maintenance	1,100	1,100	1,300
	energy	100	300	600
	supplies	100	300	600
TOTAL		1,300	1,700	2,500
TOTAL FOR WELLS	$	10,700	21,600	51,800

.3.4

Replacement wells/other supplies

- maintenance at 1% of capital cost
- inputs: energy $0.25/$m^3$ - All

  supplies $0.25/$m^3$ - CWS, Isolation, Flyingshot

  supplies $0.50/$m^3$ - Information, North Gate, Tawayik

		Low	Medium	High
CWS Well:	maintenance	600	600	600
	energy	100	100	100
	supplies	100	100	100
TOTAL		800	800	800
Isolation Well:	maintenance	650	650	650
	energy	100	200	400
	supplies	100	200	400
TOTAL		850	1,050	1,450
Flyingshot Well:	maintenance		700	700
	energy		100	300
	supplies		100	300
TOTAL		-	900	1,300
Information Surface Water Supply:				
	maintenance	700	700	700
	energy	150	300	600
	supplies	300	600	1,200
TOTAL		1,150	1,600	2,500

.3.4 Continued

		Low	Medium	High
North Gate Well:	maintenance		300	300
	energy		100	200
	supplies		200	400
TOTAL		-	600	900
Tawayik Well:	maintenance		600	600
	energy		50	100
	supplies		100	200
TOTAL		-	750	900
TOTAL FOR REPLACEMENT SOURCES	$	2,800	5,700	7,850

.3.5

VCRWSS Pipeline

- maintenance at 1% of capital cost
- water cost at $1.00/m^3$
- distribution booster pump energy at $0.25/m^3$

	Low	Medium	High
Maintenance cost	7,400	8,900	12,200
Water cost	14,600	35,500	92,400
Distribution cost	2,300	5,100	12,200
TOTAL $	24,300	49,500	116,800

.3.6

Water Hauling

- assumes an average tanker load is 7 m^3
- assumes cost to haul one tanker load averages $1.00/km (equipment and labor)
- cost of water included in VCRWSS pipeline operation costs (See 14.3.5)

(Round trip distance in km)	Low	Med	High
Oster Campground (30)	400	1,950	4,600
Oster Station (30)	1,400	2,850	5,700
Information Station (25)	700	1,800	4,100
Information Station (25)	1,200	2,400	4,800
CWS Station (55)	2,600	2,600	2,600
Isolation Station (45)	2,150	4,300	8,600
North Gate Station (10)	-	500	1,000
Flyingshot Campground (35)	-	2,250	5,400
Tawayik Campground (20)	-	500	1,000
TOTAL	8,450	19,150	37,800