UNIVERSITY OF ALBERTA

EVALUATION OF LAGOON TREATMENT IN ALBERTA

BY

DENNIS S. PRINCE ©

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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 **An Evaluation of Lagoon Treatment in Alberta** submitted by **Dennis S. Prince** in partial fulfillment of the requirements for the degree of **Master of Science** in **Environmental Engineering.**

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Dedication

To my wife, Jan, for the encouragement to return to school and the sacrifices made in fulfilling that goal.

Abstract

An in-depth evaluation of municipal sewage lagoon treatment in Alberta was undertaken to establish the performance level of lagoon treatment technology. A common public perception is that lagoons are old technology that just stores the wastewater and little treatment takes place. The purpose of this thesis is to provide a factual evaluation of the actual lagoon performance.

The standards, impacts, concerns, effluent quality, and economics of lagoon treatment are the main topics in this thesis. A literature review provided an overview of lagoon treatment with emphases on their operation in regions where ice cover occurs. The standards of other provinces were summarized and compared to Alberta's standards. Alberta's standards were found to be the most stringent of a y province and were the only province requiring anaerobic cells and 365 days of storage.

The areas of concerns and economics were investigated by means of a survey of lagoon operators. The survey results showed that the vast majority of lagoon operators do not receive complaints about lagoon systems. The annoyance complained about the most was odour (17% of sites). The economic analysis demonstrated that lagoons tended to be the least costly treatment alternative but the relationship was sensitive to land value.

The questions of effluent quality and impacts were addressed by analyzing the effluent records for most of the lagoons in Alberta. The lagoons with anaerobic cells and fall discharge produced effluent quality that was superior to mechanical plants for all parameters except TSS. The 4S-2L lagoons with fall discharge and 12 months of storage had an average BOD and TSS of 6 mg/L and 14 mg/L respectively. The consistency of this systems performance is also shown by the 95% confidence limit of the means being 8.2 mg/L and 18.8 mg/L respectively.

A time series sampling program of a discharging lagoon was conducted to ensure effluent quality was homogeneous throughout the discharge and to determine if lagoon records, which consist of grab samples, were representative of effluent quality. Overall it was found that effluent quality was generally consistent over the discharge period. The available lagoon upgrade techniques were reviewed and evaluated for possible application in Alberta. The important factors affecting lagoon treatment were determined to be season of discharge, month of discharge, anaerobic cells and storage time. The lagoon database for effluent quality also provided a means to evaluate the factors affecting lagoon treatment.

The minimal impact and good quality of effluents from lagoons is indicated by the modest dilution ratio required to meet water quality criterion. For lagoon systems with anaerobic cells a dilution ratio of only 1 to 1 required in the fall and a ratio of 10 to 1 is needed in the spring. Mechanical plants require a dilution ratio of roughly 1000 to 1 to meet receiving water criterion.

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1.0 OVERVIEW OF LAGOON TREATMENT

1.1 Introduction

The term lagoon is widely used in society and has a variety of meanings. In this report the term lagoon relates to a shallow earthen basin designed for the purpose of primary and secondary treatment of wastewaters. In particular the report concentrates on its use in the province of Alberta. Other terms used in the literature for lagoons include wastewater ponds, stabilization ponds, and oxidation ponds.

Lagoons are a popular method of treatment and there is substantial literature about all facets of standard lagoon treatment practice but the controlled discharge lagoons used in Alberta are a unique subset of standard lagoons which normally have continuous discharge. Intermittent discharge lagoons are used to avoid effluent discharges during periods of poor effluent quality and low assimilative capacity of the receiving water that occurs in the winter due to ice cover. Not all the characteristics and processes of standard lagoons are applicable or of concern to lagoons with controlled discharge. As this report addresses lagoon treatment in Alberta the scope of the discussion will be focused on intermittent discharge lagoons however where applicable available literature on continuous discharge lagoons will be used to provide insights to many of the processes that are common to both modes of operation.

The public perception is that lagoons are simply wastewater storage facilities which provide little treatment. However, studies have repeatedly determined lagoons to be one of the best treatment alternative for small communities in terms of performance and economics. Many authors have listed the advantages and disadvantages of lagoon treatment and the lists are all very similar to one another. The following is a list developed from Karn (1979):

ADVANTAGES

- low energy usage
- reduced lab costs
- controlled seasonal discharges
- lower construction and operating costs
- accepts surge flow more readily
- low chemical usage
- less sludge disposal problem
- adaptable to land application of final effluent
- lower mechanical failure potential
- potentially increased design life
- wildlife habitat

DISADVANTAGES

- possible spring odour
- larger land usage
- operations somewhat dependent on climatic conditions
- possible ground water contamination
- potential for higher suspended solids

This report presents an in-depth study of lagoon treatment in Alberta and assesses lagoon performance in terms of effluent quality, minimization of impacts, public concerns, and economics. It also includes a comparison of Alberta Environmental Protection's lagoon standards and guidelines with the standards of other jurisdictions and discusses possible upgrade techniques for lagoon treatment. Often comparisons will be drawn to other treatment technologies to determine if there are other options that can better meet the treatment needs of small communities.

1.2 Objective

The objective of this thesis is the evaluation of lagoon treatment in Alberta. Included in this evaluation are in-depth analyses of the following aspects of lagoon treatment:

- standards and guidelines
- effluent quality
- impacts
- concerns
- economics
- possible upgrades

Comparisons to other treatment alternatives are made where applicable in order to establish which alternative best meets the treatment needs.

1.3 History

The history of lagoon treatment in Canada dates back to the 1940's (Fisher, 1967) while globally it seems the first lagoon treatment practices are found in China about 1000 years ago (Allum and Carl, 1970) but the history of the processes involved in lagoon treatment dates back to the beginning of time. Traditionally the natural processes in rivers have provided good mixing and aeration that has stabilized organic matter that found its' way into the water ways. For most rivers it has only been in the last few centuries that the natural treatment processes have been over loaded. The industrial revolution attracted people from rural farming areas seeking a better standard of living into large cities. This tended to concentrate the wastes produced and in some locations over loaded the natural treatment processes in the water ways with a variety of organic and inorganic materials. The industrial activity also brought new additions of these materials onto the natural treatment processes in the rivers and lakes. The over loading of the natural purification system of the water bodies caused drastic changes like declines in fish and other aerobic aquatic organism populations, unsightly appearances, and severe odour problems. In North America the problems were most severe in central Canada and eastern United States where the population and industrial activity was centered. The changes in water bodies did not go unnoticed and a public outcry erupted that demanded measures to correct the situation. Treatment systems evolved with the goal of stabilizing the materials in the wastewater before discharge into water bodies. The systems that developed matched the needs of the communities. Large communities developed sophisticated and operationally complex systems with relatively short detention times that required large amounts of energy to stabilize the wastewater. The treatment system that best met the needs of small communities where suitable land was available was the lagoon.

Fisher (1967) reported that Alberta led Canada in lagoon treatment and was the first to use lagoons in 1947. He also (Fisher *et al.*, 1968) gave a brief history of lagoons in Canada and commented on how the growth of this treatment practice was almost exponential in the 50's and 60's. In Saskatchewan there were 275 municipalities being served by lagoons by the end of 1965. Manitoba's first lagoons where constructed in 1955 and by 1961 there were 29 lagoons in operation. Alberta's first lagoon was built in 1947 and by 1960 there were 114 lagoons in use. In 1956 Ontario built the first lagoon in that province and by 1964 there were 43 installations. Prince Edward Island first used lagoons in 1957 and there were 10 lagoons in use in 1965. Lagoons began being used in New Brunswick in 1959 and there were 9 lagoons in operation in 1963. Nova Scotia had one lagoon in operation in 1962 and Newfoundland had not used lagoons by 1965.

In 1990 there were 392 municipally owned treatment facilities in Alberta (Alberta Environment 1990) and 315 or 80% of them are lagoon systems. Figure 1.1 demonstrates that lagoons in Alberta are mainly used by small communities with 70% of the lagoon systems serving populations of less than 1000. Mathavan *et al.* (1989) reported that Saskatchewan had 189 of 242 treatment facilities (78%) using lagoon technology. Lagoons continue to be the mainstay for wastewater treatment in small communities.

1.4 Technical Aspects

Early lagoons consisted of simply one cell which was used for treatment and storage. With a greater understanding of processes involved in lagoon treatment designs have improved to include a number of cells each with different objectives. The three types of cells commonly used in a lagoon system are anaerobic, facultative, and storage cells. The anaerobic or short detention cells are sedimentation cells with detention times in the order of days, due to high organic loading they are generally devoid of oxygen so that the biological processes are anaerobic. The facultative or treatment cells have detention times in the order of months and have aerobic conditions near the surface and anaerobic condition in the bottom portion. Aerobic, anaerobic, and facultative microorganisms are all involved in the treatment process in these cells. The storage cells have detention time of several months up to a year and aerobic conditions predominate during ice free periods with only a small portion of the bottom water being anaerobic. During periods of ice cover the cell becomes anaerobic.

Wastewater treatment by lagoons relies on many complex and interrelated processes which when managed properly can provide a robust overall treatment process that consistently provides a good quality effluent. The main wastewater treatment stages that are of interest in lagoons are as follows:

- sedimentation of organic and inorganic solids;
- anaerobic digestion of settled organic solids;
- the symbiotic relationship between bacteria and algae;
- nutrient removal; and
- natural disinfection.

This is not an all-inclusive list of the processes that take place in a lagoon but the processes listed are the ones of major importance to wastewater treatment.

The discussion of the above processes that follows is intended to provide a general understanding of lagoon treatment to the level required for the evaluation of Alberta lagoons in later chapters. An exhaustive review on the subject of lagoons can be found in other sources (McKinney, 1982; Middlebrooks *et al.*, 1978; Smith and Finch, 1985)

1.4.1 Sedimentation

Sedimentation as summarized by Eckenfelder (1989) can be divided into three classifications: discrete, flocculent, and zone settling. The nature of the particles determines the type of settling. In discrete settling the particles do not change shape, size, or density. Flocculent settling occurs when particles agglomerate, changing their size and settling velocity. Zone settling involves a flocculent suspension which forms a lattice structure and settle as a mass. Discrete settling deposits grit in the vicinity of the inlet to the lagoon and flocculent settling is responsible for the removal of the biological flocs that form and is of interest in facultative lagoon performance (Tikhe, 1975). Zone settling occurs in the bottom portion of the lagoon, where high oxygen uptake rates cause anaerobic conditions to prevail in these sludge blankets. Suspended solids removal of 40 to 70% due to sedimentation alone is reported in the literature (Bouthillier and Brown, 1971; Brisbin *et al.*, 1967). The largest absolute reduction of effluent quality parameters is attributed to sedimentation. Sedimentation is the only process substantially improving wastewater quality when ice cover and cold temperatures in the winter slow down the biological processes.

1.4.2 The Bacteria and Algae Symbiosis

The term symbiotic refers to two or more species that are reciprocally dependent on one another and because bacteria and algae can occur separately in nature, the relationship is not truly symbiotic in the strict sense of the word (Ganapati, 1975). The term symbiosis is used with a more general meaning when referring to the bacteria-algae relationship. The loose bacteria-algae symbiosis is illustrated in the aerobic zone in Figure 1.2. Algae require a supply of CO_2 which is a waste product of bacteria metabolic activity and in turn bacteria requires a supply of oxygen which is a waste product of algal photosynthesis. Golueke (1977) stated that in the loose symbiosis between algae and bacteria, the algae are more dependent on the bacteria because of the inability to utilize complex organic compounds as a nutrient source and the need for bacteria to break them down. A discussion of algae and bacteria follows.

1.4.2.1 Algae

McKinney (1982) explained that much of the research on algae has been devoted to classifying and naming of the various algal species however little is known about the characteristics of these species, therefore identification of the family or group of algae is of interest because the accompanying characteristics are not known (McKinney, 1982). The four major divisions of algae that are of interest to wastewater lagoon treatment are: *cyanophyta* (blue green algae), *chlorophyta* (green algae), *euglenophyta* (motile green algae), and *chrysophyta* (yellow-brown algae). The identification of the main algal groups in wastewater lagoons is an important indicator of the treatment state in the lagoon (McKinney, 1982).

Algae use energy from light to combine stable CO_2 with water, nitrogen, phosphorus and other elements to produce unstable protoplasm and oxygen. This cell protoplasm undergoes continual endogenous respiration which appears as just the reverse of the first reaction.

Algae Photosynthesis

$$5CO_2 + 3H_2O + NH_3 \xrightarrow{\text{light}} C_5H_9O_{2.5}N + 5\tfrac{1}{4}O_2$$

Endogenous Respiration

$$C_5H_9O_{2.5}N + 5\tfrac{1}{4}O_2 \rightarrow 5CO_2 + 3H_2O + NH_3$$

The key to algae providing a net oxygen gain to the treatment system lies in the fact that only 80% of the algae mass is biodegradable under endogenous respiration. The non-biodegradable residual is basically the cell wall structure. Endogenous respiration consumes the protein in the cell which is the store of the nitrogen. The composition of algae changes somewhat depending on age because of this consumption of protein. Young algae cell composition is of the form $C_5H_9O_{2.5}N$, while older algae cells have a composition of $C_9H_{17}O_6N$ (McKinney, 1982).

Abeliovich and Weisman (1978) suggested that algae may not only use CO_2 as a carbon source but may also be able to assimilate organic matter, he found that 15% of algae carbon in a high rate oxidation pond was derived from glucose which was artificially introduced. He further speculated that algae may not be able to compete for the easily assumable organic matter with the bacteria.

Algae growth rate is much slower than bacteria mainly because the algae are larger. Goldman and Graham (1981) found the growth rate of *chlorella* (a green algae) to be 2.1/day which means the cells double every 11.4 hours. In ideal conditions of light and nutrient availability growth occurs unimpeded until nutrient and light become limiting. Azov *et al.* (1982) found that CO_2 was the limiting nutrient in determining the algae cell production. In a high rate oxidation pond ammonia concentrations above 2.0 mM and a pH of over 8.0, inhibits photosynthesis and growth of algae cells (Abeliovich and Azov, 1976). The pH fluctuations are a result of the consumption and evolution of carbon dioxide. Figure 1.2 shows aerobic bacteria produce CO_2 which lowers the pH and algae consume CO_2 in the day time which raises the pH resulting in higher pH near the surface. At night algae continue autorespire and produce CO_2 which lowers the pH and results in daily pH fluctuations. High pH will cause the precipitation of phosphates and $CaCO_3$, this is the only way algal respiration activity affects alkalinity.

McKinney (1982) stated that temperature has a dramatic effect on algae; a change of 10°C causes the metabolisation rate to change by a factor of two. He commented that one of the most important temperature effects on algae is the large scale die-off that occurs with a sudden drop in temperature and speculated it may be due to ice crystals forming inside the cells.

At times the natural sunlight intensity exceeds algae requirements. When this occurs the organisms adjust their depth in the water column to find optimal light conditions, even nonmotile algae can change position to find optimal light conditions (McKinney, 1982). Goldman (1979) stated that the efficiency of conversion of solar energy to algae biomass is less than 5% due to; only light in the visible region (400 to700 nm) being useful for photosynthesis, only 45% of the total suns energy reaches the algae, and the efficiency of algal cells. He found the intrinsic characteristics of the photosynthesis process limit the maximum algae biomass yield to 30 to 40 g dry wt /m^2/day and this rate is only sustainable over the short term. Due to the rapid generation period of algae, certain species tend to dominate through natural selection regardless of which algae is used as an inoculum. Goldman (1979) found sunlight more important than temperature when determining dominant algae species. Eckenfelder (1980) found that the dominate algae group is mainly dependent on temperature and light intensity while El-Gohary *et al.* (1991) found the dominate algae group varied with lagoon detention time and noticed a relationship between algal growth and ammonia and nitrate concentrations (ammonia decreased and nitrate increased with increased algal concentration). The lagoon studied by El-Gohary was dominated by green algae (*scendesmus*) and only *oscillatoria* was present in good numbers from the blue green algal group for 50 to 60 days of detention time. Uhlmann (1978) investigated the rate of algae production as it depends on temperature, nutrient load, and detention time and found the values as high as 50 mg dry weight /(L·d).

1.4.2.2 Bacteria

The bacteria in wastewater lagoons have the ability to completely metabolize the organics found in the wastewater under aerobic conditions (McKinney, 1982). Facultative bacteria dominate the bacteria populations because lagoon systems at times experience anaerobic conditions. The dominant group of bacteria is determined mainly by the seasonal temperature fluctuations and competition for food. The most common bacteria found in lagoons are achromobacter, pseudomonas, and flavobacter (McKinney, 1982). Aerobic and strictly anaerobic bacteria are present given the right conditions. Anaerobic bacteria are discussed later under the topic anaerobic digestion.

The protoplasm of bacteria is essentially the same material as algae protoplasm. Studies indicate the composition of bacteria protoplasm is represented by the formula $C_5H_9O_{2.5}N$ (McKinney, 1982). Bacteria use the process of metabolism to generate protoplasm (more bacteria) and the energy required for maintenance comes from endogenous respiration (the degradation of cellular material). The metabolisation of organic matter can be represented by the following reaction:

$$\text{organic mater} + \text{bacteria} + O_2 + \text{nutrients} \rightarrow \text{more bacteria} + CO_2 + H_2O$$

Like algae, 80% of the bacterial mass is endogenously biodegradable and roughly 20% is inert volatile suspended solids. Under optimal conditions approximately 1/3 of the organic matter in the wastewater is oxidized to furnish the energy to convert the remaining 2/3 to cell mass. Based on heat of combustion of cell mass, one gram of BOD_5 metabolized will produce 0.85 grams of bacterial mass (McKinney, 1982).

The studies on the growth rate of aerobic bacteria indicate a rate of 0.2 to 0.3/hr (DeBoer *et al.*, 1981) which means a doubling of bacterial mass every 20 min. The maximum rate of growth will continue limited only by the speed at which the bacteria can metabolize the substrate until either the food or other nutrients becomes limiting or until the microbial mass interferes with the individual bacteria acquiring food. The growth rate is also temperature dependent. Seasonal changes in metabolism rates in bacteria in cold climate were investigated by Halvorson *et al.* (1969) and found the highest metabolism rate from the bacteria in the summer with warm temperatures but he also determined the metabolism rate in the winter while slower still had a contribution to wastewater stabilization. Miller (1967) stated that psychrophilic microorganism do exist and grow at appreciable rates at very low temperatures.

1.4.3 Anaerobic Digestion of Settled Organic Solids

When the oxygen supply cannot maintain DO concentrations the lagoon system becomes anaerobic. Anaerobic metabolisation processes gain only 3 to 6% of the energy gained aerobically and require 7 to 10 times as much organic matter to produce the same protoplasm (McKinney, 1982). Anaerobic bacteria do not metabolize the organic wastes to stable CO_2 but change it to a simpler form. The slower and more energy demanding anaerobic processes cannot compete with aerobic bacteria for limited substrate in aerobic conditions and only establish populations in anaerobic conditions. The anaerobic digestion of the settled organic solids takes place in the sludge layer that is completely devoid of oxygen. The digestion is a two stage process of converting the organic matter into a intermediate acid which is then converted into methane (see Figure 1.2). There are two groups of bacteria that perform these steps and they are aptly referred to as acid formers and methane generators. These bacteria function best in the meso or thermo temperature ranges. The temperatures in Alberta lagoons are below optimum for most of the year so that the rate of anaerobic digestion is below optimum.

1.4.4 Nutrient Removal

1.4.4.1 Nitrogen Removal

The three major processes that remove nitrogen from lagoon systems are nitrification-denitrification, volatilization, and uptake and sedimentation by bacteria and algae.

The nitrification-denitrification process is a series of microbially catalyzed redox reactions. Nitrification is the oxidation of ammonia nitrogen to nitrite and then to nitrate in aerobic conditions, the following equations show the chemical processes (Snoeyink and Jenkins, 1980):

$$2NH_4^+ + 3O_2 \rightarrow 2NO_2^- + 4H^+ + 2H_2O \quad \text{(Nitrosomonas - aerobic conditions)}$$

$$2NO_2^- + O_2 \rightarrow 2NO_3^- \quad \text{(Nitrobacter - aerobic conditions)}$$

The microbes that catalyze these reactions gain little energy from the process and therefore generate little biomass. In the activated sludge process a significant population develops because of solids recycle practices but in lagoons the populations remain small and long detention times are required to provide appreciable nitrification.

Denitrification is the reduction of nitrate to nitrogen gas in anaerobic conditions. The following equation details the chemical reaction:

$2NO_3^- + 12H^+ + 10e^- \rightarrow N_{2(g)} + 6H_2O$ (facultative microbes - anaerobic condition)

Facultative microbes have the ability to use nitrites and nitrates as their electron acceptor rather than oxygen acquiring only slightly less energy. The process must take place in anaerobic condition and the nitrogen gas produced has a low solubility and once saturation is reached may be transferred to the atmosphere following gas transfer principles.

Sparling and Stibbard (1989) set up air sampling units on a lagoon surface to collect gases and found that nitrogen was evolving at a rate that exceeded the rate expected by temperature and pressure changes. This is good evidence that denitrification was occurring in lagoon system. The authors stated that the processes are temperature and time dependent.

The volatilization of ammonia can be a significant factor in nitrogen reduction. The partial pressure of ammonia in solution increases with increasing pH and therefore algal activity causing high pH in lagoons will increase ammonia volatilization. Other factors that increase ammonia losses to the atmosphere are increased wind speed and increased temperature (Strattion, 1968, 1969; Weiler, 1979). Stratton (1968) quantified the effect of temperature and pH on the volatilization of ammonia from a stream and predicted a 50% reduction in ammonia concentration in 11 hours in a stream with pH 8.5 and temperature of 20°C.

Nitrogen removal by uptake and later sedimentation by bacteria and algae is not a significant process in nitrogen removal. As previously stated, an appreciable amount of nitrogen is taken up in the production of new bacteria and algae cells but most of this nitrogen is in the protein of the protoplasm which is biodegraded and released through endogenous respiration. There is only a small portion of the cellular nitrogen in the cell wall which is the stable portion of the bacteria or algae cells that settles out.

McKinney (1982) stated that blue-green algae have the ability to fix atmospheric nitrogen which would add nitrogen to the wastewater.

1.4.4.2 Phosphorus Removal

Phosphorus removal can take place by two processes; first, it can be assimilated into the cell structure of algae and bacteria and settled out in the inert portion of the cell mass after the cell dies; second, the conditions of high pH which can occur near the surface of a lagoon due to algae activity can precipitate the phosphorus. Bogan (1961) found through laboratory studies and pilot scale tests that algae reduced orthophosphate concentrations below 1 mg/L in 6 to 12 hours with adequate light (100 to 200 lumen), and he also found that this much light does not penetrate lagoons past roughly 300 mm deep. This report does not address endogenous respiration releasing most of the phosphorus back to the system. Golueke (1977) and Moutin, *et al.* (1992) stated that the greater part of phosphorus removal was due to precipitation due to drastic pH fluctuations and not assimilation by algae.

1.4.5 Natural Disinfection

One of the goals of wastewater treatment is the protection of public health. The wastewater characteristic of main concern to public health is the microbial quality of the effluent being discharged to the receiving environment. Table 1.1 is a summary of the common pathogenic microorganisms found in feces and the removal efficiencies of treatment processes. The table indicates that lagoons are capable of the highest removal efficiencies using natural disinfection. The natural disinfection processes that take place in a lagoon include: sedimentation, adsorption to solids, radiation from the sun, predation by other organisms, and nutrient deficiencies. Many factors have been related to natural disinfection processes, they are: temperature, pH, detention time, number of cells, depth, turbidity, algae growth and concentration, organic loading, and sunlight intensity (Davies and Gloyna, 1972; Johnson *et al.*, 1978; Marais, 1974; Mckinney, 1982; Slanetz *et al.*, 1970; Little *et al.*, 1970; Bowles *et al.*, 1979; Qin *et al.*, 1991; Parker, 1962; and Curtis *et al.*, 1992). Amin and Ganapati, (1972) discussed the uncertainty and difference of opinion that exist about the dominant processes of natural disinfection and states that they agree that purification takes place during storage, however how it is affected is unknown.

There is consensus that temperature, detention time, and number of lagoons are significant factors in the natural disinfection processes (Slanetz *et al.*, 1970 and Little *et al.*, 1970). Curtis et al. (1992) proposed a mechanism of disinfection that can rationalize much of the confusion and contradiction about natural disinfection processes. They demonstrated that sunlight induced damage called photooxidation may be the dominate natural disinfection process. The UV rays from the sun do not provide a major component of disinfection because they do not penetrate the lagoon more than 300 mm. The longer wave lengths of light that are not absorbed and penetrate deeper into the pond activate key sensitizers (which they think are humic substances) which form active oxygen forms that damage the cells. The process is strongly affected by the oxygen concentration which is related to algae population and BOD, and is chemical in nature and therefore affected by temperature and pH. This approach can explain much about past findings as many of the factors previously determined important can be related to pH, temperature, and DO. There are interesting tradeoffs and balances illuminated with this theory, the impact of humic substances providing sensitizers (increasing disinfection) will be played off against their ability to attenuate light penetration (decreasing disinfection) and the amount of algae producing oxygen (increasing disinfection) will again be played off against the reduction of light penetration due to algae.

Grimason *et al.* (1993) looked at the occurrence and removal of *giardia* and *cryptosporidium* in Kenyan wastewater Lagoons. *Giardia* was found in 9 of 11 raw wastewater samples investigated and in 6 of the 11 *cryptosporidium* was found in the raw wastewater. None of the lagoons had *cryptosporidium* in the final effluent and one lagoon was found to have *giardia* in the effluent. The minimum detention time required for the removal of both was 37.3 days.

Davies and Gloyna (1972) investigated the effects of algae species on the die-off of indicator organisms and found a higher die-off rate with mixed species than one particular species. McGarry and Bouthillier (1966) studied the survival of *salmonella typhi* in lagoons and found nutrient loading and temperature to be factors that affect the rate. Marais (1974) found that die-off rates of indicator organisms in lagoons followed Chick's law $dN/dt = -KN$ and that lagoons in series had improved removal over a single lagoon with the same detention time.

Mara (1989) conjectured that maintaining a stratified storage lagoon, which acts like a shallow lagoon, may perform better in terms of bactericidal action even if the detention time is shorter. Wind breaks to maintain stratification were considered to be useful.

1.4.6 Higher Animals

Protozoa and higher animals play a roll in lagoon treatment by feeding on bacteria and algae. McKinney (1962) gave an account of the role of protozoa, crustaceans, and rotifers in lagoons. The most important group was ciliata, the ciliated protozoa which are highly motile and efficiently capture bacteria. Typical genera of crustaceans found are *cyclops*, *daphnia*, and *moina*. *Daphnia* was reported to be the most important crustacean (McKinney, 1962). *Rotifers* clean up large organic particles, algae, bacteria, and cellular debris (McKinney, 1962). Deborn et al. (1977) studied aerated lagoons in Nova Scotia for *daphnia* population density changes throughout the year and found that *daphnia* increased in size (4.4 mm) and in population (800/L) during the spring and population decreased to zero in January and he estimated that at the peak population density, the lagoon contents were being filtered through the daphnia once in 24 hours. In field work done for this report on lagoon effluent from the Village of Legal, boatsman, backswimmer, *daphnia* (many), dragonfly larvae, and leaches were identified in the effluent.

A lagoon system studied by Mara (1989) found *daphnia* grazing vigorously on algae in the storage lagoon and they were unable to find *daphnia* in previous cells. He speculated that it was due to the higher ammonia concentrations in previous cells.

1.5 Factors Affecting Lagoon Processes

The factors that affect lagoon processes can be classified into two categories; first, those factors related to climatic conditions and second, the factors which are controlled by the design or operation strategy of lagoon systems. The two sets of factors that affect lagoon treatment are as follows:

Climatic Factors	Design or Operational Factors
Temperature	Detention Time
Sun light	Depth of Cells
Wind	Configuration Of Storage Volume
Ice	Short circuiting
Snow Cover	Stratification
	Raw Wastewater Characteristics

1.5.1 Temperature

Cooler temperatures slow bacteria and algae metabolism, a 10° C temperature change causes about a two fold change in metabolism for both bacteria and algae (McKinney, 1982). Temperature is also an important factor in determining the dominant algae and bacteria species and groups in the lagoon system. The poorer performance of lagoons reported in the cooler seasons is an indication of the effects of temperature on lagoon treatment.

As previously discussed the biological processes in anaerobic cells are slower at low temperatures which make the cells predominately sedimentation and sludge storage cells for all but a few months of the year in Alberta.

The impact of temperature on controlled discharge lagoons depends on the season of discharge. The effluent quality of a fall discharge is not dependent on summer temperatures because there is adequate time for wastewater treatment even at low rates but the rapid drop in temperature in the fall is important because it kills a large portion of the algae which settle and do not leave with the effluent. Spring discharges are dependent on temperature because time between ice melt and discharge is not long enough to be independent of biological reaction rates.

1.5.2 Sun Light

The sun is the driving force in lagoon treatment. The production of algae which provides oxygen to the system is tied to the hours and intensity of sunlight which is also a factor in the natural disinfection process. The northern locations with the long hours of sunlight in the summer have increased potential for algae and oxygen production and natural disinfection. The ice and snow cover of the winter months limits the effectiveness of sunlight related processes.

1.5.3 Wind

Wind increases surface aeration, evaporation and mixing. Middlebrook (1978) states that early lagoon designs tried to maximize the effects of wind action while later designs tried to minimize the wind effects because mixing was no longer desirable and surface aeration was not considered a significant factor.

There are some that advocate mixing to be beneficial to lagoon treatment while others argue that better treatment can be accomplished by minimizing mixing. Those that promote mixing base it on the increased aerobic zone of activity while those against mixing extol the benefits of the lower anaerobic zone which should be maintained. McKinney (1982) states that wind is an important physical factor to lagoon treatment because it provides mixing. Excessive wind can also cause berm erosion and protection of the banks may be necessary.

1.5.4 Ice

The development of ice cover means that the water has an average temperature below 3.98 °C. The warmest water (highest density) will be at the bottom of the lagoon and the coldest at the top (0 °C). The ice seals the surface of the lagoon to the diffusion of oxygen. Oxygen transfer to the lagoon is an important factor in maintaining aerobic conditions. Algae may continue to produce limited amounts of oxygen under the ice cover. However, the rate may be very low due to the low temperature. The associated anaerobic process rates are low at these low temperatures leaving sedimentation as the main process affecting the wastewater during ice covered periods.

1.5.5 Snow Cover

Snow cover reduces or prevents sunlight from reaching the liquid water. As a result any algae living in the water column will not be able to carry out photosynthesis and will continue to respire. Endogenous respiration will lead to the death of the algae. Depending on density and size the algae may agglomerate and settle to the bottom of the lagoon.

1.5.6 Detention Time

Detention time represents the amount of time available for treatment processes to occur in the wastewater and combined with a given process rate will determine the level of treatment possible. The actual detention time in a continuous discharge cell due to the occurance of short circuiting and stratification can only be determined by tracer studies.

The detention time in anaerobic cells is based on the time needed for settling (order of days) while detention time in facultative cells is based on treatment time needed (one to two months). In a controlled discharge lagoon the overall detention time is known and is established primarily based on the desired time of discharge for the receiving environment which is usually well in excess of the time requirements for treatment, although treatment time may be limited for spring discharges.

1.5.7 Depth of Cells

The most important effect of depth on lagoon ecology is the decreasing light penetration with increasing depth (Middlebrooks *et al.*, 1978). Sunlight penetrates only the top portion of a lagoon cell so that the depth of the cell will reflect the level of dependence the treatment processes have on sunlight. The anaerobic cells are deep (3 to 3.5 m) because sunlight is not important to the cell processes which are settlement and storage of raw wastewater solids (deeper cells have more economical berm area to storage volume ratio). Oswald (1968) suggested making anaerobic cells as deep as possible. The facultative treatmemt cells are 1.5 m deep to allow the sunlight to establish aerobic conditions in a significant upper portion of the lagoon while protecting the anaerobic conditions desired in the lower portions. The storage cells are deeper than the facultative cells because of the much longer period available to continue the natural disinfection process. In controlled discharge lagoons the storage cell functions as a treatment cell for the wastewater stored over winter and depth becomes important.

1.5.8 Configuration of Storage Volume

Middlebrooks (1978) stated that multicelled systems are superior to one cell lagoons because of reduced short circuiting, reduced erosion, and more flexible operation with the disadvantage being increased cost of construction. Short circuiting is not a problem in the storage cells of controlled discharge lagoons which means multicelled storage is not a great advantage with controlled discharge lagoons. The effects of fetch length on wind induced erosion may warrant consideration.

In controlled discharge lagoons the size of the cells is controlled by the detention time and depth which factors have been discussed previously.

1.5.9 Short Circuiting

In the storage cells of controlled discharge lagoons short circuiting is not a concern but the anaerobic and facultative cells can be affected by short circuiting. Finney and Middlebrooks (1980) found that models being used for facultative lagoon design gave inconsistent results because of the lack of knowledge about the actual detention time in the lagoon and stated that improved performance due to lagoons in series is probable due to reduced short circuiting. Short circuiting will not have a significant impact on the effluent quality in controlled discharge lagoons unless drastic short circuiting is occurring in the anaerobic cell flushing solids into the facultative cell and similarly to the storage cell.

1.5.10 Stratification

Stratification is generally a result of density differences caused by temperature. Temperature differences are cased by sun light warming the surface of the lagoon and by the influent wastewater usually being warmer than the cell wastewater. There is generally limited mixing between stratified layers of the lagoon cells unless wind action can generate sufficient currents. Stratification increases short circuiting and as previously discussed this is not a problem in the storage cell but may cause problems in the anaerobic and facultative cells.

As discussed earlier, Mara (1989) suggested that a stratified storage cell may provide improved natural disinfection.

1.5.11 Raw Wastewater Characteristics

McKinney (1982) stated that for municipal wastewater the lagoon effluent has no relation to influent and variation in effluent quality are more a function of temperature, wind mixing, solids separation, detention time and algal growth than to influent characteristics.

1.6 Physical Description

Lagoon systems in Alberta are made up of a combination of the three different types of lagoon cells; anaerobic, facultative and storage. Anaerobic lagoons in Alberta are characterized by; detention time of 2 to 5 days, depths of 3.0 to 3.5m, zero dissolved oxygen, and the dominant process taking place is sedimentation. There is also some anaerobic digestion taking place but due to sub-optimum temperatures, the rate is slow. Facultative lagoons are characterized by; detention time of a few months, depths of around 1.5m, aerobic conditions at the surface and anaerobic conditions near the bottom, and the dominant process is the bacteria-algae reduction of soluble substrate (sedimentation, nutrient removal, and disinfection are also important). Storage lagoons are characterized by; 8 to 12 month detention time, 2.5 m max. depth, aerobic conditions (except in the spring when it will be similar to a facultative lagoon.), and the main processes microbial removal of nutrients, natural disinfection and continued settling.

Common piping and valve arrangements are summarized in Figure 1.3. The anaerobic cells can operate in series or parallel with overflow to the facultative cell. The lagoon cells are contained by earthen berms topped with soil and vegetation, shore protection is sometimes necessary. Plates 1.1 and 1.2 are photos of the lagoon at the Village of Legal and it is an example of the physical appearance of a well maintained lagoon.

1.7 Seasonal Variation

The most important seasonal effects that take place in lagoons are due to temperature change and the resulting ice and snow cover. The biological population distributions and process rates are significantly affected by the temperature changes (McKinney, 1982). Although some researchers have found aerobic conditions under moderate ice cover, (Sparling, 1967 *cirri*) the rapid temperature drop that kills the algae combined with heavier ice and snow cover explains the anaerobic conditions that predominate Alberta lagoons in the winter.

The seasonal differences in the different types of lagoons can be seen in Figure 1.4 where biological activity is greatly decreased. In the winter operating conditions, the lagoon is providing primary treatment only. Slaughter *et al.* (1979) reported BOD_5 of 90 mg/L, ammonia of 16 mg/L, and hydrogen sulfide of 26.1 mg/L in a Ontario lagoon discharging in February and reported fish mortality due to the toxic effects.

Most problem causing conditions occur in the lagoon at the time of spring breakup. The anaerobic conditions that have prevailed over winter produce a population of a sulfur reducing bacteria *desufovibrio* which reduce sulfates to hydrogen sulfide and if the pH is low (algae have not established an aerobic zone and higher pH) the hydrogen sulfide will escape into the atmosphere causing odour problems, one of the main concern with lagoon operation. The rising spring temperatures and wind may cause the pond to turn over or mix which is also associated odour problems. Thus there are often complaints about odour problems at spring breakup time (McKinney, 1982).

1.8 Operational Requirements

Lagoons require little operational time and skill level which is one of the major advantages of this treatment technology. The basic operational activities of a lagoon system as outlined by Alberta Environmental Protection (1988) are:

- checking of any mechanical parts for wear or corrosion;
- grass and weed control two or three times a year;
- checking for sludge accumulation in anaerobic cell;
- consulting affected parties before discharge; and
- discharging the lagoon.

Heinke and Smith (1988 b) outlined the operation and maintaince of lagoon systems in the north and the discussion included the items in the following list.

Operation	Maintenance
Normal operation	Berms and liners
Checking of system	Inlet and outlet structures
Control of wastewater levels	Outfalls
Sampling	Odour problems, weed and insect control
Record keeping	Fencing and signs
Safety	Maintenance of access road
	Sludge management

Table 1.1 : Some Pathogenic Organisms and Their Removal Efficiencies
(adapted from Heinke *et al.*, 1988 a)

Organism	Disease	Primary sedimentation (% removal)	Activated sludge (% removal)	Lagoon (% removal)
VIRUSES		0 to 30	90 to 99	99.99 to 100
Adenoviruses	Various ailments			
Coxsackie viruses	Various ailments			
Echoviruses	Various ailments			
Hepatitis A virus	Infectious hepatitis			
Norwalk agent	Gastroenteritis			
Polioviruses	Poliomyelitis			
Reviruses	Various conditions			
Rotaviruses	Gastroenteritis			
BACTERIA				
Campylobacter fetus	Gastroenteritis	Not reported		
Escherichia coli	Gastroenteritis	50 to 90	90 to 99	>>99.99
Salmonella spp.	Salmonellosis	50 to 90	90 to 99	99.99 to 100
S. typhi	Typhoid fever	As above		
S. paratyphi	Paratyphyiod fever	As above		
Shigella spp.	Shigellosis	50 to 90	90 to 99	99.99 to 100
Vibrio cholerae	Cholera	50 to 90	90 to 99	100
Yersinia enterocolitica	Yersiniosis	Not reported		
PROTOZOA				
Balantidium coli	Balantidiasis	Not reported	-	-
Cryposporidium	Diarrheal disease	10	-	-
Entamoeba histolytica	Amebiasis	10 to 50	50	100
Giardia lamblia	Giardiasis	10 to 50	-	-
HELMINTHS (OVA)		50 to 70	80 to 100	100
Echinococcus granulosus	Hydatidosis			
Ech. multiloculais	Hydatidosis			
Enterobius vermicularis	Enterobiasis			
Mymenolepis nana	Hymenolopiasis			
Echinococcus granulosus				
Ech. multiloculais				

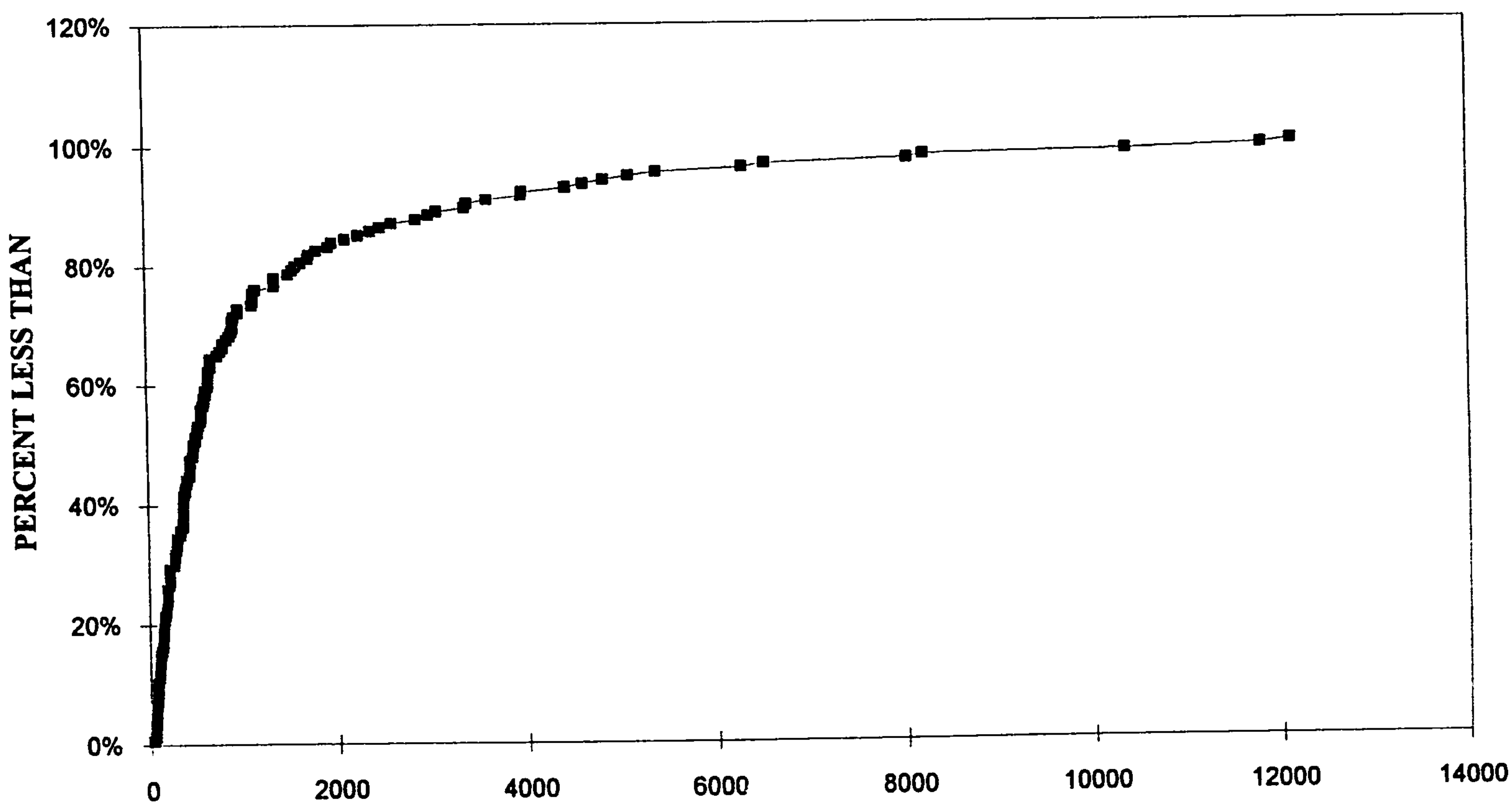


Figure 1.1 : Distribution of Community Sizes (Total 154 communities)

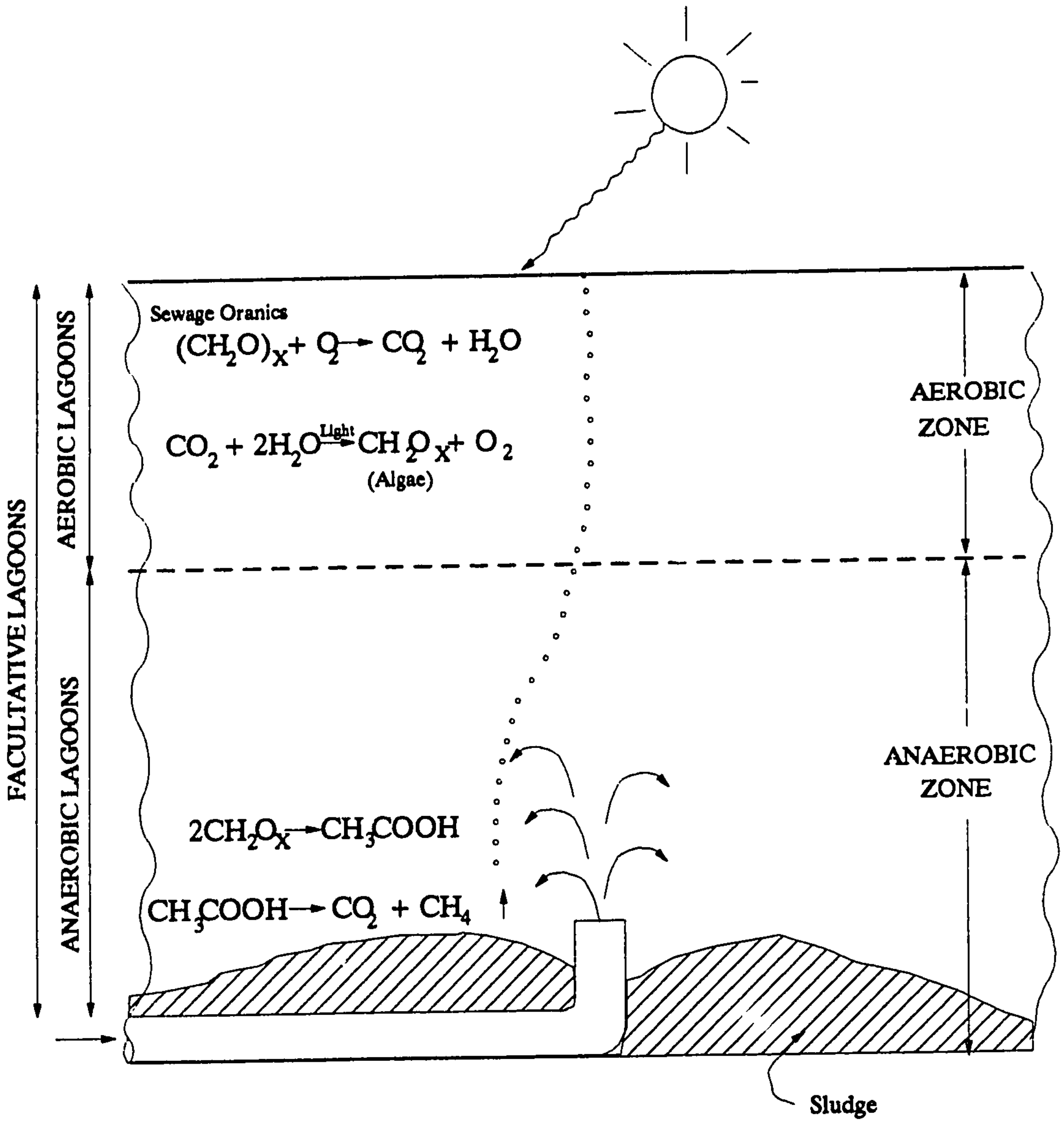


Figure 1.2 : A Schematic Faculatative Lagoon (adapted from Oswald, 1968)

Wastewater Stabilization Pond Requirement

Design Average Daily Flow m^3	Number of Anaerobic Cells	Requirements for Facultative cell(s)	Requirements for 12 Month Storage Cell(s)
Less than 70	0	YES*	YES Max. depth = 2.5m*
70 - 250	0	YES	YES Max. depth = 2.5m
250 - 500	2	YES	YES Max. depth = 2.5m
Greater than 500	4	YES	YES Max. depth = 2.5m

* Revised in 1989

Typical Wastewater Stabilization Ponds

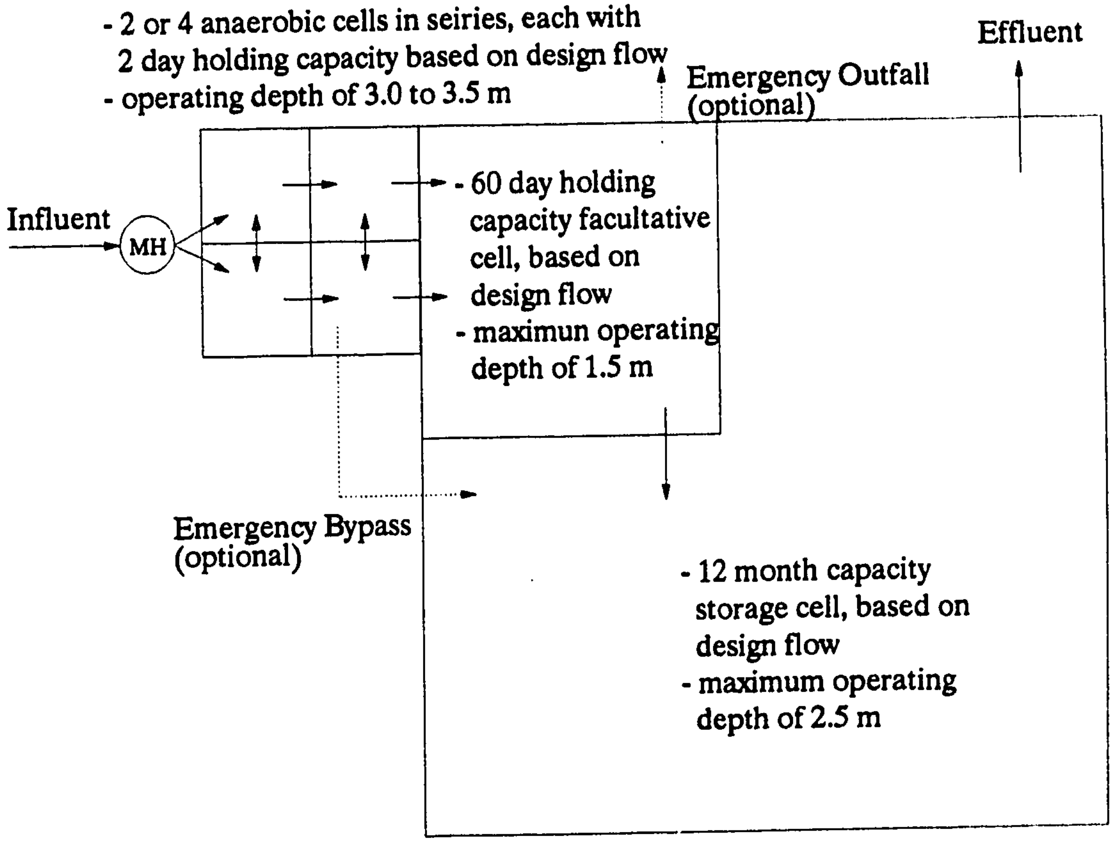


Figure 1.3: Alberta Environmental Protection Lagoon Requirements
Adapted from "Standards and Guidelines For Municipal Water Supply, Wastewater, and Storm Drainage Facilities. (1988)

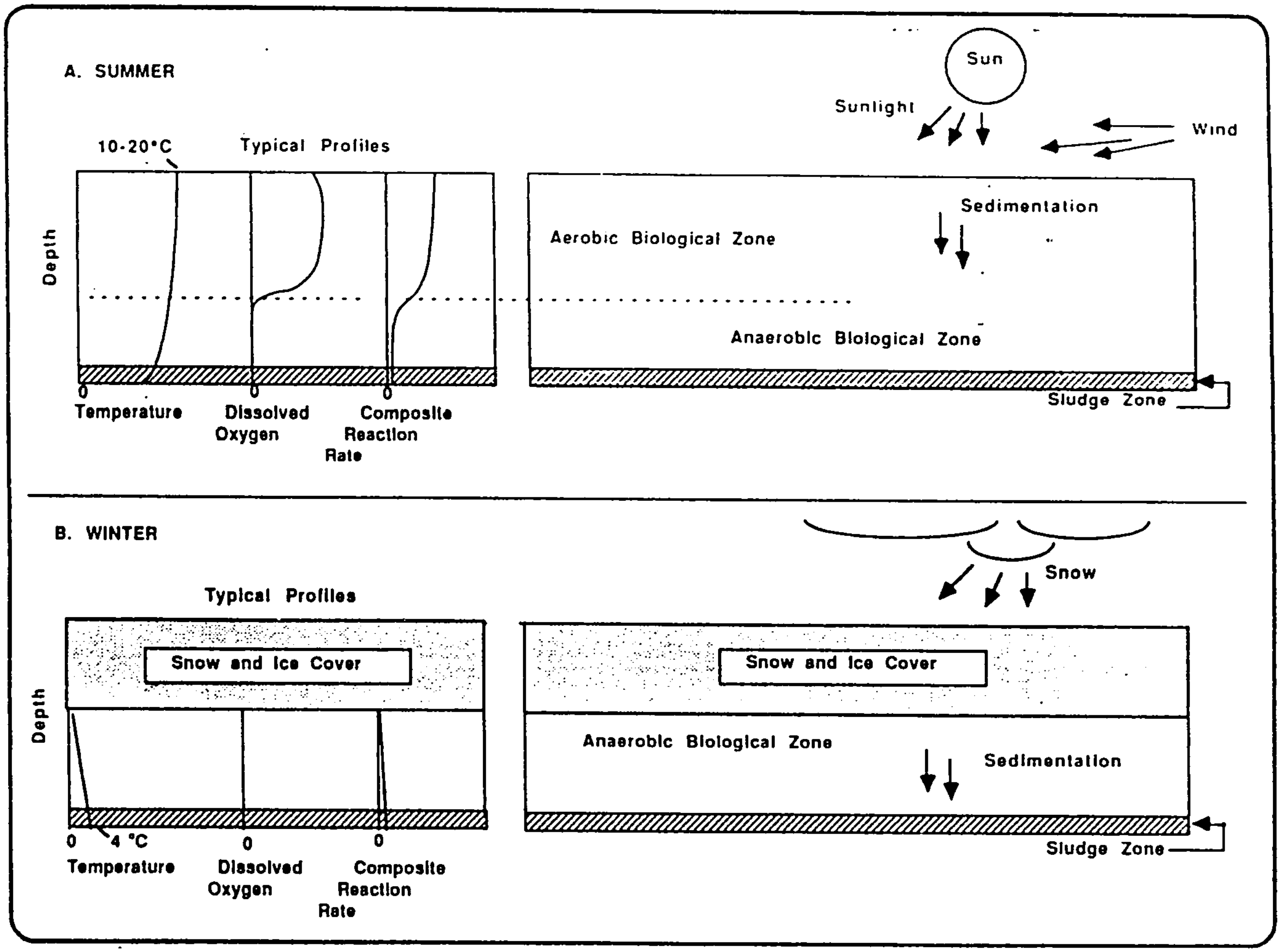


Figure 1.4 : Lagoon Processes in Summer and Winter (adapted from Heinke *et al.*, 1988)

Plate 1.1 : Example of Lagoon Layout, Anaerobic and Facultative Cells (Legal, Alberta)

Plate 1.1 : Example of Lagoon Layout, Storage Cell (Legal, Alberta)

2.0 STANDARDS AND GUIDELINES

2.1 Introduction

This chapter presents the standards and guidelines for lagoon treatment in Alberta and draws comparisons to standards of other jurisdictions. The focus of this discussion is the aspects of the design standards that effect effluent quality or the level of impact on the environment. The intent of this evaluation is to determine if Alberta's standards are comparable to other standards and to insure that the province is not lagging far behind the rest of the country with any innovative improvements to lagoon designs.

2.2 Alberta Standards

The recently passed Environmental Protection and Enhancement Act, Regulation 119/93 states the following:

> 5(1) A wastewater system and a storm drainage system must be designed so that they meet at a minimum
>
> (a) the standard and design requirements set out in the latest edition of the *Standards and Guidelines for Municipal Waterworks, Wastewater and Storm drainage Systems* published by the Department, or
>
> (b) any other standard and design requirements specified by the Director.

Section 5.4 of Alberta Environmental Protection's Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems (AEP's Standards and Guidelines) defines the minimum wastewater treatment requirements as the provision of best practicable technology (BPT). The section continues, "while consideration is given to the surface water quality in the province, the major factor used to establish wastewater treatment levels is the provision of affordable and demonstrated treatment technologies, i.e., BPT." Lagoons with 12 months of storage are identified as treatment alternatives that meet the BPT guideline.

Lagoons providing 12 months of storage are not governed by end of pipe effluent quality standards as are continuous discharge mechanical plants. The requirements for lagoons are detailed design standards and configurations based on average daily flow. Facilities meeting these detailed design standards are in compliance with regulations. Figure 1.3 summarizes lagoon configuration and design requirements. AEP's standards and guidelines stipulates design standards for many other aspects of lagoon design, the following is a list of headings discussed under lagoon treatment:

5.5 Wastewater Stabilization Ponds

- 5.5.1 General Requirements
- 5.5.2 System Components and Configuration
  - 5.5.2.1 Anaerobic Cell(s)
  - 5.5.2.2 Facultative Cell(s)
  - 5.5.2.3 Storage Cell(s)
- 5.5.3 Design Considerations
  - 5.5.3.1 Setback Distances
  - 5.5.3.2 Physical Site Constrains
  - 5.5.3.3 Fencing
  - 5.5.3.4 Warning Signs
  - 5.5.3.5 Access
  - 5.5.3.6 Surface Runoff Diversion
- 5.5.4 Seepage Control
  - 5.5.4.1Seepage Control Criteria
  - 5.5.4.2 Site Selection and Investigations
  - 5.5.4.3 Liner Design
  - 5.5.4.4 Groundwater Monitoring
  - 5.5.4.5 Detailed Liner Standards

5.5.5 Construction Features

5.5.5.1 Berms
5.5.5.2 Inlet Structures
5.5.5.3 Outlet and Drain Structures
5.5.5.4 Flow Measurement

5.5.6 Evaporation Ponds

5.5.6.1 Sizing
5.5.6.2 Depth
5.5.6.3 Configuration

5.5.7 Operation and Maintenance

While many of these sections and subsections are important to the successful operation of a facility, the focus of this evaluation centers on the guidelines in section 5.5.2 because they determine effluent quality.

2.3 Comparison to Other Jurisdictions

Design criteria from other Canadian Provinces were obtained to compare with Alberta's. Provinces investigated included British Columbia, Saskatchewan, Manitoba, Ontario, Newfoundland, New Brunswick, and Nova Scotia while standards from P.E.I. and Quebec were not received. The three design criteria used by the provinces investigated are; surface loading rates (kg BOD_5 / ha•day), detention time, and effluent quality standards. With controlled discharge lagoons of a given depth, the surface loading rate and the detention time are coupled together by BOD_5 concentration of the raw wastewater, and as a result they are really the same factor. Effluent quality is determined by facility design and time of discharge. The number and type of cells, and the detention time is the criterion used for comparison of standards.

Table 2.1 is a summary of the current standards and guidelines for lagoon design from several provinces. The table illustrates three different styles of regulations. Sewage treatment standards in British Columbia are based on effluent quality and the dilution capacity of the receiving water. Some communities in B.C. require no treatment at all. Ontario refers to the US EPA for design standards which are general guidelines that specify loading, number of cells, and depth and while guidance is given for the other criteria, specific design requirements are not. The remaining provinces listed in the table use a very detailed design standard which stipulates most aspects of lagoon design.

The prairie provinces are the only ones that require controlled discharge on all lagoon designs. Saskatchewan and Manitoba stipulate roughly six months of storage while Alberta requires 12 months. Most provinces want at least two cell used in the lagoon designs however none other than Alberta require anaerobic cells. The requirements for depths of cells are similar in all jurisdictions. Alberta and Newfoundland allow roughly 5 $m^3/(ha \bullet d)$ seepage through the liner while New Brunswick and Nova Scotia allow 40 $m^3/(ha \bullet d)$.

2.4 Summary

This analysis has demonstrated that Alberta's standards are not only comparable to other jurisdictions but often superior. Alberta is the only province the stipulates 12 months of storage and the requirement of anaerobic cells.

Province	Loading	Controlled Discharge	Detention Time days	Multiple Cells	Cell Depth	Liner	Seepage **	Setback Distance
British Columbia	Site specific effluent quality standards that depend on dilution, no detailed lagoon standards							
Alberta	N/A	yes	Anaerobic 2 days Facultative 60 days Storage 365 days	* 0A-1F-1S flow < 70 m^3 2A-1F-1S flow < 250 m^3 4A-1F-1S flow > 250 m^3	Anaerobic cell 3.0 to 3.5 m Facultative cell 1 5m storage cell min = 0.5m, max = 2.5m	Natural in situ liners - 0.9m Compacted clay - 0.6m meet seepage requirements	max K (m/s) = (5.2 x 10^-9 m/s x T(m)) / (2+T(m)) design K= lab K x 0.1	300 m to nearest resident
Saskatchewan	Primary cell 30 kg BOD/ (ha-d)	yes	Combined storage 180	min of 2	Treatment cell min=0.6m, max=1 5m Storage cell min=0 3m, max=2.1m	meet seepage requirement	15 cm/a? (0.3m of 10^-7 clay)	300 m to resident 600 m to built up area 460 m to shore of water body
Manitoba	Primary cell 44.6 kg BOD/ (ha-d)	yes	Nov 1 to May 15, 197 days	not specified	min = 0.3 m max = 1 5 m	normal cases 1 meter of 10^-7 cm/s	see liner	457 m to community 305 m to resident
Ontario	19 6 kg BOD/ (ha-d)	site specific	site specific	min two max size 8 ha	Treatment cell 1.8 m Storage cell 2.7 m	site specific	site specific	none specified
New Brunswick	35 kg BOD/ (ha-d) 500 people / ha	if ice expected	sufficent for BOD reduction	min two	Treatment cells 1.5 to 1 8 m Storage cells 2.0 m min depth 0 6 m	meet seepage requirements	max K (m/s) = 4.6 x 10^-8 m/s x 1 2(m) / (1 2(m)+T(m)) 40 m^3/(ha-d) design K= lab K x 0.1	
Nova Scotia	22 kg BOD/ (ha-d) 250 people / ha	site specific	sufficent for BOD reduction	min two small communities one max size 5 ha	Treatment cells 1.5 to 1 8 m Storage cells 2.0 m min depth 0.6 m	min 0 5 m compacted clay	max K (m/s) = 4.6 x 10^-8 m/s x T(m) / (D(m)+T(m)) 40 m^3/(ha-d) design K= lab K x 0.1	habitation 150 m built up areas 300 m
Newfoundland	20 to 30 kg BOD/(ha-d	site specific	ontrolled discharge 180 da Flow through 90 to 120 day	min three small communities two	min = 0.6m, max = 1.8m	meet seepage requirements	max K (mm/s) = (3.0 x 10^-9) x T(mm) 4 68 m^3/(ha-d)	habitation 450 m

* A = anaerobic, F = facultative, S = storage

** T = liner thickness, D = lagoon depth

Table 2.1 : Design Criteria for Lagoons

(see current provincal guidelines)

3.0 ANALYSIS OF LAGOON EFFLUENT QUALITY

3.1 Introduction

The purpose of this chapter is two fold, first Alberta Environmental Protection's (AEP) lagoon standards are evaluated for effluent quality and second an in-depth analysis of lagoon treatment is performed.

The first major section of this chapter is an overview of the database used in the evaluation of lagoon effluent quality. The question of grab samples being representative of lagoon effluent quality is addressed. This section also discusses the tools and methodology of data manipulation.

In the second major section of this chapter only lagoons meeting AEP's standards and guidelines are analyzed to determine the level of treatment provided through the guidelines. Each lagoon configuration recommended by AEP is evaluated for the effluent quality parameters biochemical oxygen demand (BOD), total suspended solids (TSS), phosphorus (P), ammonia, and total Kjeldahl nitrogen (TKN). Comparisons to other treatment technology standards and performance are made.

The third major section of this chapter uses all the lagoon data available to provide an in-depth look at lagoon treatment. Significant factors affecting lagoon effluent quality are identified and used to group the lagoon sites. The effluent quality parameters BOD, TSS, P, ammonia, and TKN were addressed individually and comparisons are made to establish the relative importance of the significant factors to each effluent quality parameter.

3.2 The Lagoon Database

The evaluation of lagoon effluent quality was based on over 500 samples taken from 190 lagoons mostly between the years 1983 and 1986 and 1500 samples taken from mechanical plants between the years 1982 and 1992. The samples were collected and analyzed by AEP staff as part of licensing requirements for mechanical plants and in a continuing effort to assess lagoon effluent quality. Results of the sampling program were recorded in a database using the NAQUADAT format. A total of 28 parameters were listed in the database and though the data was not complete for all samples, the major parameters were usually present.

The location and date of each sample was identified and other information like type of treatment system, design capacity, average flow, detention time, and drainage route was obtained from the AEP Facilities Survey document (1990). Several issues of the facilities survey from different years were referenced to ensure correct identification of the treatment system that was in place at the time of sampling. This other information was linked to the sample analysis results and used for sorting and grouping of the data.

The data was down loaded from AEP mainframe computers to a personal computer database format. The software packages used to transform the data, generate summary statistics, and link the data to other information were Clipper® and dBase IV®; while spreadsheet work like statistical testing and table and chart generation was accomplished with Microsoft Excel®. Lotus Freelance® was also use in graphical applications.

3.2.1 Representative Sampling of Lagoon Discharges

The database of lagoon effluent quality was based on single grab samples taken during lagoon discharges. While the timing of the samples was not specified, discussions with AEP staff indicated a waiting period of a day or two after the valve had been opened before the discharge was sampled. To determine if large variations in effluent quality occurred during discharges and hence determine if the grab samples were representative of the overall quality, a detailed monitoring of effluent quality was completed. The site selected for the investigation was the Village of Legal which is located one hour northwest of Edmonton. Daily samples were taken over the17 day period the lagoon discharged and were analyzed using procedures outlined in "Standard Methods for the Examination of Water and Wastewater" (1992) for biochemical oxygen demand (BOD), total suspended solids (TSS), volatile suspended solids (VSS), total coliforms (TC), and fecal coliforms (FC). Lagoon levels were also measured and surveyed in order to give an estimate of the daily discharge volume. The results and graphical representation of the data can be found in Table 3.1 and Figure 3.1. The data shows that except for spikes at the start and finish of the discharge the parameter levels remain fairly constant. A possible explanation for the one spike in the middle of the discharge is that at about this time the bottom of the ice cover lowered to the tops of the weeds causing the flow to no longer go over the weeds but through them and the higher velocities generated in the vicinity of the outlet may have sheared material off the weeds. The results of similar work by Milos and Beier (1978) show more variability in quality than was found in the Legal lagoon but except for the start and finish the effluent quality was fairly constant.

Based on this analysis it is concluded that the database of lagoon grab samples was generally representative of overall effluent quality in the lagoon discharges.

3.3 Data Analysis Technique

The data analysis involved the grouping of the treatment sites and the calculation of statistics (means and standard deviations) for the comparison of effluent quality. The methods used for these activities are briefly explained.

Statistical comparison tests were used extensively to establish the significance in the differences between the methods of treatment. The test used was the student t-test because there was generally not enough sites to use the more powerful normal distribution. The null hypothesis for any of the comparisons between the means was that the means were equal and the alternate hypothesis was that one mean was greater than the other. The null hypothesis was rejected and one mean was said to be significantly greater if the α value (which is the probability of type one errors, or the probability the difference noticed was due to chance alone) was less than 5%. Frequently in later discussions α values are given to indicate the level at which the differences noticed are significant.

The use of the t-test requires two conditions; first, the data within the groups is normally distributed and second, the variance is homogeneous between the two groups. If the data is not normally distributed a transformation may be used to transform the data to a normal distribution. Box *et al.* (1978) outline a technique for determining what transformation is necessary for a group of data to become normally distributed. The slope of the regression line of lagoon data groups in Figure 3.2 is an indication that a log transformation is required (slope of 1.00 indicates log transformation, see Box *et al.* (1978)). Figure 3.3 is a distribution of lagoon data with an idealized log-normal curve overlaid which demonstrates the log-normality of the data. Based on these findings all further data manipulation and statistical calculations was performed on the natural logarithm of the data.

Constant or homogeneous variance between two data sets is established using the f-test (Box *et al.*, 1978). If two groups of data fail the f-test (variance is not the same) other statistical test are available for comparisons of means. In Figures 3.30 to 3.34 the negative α values indicate that the data groups failed the f-test but application of other tests did not give different results.

The means and standard deviations of the treatment groups are based on site averages of effluent quality.

3.4 Evaluation of Alberta's Lagoon Standards

3.4.1 Lagoon Performance

Lagoon systems are a treatment option that meets the best practicable technology standard as outlined in section 5.4 of AEP's "Standards and Guidelines for Municipal Water Supply, Wastewater, and Storm Drainage Facilities" (AEP's Standards and Guidelines). As discussed earlier, configuration of the lagoon system depends on the size of the population being served, as outlined in Figure 1.3. The AEP's Standards and Guidelines no longer recommends lagoons with only one cell, however these systems will be included in this part of the report because it has only been recently changed. The minimum storage requirements are twelve months for any lagoon system that discharges to an Alberta drainage course. Although, if the final effluent is used for an approved municipal wastewater irrigation program, the required storage time may be reduced. For this initial discussion consideration was only given to lagoon systems with 12 month storage. The effect of storage along with other factors will be considered in later discussions. It is important to note that the season of discharge was not taken into account here because the guidelines only state that fall discharge was preferred to spring however it was not a requirement.

Lagoon configurations are referred to as "4S-2L" which indicates 4 short or anaerobic cells and 2 long detention cells (1 facultative cell and 1 storage cell).

The performance of the lagoon configurations outlined by AEP for the parameters BOD, TSS, total Kjeldahl nitrogen (TKN), ammonia, and phosphorus are summarized in Table 3.2. The average, upper and lower 95% confidence limits of the mean, the number of sites that the data was based on, and the number of samples taken at those sites are listed.

3.4.2 Mechanical Plant Performance

For the purpose of comparison, the effluent quality parameters for other treatment technologies used in Alberta have also been compiled . The other treatment technologies include activated sludge plants (AS), aerated lagoons (AL), rotating biological contractors (RBC), and extended aeration (EA). These treatment technologies will be referred to as mechanical plants due to the mechanical energy used in the treatment system. The data for the mechanical plants was obtained from the same source as the lagoon data and spans roughly the same time period. There was more data available for mechanical plants than for lagoons, even though there were many more lagoons in Alberta, because the mechanical plants were sampled monthly and lagoons were sampled on an as required basis.

Table 3.3 contains a summary of the data available on mechanical plants for the same five parameters listed for lagoons. Also listed in the table are the average, upper and lower 95% confidence limits of the mean, the number of sites that the data was based on, and the total number of samples taken.

3.4.3 Evaluation of Standard Lagoon Effluent Quality

The data listed in Tables 3.2 and 3.3 is presented in a graphical format in Figures 3.4 through 3.13. The bench marks used for comparison of the lagoon effluent quality will be Alberta's standards and guidelines for wastewater effluent quality, the performance of other treatment technologies (data from Table 3.3), surveys of natural concentrations from Canadian Council of Resource and Environment Ministers (1987), and other physically significant water quality values. For comparison these limits and values will be listed on the figures. The limits set for ammonia by Canadian Council of Resource and Environment Ministers (1987) are pH and temperature dependent so that a succinct assessment was not possible with the information given.

3.4.3.1 Lagoons 4S-2L

The 4S-2L lagoons performed similarly to 2S-2L lagoons in terms of BOD with an average of 9.1 mg/L and an upper 95% confidence limit of 11.4 mg/L. Figures 3.4 and 3.8 give a good indication of how well this lagoon design has performed. These systems were well within the BOD standards for any treatment facility and almost 85% of these facilities produced effluent that was roughly half of the BOD standard for mechanical plants servicing less than 20,000 people. The effluent from these lagoons was statistically significantly lower ($\alpha < 5\%$) in BOD than the effluent from all the mechanical plants.

The lagoon system with the lowest TSS average was the 4S-2L design. The average TSS for these systems was 20.4 mg/L with an upper 95% confidence limit of 25.6 mg/L which is very close to the guideline for mechanical systems servicing less than 20,000 people. In comparisons to the mechanical systems, all the mechanical systems were numerically better than this lagoon configuration but not all were significantly better (α = 1.5%, 30%, 13%, 0.5% for AS, AL, EA, and RBC respectively). The Figures 3.5 and 3.10 give a graphical representation of these comparisons. It is important to recognize the different composition of TSS from lagoons and TSS from mechanical plants. The majority of lagoon TSS is algae which occurs naturally in the environment and depending on how long it survives after discharge will determine if the net impact on the oxygen balance of the receiving environment is positive or negative. Mechanical plant TSS will be comprised of unsettled organic matter of wastewater origin and bioflocs, both materials are foreign to the receiving environment.

The average concentration of phosphorus in the effluents of the 4S-2L lagoons was 2.2 mg/L and the upper 95% limit was 2.8 mg/L. This average was lower than the average concentration of phosphorus in the effluents of all types of mechanical plants and significantly lower than all but AS plants where the α value was 20 %.

The 4S-2L lagoon discharges had an average ammonia concentration of 1.3 mg/L and the upper 95% limit of the mean was 2.2 mg/L. This average was significantly lower than the average concentration of ammonia in the effluents of all types of mechanical plants except for EA plants. Figures 3.7 and 3.12 show the ammonia levels for the 4S-2L lagoon were within the limits plotted from Canadian Water Quality Guidelines (limits based on fish toxicity and are pH and temperature dependent).

Lagoons with the 4S-2L configuration have produced effluents with an average TKN of 5.3 mg/L and an upper limit of 6.6 mg/L. This average was significantly lower than AS plants and aerated lagoons and while the average is lower than RBC plants, the difference was not significant. EA plants had the same average as the 4S-2L lagoons but the data was not as tightly grouped. In Figure 3.8 these comparisons were plotted and the range of TKN data was above the natural concentration range of TKN in western surface waters which is 0.15 to 2.6 mg/L and Figure 3.13 indicates that roughly 20% of these systems were within this range.

3.4.3.2 Lagoons 2S-2L

The 2S-2L lagoons perform almost identically to the 4S-2L lagoons for removal of BOD . The average concentration was 9.7 mg/L with an upper limit of 12.5 mg/L. These systems were within the BOD standard for any treatment facility and almost 90% of these facilities have produced effluent that meets BOD standards for mechanical plants. The effluent from these lagoons was statistically significantly lower in BOD than the effluent from the mechanical plants (see Figures 3.4 and 3.9).

For the lagoon configuration of 2S-2L the average value of TSS was 21.9 mg/L with an upper limit of 33.6 mg/L. The majority of the facilities were within the 25 mg/L mechanical plant standard but roughly 35% of them were over that limit. All the mechanical plants were lower in terms of average TSS when compared to this lagoon configuration and the significance of the differences depended on the type of plant (α = 3.5%, 23%, 15%, 1.5% for AS, AL, EA, and RBC respectively). Figures 3.5 and 3.10 give a graphical representation of these comparisons.

The level of treatment for phosphorus removal in the 2S-2L lagoon configuration was similar to the 4S-2L lagoon with an average effluent concentration of 2.0 mg/L and an upper limit of 2.9 mg/L. The Figures 3.6 and 3.11 show that this level of treatment was lower than all the mechanical plants and differences were significant for all except when compared to A.S. plants where the α value was 15%.

The average ammonia concentration in the effluents discharged from 2S-2L lagoons was 1.4 mg/L with an upper limit of 4.2 mg/L. This average was numerically lower than the average values for the AL, AS, and RBC mechanical plants with the α

values for significance being 0%, 15%, and 11% respectively. The average for EA plants was very similar to the 2S-2L system.

The 2S-2L lagoon discharges had an average TKN concentration of 6.8 mg/L with the upper limit of 9.9 mg/L. For TKN levels the 2S-2L lagoon effluents were significantly lower than the AL, lower than AS but not significantly, and higher thar RBC and EA plants but the difference was not significant. Figures 3.6 and 3.11 demonstrate these comparisons graphically.

3.4.3.3 Lagoons, 0S-1L and 0S-2L

The 0S-1L and 0S-2L lagoon systems had similar performance for all the parameters under discussion except for TSS (this can be seen in Figures 3.2 to 3.11). These two configurations will be discussed together.

These lagoon systems did not perform as well as the previous systems with the average BOD value of about 25 mg/L which is the guideline for mechanical systems less than 20,000 people. Roughly half of these lagoon systems exceeded this guideline as shown in Figures 3.4 and 3.9. The effluents from AL and EA systems were significantly lower in BOD than these lagoons, the other mechanical systems were lower but the difference was not as significant (α was 6 to 11% for RBC and 10 to 15% for AS plants).

The 0S-1L and 0S-2L lagoon configurations had average levels of TSS of 33.4 mg/L and 46.9 mg/L with upper limits of 53.6 mg/L and 65.3 mg/L. The 0S-2L system had a lower average TSS but this difference was not significant (α =16%). The majority of the facilities were above the 25 mg/L mechanical plant standard. All the mechanical plants had lower average TSS levels and these differences were statistically significant. The Figures 3.5 and 3.10 give a graphical representation of these comparisons.

The average phosphorus concentration in the effluents of the 0S-1L and 0S-2L lagoons was 3.3 and 3.6 mg/L with upper limits of 6.4 and 5.4 mg/L. The phosphorus levels in the mechanical plants were similar to these lagoons and the only difference was that the upper limits of these lagoons were higher than the mechanical plants (see Figures 3.6 and 3.11).

The effluents of 0S-1L and 0S-2L lagoon systems had average ammonia concentrations of 3.7 mg/L with upper limits of 18.0 mg/L and 9.5 mg/L respectively. AS and RBC mechanical plant effluents were similar to these lagoon system effluents. EA plant effluents were significantly lower in ammonia. The AL plant effluents were higher in ammonia than the 0S-1L and 0S-2L systems but the differences were not as significant with α values of 15% and 8% respectively (see Figures 3.7 and 3.12).

The 0S-1L and 0S-2L lagoons have produced effluents with average TKN concentrations of around 12 mg/L and upper limits of 18 to 22 mg/L. Figures 3.6 and 3.11 show that the RBC and EA plants produced effluents that were significantly lower in TKN than the 0S-1L and 0S-2L lagoons. AS plant effluents were lower in TKN but the data does not indicate significant differences. The AL plant effluents were higher in TKN than the 0S-1L and 0S-2L but again the differences were not significant (see Figures 3.8 and 3.13).

3.4.4 Summary

The 4S-2L and 2S-2L lagoon configurations produced effluents that had lower levels of all the parameters except TSS when compared to the mechanical plants and often the differences were statistically significant. The mechanical plants compared to 0S-1L and 0S-2L lagoon configurations had significantly lower levels of BOD and TSS and the levels of P, ammonia, and TKN were lower but not significantly. The comparison of effluent quality between different lagoon configurations showed systems with short detention cells have better average effluent quality than systems without in terms of all the parameters investigated however BOD was the only parameter that was significantly different.

3.5 Lagoon Treatment

3.5.1 Factors Affecting Lagoon Treatment

The several factors that can affect the effluent quality from a lagoon treatment system are the lagoon configuration (number of short detention cells, number of long detention cell), month of discharge, season of discharge, geographical location, storage time, percent capacity of the system, size of the system (population served), and raw wastewater characteristics. An effort has been made to examine all of these factors to determine which had an impact on lagoon effluent quality. The effluent quality parameters used to determine a factor's significance were BOD and TSS. The treatment facilities were then sorted into representative groupings and comparisons were made without the interference of hidden variables. The important factors were also analyzed to determine their relative and absolute (to a lesser extent) importance in the removal of regulated parameters like BOD and TSS and other parameters of interest like TKN, ammonia, and P.

3.5.1.1 Size of System

Figure 1.1 shows that 85% of the 154 lagoon facilities in the database served populations of less than 2000 people and 50% of facilities served 500 or less. To determine the effect that facility size has on the effluent quality, BOD and TSS data was plotted against the facility size (wastewater flow rate). Figures 3.14 and 3.15 show that the data does not correlate well with the flow. Further analysis done by grouping all facilities with a population less than 1000 persons (roughly 400 m^3/day) and comparing them to those communities with a population greater than 1000 persons showed that there was no real difference in the effluent quality (see Table 3.4).

The analysis indicates that facility size was not a significant factor in determining the effectiveness of the lagoon treatment systems.

3.5.1.2 Raw Wastewater Characteristics

Sufficient data was not available for an analysis of the effect of the raw wastewater characteristics. McKinney (1982) stated that due to the nature of lagoon treatment raw wastewater characteristics have little influence on effluent quality and that effluent quality is determined by other factors. For municipal lagoons the effect of raw water characteristics was assumed negligible.

3.5.1.3 Percent of Design Capacity

One of the concerns in the lagoon data was many of the treatment facilities design capacity far exceeded the current need. Figure 3.16 presents the distribution of percent of capacities that facilities were currently operating at and indicates that 30% of the lagoon facilities in the database were being used at less than half the design capacity. The changes that will occur to a lagoon system operating at less than the design capacity include the storage cell not reaching the design depth and cells that overflow to the next cell will have detention times longer than the design detention time.

The data was analyzed to determine the impact operating at less than the design capacity had on the effluent quality. Figures 3.17 and 3.18 showed with fall discharges there was no significant difference in the BOD or TSS for different percent of capacities.

The spring discharges do not demonstrate any significant differences in BOD but there was one case where the difference in TSS was significant.

BOD and TSS have also been plotted verses the percent of capacity at which the facility was operating. The wide distribution of data in Figures 3.19 and 3.20 indicates a poor correlation.

It can generally be concluded that percent of design capacity was probably not an important factor in determining the effluent quality of this type of lagoon systems.

3.5.1.4 Geographical Location

In evaluating this factor sites were mapped with symbols that indicate the BOD quality of the effluent. Figures 3.21 and 3.22 are maps showing the geographical distributions of 4S-2L (or better) lagoon effluents with spring and fall discharges. Figure 3.22 has also been overlaid with a map showing the geographical distribution of annual hours of sunshine throughout the province. From visual observation of the figures there seemed to be no correlation between BOD effluent quality and location or hours of sunshine. A statistical analysis comparing the lagoons from the different sunshine regions did not show a correlation between sunshine and effluent quality (see Figures 3.23 and 3.24 for BOD and TSS respectively).

The lagoon data did not demonstrate that geographical location was a factor in determining effluent quality in the Province of Alberta. There were examples of excellent lagoon effluents being produced in some of the most northern climates.

3.5.1.5 Season of Discharge

The season of discharge was an important factor to the BOD quality of the effluent as shown in Figure 3.29 where the treatment systems on the left were sorted in order of lowest to highest average BOD. All the fall discharges had lower BOD than the spring discharges regardless of configuration. The trend of TSS was not as defined as shown in Figure 3.30. In some cases fall discharges had not performed as well as some spring discharges although the majority of fall discharges were better than the spring discharges.

The season of discharge was a significant factor in the effluent quality with respect to BOD and TSS.

3.5.1.6 Month of Discharge

A concern in the analysis of the lagoon data was the effluent quality varying within the time frames used for the seasons. In other words the months of the season may have been significantly different from one another in terms of effluent quality. The season of winter in this report was assumed to include December, January, and February; spring included March, April, and May; summer included June, July, and August; and the fall months were September, October, and November.

Figures 3.25 and 3.26 are a summary of means and standard deviations of lagoon systems grouped by month of discharge and configuration.

In the spring there was a significant decrease in BOD from April to May and a significant increase in TSS. This is expected in a lagoon system because through the winter months there is little to no soluble BOD removal because the lagoon is ice covered. After the ice was gone and the algae began to establish aerobic conditions there was a decline in BOD. Although the metabolism rate of the aerobes was slower at the colder temperatures, it seems that in about one to two months of ice free treatment the effluent quality was lowered below the 25 mg/L BOD level. The rise in the TSS can be explained by the increased algal activity due to the ideal conditions of nutrients and sunlight that existed after the ice cover had melted.

The fall discharges showed significant differences in effluent quality between the different months. Both the BOD and the TSS were significantly higher in September than October and November. The explanation for this was discussed in detail earlier, in short the cold weather caused algae populations to die off which lowered both the BOD and TSS. The BOD levels in all months of the fall were considered excellent. The levels of TSS in the September discharges were high and the decrease in October and November was important for these systems to produce a good effluent in terms of TSS.

An evaluation of the effect of the month of discharge coupled with storage time was undertaken to see if the trends noted above apply to both 6 and 12 month storage times. Figures 3.27 and 3.28 are a summary of t-tests performed on 4S-2L lagoon data sorted by month of discharge and storage time. Of interest in these figures are lagoons with the same storage time compared at the different months. The data from the lagoons with 6 and 12 months of storage had the same results as the pervious discussion in that there was a drop in BOD from April to May and from September to October and there was a increase in TSS from April to May and drop in TSS from September to October. The change in effluent quality was statistically significant for the 12 month storage lagoons but not for the 6 month lagoons.

The month of discharge was a significant factor in the quality of lagoon discharges. When storage time was taken into account the trends with the month of discharge were the same but the level of significance was not as high with 6 month storage lagoons.

3.5.1.7 Storage Time

In Figures 3.27 and 3.28 (which were also referenced in evaluation of the month of discharge) comparisons between the same month of discharge and different storage times indicate that in terms of BOD the lagoons with 12 month storage had a lower BOD than lagoons with 6 months of storage but the differences were not very significant. Storage time seemed to be more important in the spring (α = 14%, 12% for Apr. and May) than in the fall (α = 46%, 25%, and 14% for Sep., Oct., and Nov.). In Figure 29 it shows storage time had a significant impact on the BOD levels in the 2S-2L systems in both the spring and fall.

For TSS the analysis was not as clear, spring discharges were not consistent and storage time did not seem to be an important factor. The months of September and November had significantly lower TSS with 12 months verses 6 months of storage but October showed little difference.

In summary, the time of storage factor was sometimes significant for the effluent quality parameters of BOD and TSS with 12 months of storage proving superior to 6 months. Storage time was more important to the BOD levels in the spring than the fall. TSS levels depended more on storage time in the fall than in spring.

3.5.1.8 Lagoon Configuration

It is clear from Figures 3.29 and 3.30 that the configuration of lagoon treatment system was an important factor in effluent quality for both BOD and TSS. The significance of configuration to the BOD level was shown by the order in which they appeared in Figure 3.29 with 4S-2L coming first and 0S-1L appearing last in both the fall and spring seasons. The significance of configuration to TSS was not as well defined but the trend was still the same (see Figure 3.30). The different configuration components did not readily show significance, it was not immediately clear from the analysis if the short or the long detention cells were the important components.

3.5.2 Tools For The Evaluation of Significant Lagoon Factors

The significant factors were determined to be season of discharge, configuration, month of discharge, and sometimes storage. All of these factors except month of discharge (because there was not enough data) were used to group the lagoon sites and calculate means and standard deviations for BOD, TSS, TKN, ammonia, and P. The data groups were compared in three different ways; first by performing t-tests on the means, second by comparing cumulative distributions of the data groups, and third they were used in a quasi-factorial analysis to determine qualitatively and somewhat quantitatively the relative order of importance of the factors.

3.5.2.1 Student T-Tests

Figures 3.29 to 3.33 contain the results of the t-tests comparing the different groups of data to each other for the five different parameters. In performing the t-tests data groups were sorted in ascending order for each of the parameters and then each group was compared with the other groups determining the α value (which is the probability of type one errors, or the probability the differences noticed are due to chance alone) and this value was recorded on a grid corresponding to the two groups being compared. The data was log-normally distributed so that the standard deviation was only applicable with the logarithm of the data, therefore instead of listing the standard deviation the upper and lower 95% confidence limits of the mean were listed.

3.5.2.2 Cumulative Distributions

The graphical representation of the data groups is in Figures 3.34 to 3.38, cumulative distributions of the each configuration type were plotted with each data point showing the season of discharge and storage time. The cumulative distributions of the data give a good indication of how well and how poorly the treatment systems performed and enable a comparison of groups of data at other regions of the distribution other than the mean value.

3.5.2.3 Quasi-Factorial Analysis

The factorial analysis was an attempt to qualify and quantify to a lesser extent the relative importance of the factors to the effluent quality parameters. The four factors used in the analysis and the value of the factors were; short detention cells (present or not), long detention cells (one or two), season of discharge (spring or fall), and storage time (six or 12 months). The weakness in this analysis was that confidence varied for the means of the different factorial sets. Some of the factorial sets had up to 26 sites to estimate the mean value of the parameter in question while the estimates of others sets were based on one site and in one case there was no site to base an estimate. In checking the robustness of the analysis the factorial sets of low confidence were varied to see what impact they had on the results and it was found that significant factors were not reduced to insignificance even when extreme values were used. This indicates that it was more likely to make errors of false negatives than of false positives in identifying factors which were significant. Generally there was some degree of confidence in the factors identified as significant but there may have been significant factors not identified due to the lack of data in some areas.

To determine which factors or interactions were significant the half-normal plot was used (see Figures 3.39-3.43). This method of analysis assumes random errors are normally distributed and that the values of insignificant effects are random errors. There were 15 effects, four main effects or single factor effects, six two factor interactions, four three factor interactions , and one four factor interaction. The absolute value of the effects were ranked from smallest to largest and assigned a percentile based on the ranking and were plotted on half normal probability paper. If all the effects were insignificant they would have been normally distributed and plotted as a straight line, any points that deviated from the straight line were not normally distributed and therefore significant effects.

3.5.3 Evaluation of Significant Lagoon Factors

This section contains a performance evaluation of the different lagoon strategies for the five parameters of interest (BOD, TSS, P, ammonia, and TKN).

3.5.3.1 Biochemical Oxygen Demand (BOD)

Figure 3.29 shows that the 2S-2L or 4S-2L, 12 month storage, and fall discharges had the best BOD effluent concentration with an average BOD concentration of 5.5 to 6.0 mg/L and an upper 95% limit of roughly 8.0 mg/L. This was excellent effluent quality and a tight confidence interval meant that facilities with this treatment configuration had consistent performance. Although these two lagoon configurations had the lowest average BOD the t-test analysis showed that they were not significantly better than most of the lagoons with a fall discharge (the exception being those with no short detention cells). The analysis also showed that all but one of the fall discharge lagoons (the exception being 0S-1L, 6 month storage, and fall discharge) had the upper 95% confidence limits of the mean below the 25 mg/L which is the AEP guideline for mechanical plants serving populations of less than 20,000. The 2S-2L or 4S-2L lagoons with 12 month storage and spring discharge also had an upper limit of less than 25 mg/L.

The cumulative distributions of the various lagoon configurations in Figure 3.34 reconfirmed and graphically illustrated what was found in the t-test analysis which was that systems with short detention cells perform better than those without, fall discharges were superior to spring, and storage time was not always important.

The half-normal plot in Figure 3.39 showed that season of discharge was the most important factor to the BOD quality of the effluent with roughly 15 mg/L difference between fall and spring discharges. Short detention cells were also shown to be important with a 9 mg/L difference between systems with short detention cells and those without. Long detention cells and storage time were not demonstrated to be important factors. Although storage time did not prove to be a significant factor through the factorial analysis, it seemed to be important with some spring discharges. This analysis has identified the major factors of importance but the factors it has not identified can not be ignored as unimportant because of the variability in the data. There were notable exceptions to these findings, for example, storage was not identified as important in this analysis but the t-tests in Figure 3.29 showed that the 2S-2L configuration was significantly sensitive to storage time for both the spring and fall discharges.

3.5.3.2 Total Suspended Solids (TSS)

The t-tests for TSS in Figure 3.30 show the lagoon configurations with short detention cells and two or more long detention cells have performed similarly in the removal of TSS. The best treatment was by lagoons with short detention cells, at least two long detention cells, 12 month storage, and fall discharge where the average TSS concentration was roughly 15 mg/L and the upper 95% limit was around 25 mg/L. The remainder of the lagoon systems had upper 95% limits over the 25 mg/L mark. Further interpretation of results was difficult because there were many inconsistencies in the data. There did seem to be a trend which indicated that the systems without short detention cells did not perform as well as systems with short detention cells.

The cumulative distributions in Figure 3.35 show graphically what was said in the previous paragraph, which was that systems with short detention cells were tightly grouped over the entire range of the curve and they were lower in TSS than the systems without short detention cells.

Even though the t-tests hint that some of the factors were significant in the reduction of TSS in lagoon discharges, the factorial analysis in Figure 3.40 was not able to confirm these inferences. None of the factors were identified as significant by the factorial analysis.

It appears that short detention cells were important to the TSS levels and in certain instances storage was important also but there were many inconsistencies in the data. Month of discharge, which was identified earlier as a significant factor but not included in this analysis, may be the most important factor for determining TSS levels in lagoon effluents.

3.5.3.2 Phosphorus (P)

Figure 3.31 shows that the lagoon systems with fall discharges were generally better than the systems with spring discharges which was confirmed by the factorial analysis in Figure 3.41 that shows that season of discharge was the only significant factor and that the difference between spring and fall discharges was roughly 1.4 mg/L. The cumulative distribution curves in Figure 3.38 show that the 4S-2L configuration was superior throughout the entire curve, while the 0S-1L system was the poorest treatment throughout the entire curve. The data indicates that in systems with the total number cells (both short and long detention) greater than one there was noticeably lower P concentrations.

3.5.3.4 Ammonia

Figure 3.32 shows that fall discharge lagoons usually had lower ammonia concentrations than spring discharge lagoons and the differences were significant. The cumulative distributions in Figure 3.37 show fairly tight groupings which indicates that lagoon configuration was not important although the 4S-2L systems were superior throughout the entire curve. In the results of the factorial analysis in Figure 3.42 season of discharge was the most important factor with a difference between spring and fall discharges of roughly 4.6 mg/L. This figure also showed that storage time was a significant factor to the removal of ammonia in lagoon effluents with a difference between 12 and 6 month storage of roughly 3.0 mg/L.

3.5.3.5 Total Kjeldahl Nitrogen (TKN)

In Figure 3.33 lagoon systems having the lowest values of TKN were those with fall discharge and short detention cells. The cumulative distribution curves in Figure 3.38 showed that the 4S-2L configuration was superior throughout the entire curve, while the 0S-1L system was the poorest treatment throughout the entire curve. Figure 3.38 also showed that the 0S-2L systems were noticeably lower in TKN than the 0S-1L systems. The data indicated that systems with the total number cells (both short and long detention) greater than one had lower TKN concentrations than single cell systems. The factorial analysis in Figure 3.43 show that season of discharge was the only factor that was significant with a difference of about 4 mg/L between spring and fall discharges.

3.5.4 Summary

The analysis of lagoon treatment has demonstrated that season of discharge, lagoon configuration, storage time, and month of discharge were all significant factors in determining effluent quality. The season of discharge was the most significant factor and the factorial analysis estimated the effect of fall versus spring discharge to be 15 mg/L reduction for BOD, 1.4 mg/L reduction for P, 4.6 mg/L reduction for ammonia, and 4.0 mg/L reduction for TKN. While season of discharge did not prove significant for TSS levels, there appeared to be improvements in TSS quality in the fall. The lagoon configuration was important and the presence of short detention cells proved significant for BOD in the factorial analysis with an effect of 9.0 mg/L. The presence of long detention cells did not have a significant impact on effluent quality. Storage time was important to effluent quality parameters and particularly to levels of ammonia with an estimated effect of 4.6 mg/L reduction between 12 and 6 months of storage. BOD levels in the spring were also affected by storage time. The month of discharge proved to be an important factor for BOD and TSS but due to insufficient data further analysis was not practical.

3.6 Bacteriological Effluent Quality

Table 3.5 is a summary of total and fecal coliform data collected by Alberta Environmental Protection from randomly selected lagoon discharges in, 1985. The data is divided into groups depending on the lagoon design and the time of discharge. The table also shows the storage time in months of each facility but the data is not grouped by these different times. The data has a log-normal distribution and for this reason the natural logarithm of the data has been used to calculate the mean and standard deviation. For the many data points that are not within the experimental range a plus (+) or minus (-) sign appears, in these cases the data used for calculations is the data shown.

Table 3.6 is an account of comparisons done between the means using the students t-test. The percentages represent the α value in a statistical significance test i.e. the probability the difference between the means is due to chance. Although there may appear to be large differences between some of the means, significance is deceiving because the data is log-normally distributed so reference must be made to Table 3.6 where t-tests were performed on the natural logarithms of the means.

The data confirms that fall discharges are of better bacteriological quality than spring discharges. This is evident by the comparison of overall fall to overall spring coliform counts where total and fecal coliform concentrations were 10^2 and 10^1 per 100 mL respectively in the fall and 10^3 and 10^2 respectively in the spring. The data demonstrates that the "4S-2L Fall" discharges are significantly better than all others, to 95% significance, except "2S-2L Fall" were it is not as significant. It is also interesting that none of the other means are different from each other to the 95% significance level, which may be due to the fact that many of the data points exceeded the experimental range of the lab analysis. The means for the spring discharges are probably much higher than calculated and if the true means were known one would expect that the "2S-2L Fall" would be significantly better than the spring discharges. Any differences between the lagoon designs for the spring discharges are obscured for the reason stated above.

3.7 Conclusions

Treatment facilities meeting AEP's standards and guidelines for lagoon design produce an excellent effluent that, for smaller communities, was comparable to mechanical plant effluent and for larger lagoon systems was superior to mechanical plants for all but one parameter investigated. The lagoon design was comparable to mechanical plants for

TSS but not superior. The difference in composition between lagoon TSS and mechanical plant TSS must be recognized.

Season of discharge was demonstrated as the most important factor affecting lagoon treatment in Alberta. Other factors that also proved significant were lagoon configuration, storage time and month of discharge.

This analysis confirms that lagoon discharges in the fall are of superior bacteriological quality than spring discharges. The analysis also shows that the 4S-2L design and a fall discharge produces a significantly superior bacteriological effluent compared to 0S designs and any spring discharges. The 4S-2L design is only marginally better than the 2S-2L design.

SAMPLE #	DATE	TIME	LAGOON ELEVATION m	VOLUME DISCHARGE m^3	TEMP. DEG. C	TSS mg/L	VSS mg/L	BOD mg/L	TC COL./100mL	FC COL./100mL
START	4-Nov	11:10 AM			-					
1	4-Nov	5.10 PM	19.089		?	6.1	1.1	1.5	283.3	6.3
2	5-Nov	10:10 AM	19.040	2446	0.5	5.8	1.2	1.0	56.7	2.7
3	6-Nov	7:20 AM	18.961	6376	0.3	5.1	1.2	1.3	103.3	1.7
4	7-Nov	6:45 AM	18.860	11375	0.8	4.6	1.2	1.3	103.3	1.7
5	8-Nov	3:45 PM	18.748	16885	1.3	4.6	1.2	1.3	43.3	0.0
6	9-Nov	7:15 AM	18.721	18208	1.0	4.4	1.1	1.3	16.7	0.3
7	10-Nov	7:55 AM	18.596	24306	1.0	4.5	1.4	2.2	9.3	0.3
8	11-Nov	8:15 AM	18.493	29299	1.0	4.6	1.6	1.6	21.3	1.3
9	12-Nov	8:25 AM	18.432	32242	0.5	8.0	2.2	2.6	8.0	3.7
10	13-Nov	8:15 AM	18.371	35175	0.5	4.2	1.6	2.2	6.0	1.0
11	14-Nov	7:15 AM	18.294	38863	1.0	4.1	1.4	2.7	4.7	-
12	15-Nov	4:45 PM	18.225	42153	2.0	4.7	2.0	2.9	9.3	-
13	16-Nov	8:35 AM	18.183	44149	1.8	5.4	2.4	3.0	24.7	-
14	17-Nov	8:30 AM	18.146	45904	2.0	10.4	3.0	3.5	15.3	0.0
15	18-Nov	9:10 AM			2.0	8.0	3.2	3.1	16.7	0.0
16	19-Nov	9:40 AM	18.095	48317	2.0	8.7	4.2	4.1	21.3	0.3
17	20-Nov	9:00 AM	18.096	49025	2.0	9.8	4.8	4.6	22.0	1.7

Table 3.1 : Legal Lagoon Discharge

CONFIGURATION	mean mg/L	lower 95% mg/L	upper 95% mg/L	n	# SAMPLES
	BOD				
Lagoon - 4S, 2L	9.09	7.25	11.39	29	55
Lagoon - 2S, 2L	9.67	7.52	12.44	16	26
Lagoon - 0S, 2L	25.45	17.52	36.97	13	24
Lagoon - 0S, 1L	23.39	15.24	35.92	8	14
	TSS				
Lagoon - 4S, 2L	20.39	16.25	25.58	30	57
Lagoon - 2S, 2L	21.90	14.28	33.58	15	25
Lagoon - 0S, 2L	33.41	20.82	53.64	13	24
Lagoon - 0S, 1L	46.92	33.72	65.28	8	14
	TKN				
Lagoon - 4S, 2L	5.25	4.22	6.55	30	57
Lagoon - 2S, 2L	6.82	4.69	9.92	15	25
Lagoon - 0S, 2L	11.53	7.54	17.63	13	23
Lagoon - 0S, 1L	12.15	6.76	21.85	8	14
	NH3				
Lagoon - 4S, 2L	1.25	0.72	2.16	30	56
Lagoon - 2S, 2L	1.39	0.46	4.22	15	25
Lagoon - 0S, 2L	3.73	1.47	9.45	13	23
Lagoon - 0S, 1L	3.66	0.74	17.96	8	14
	P				
Lagoon - 4S, 2L	2.18	1.69	2.83	30	57
Lagoon - 2S, 2L	1.98	1.35	2.92	14	24
Lagoon - 0S, 2L	3.56	2.34	5.44	13	23
Lagoon - 0S, 1L	3.27	1.68	6.36	8	14

Table 3.2 : Lagoon Effluent Quality

CONFIGURATION	mean mg/L	lower 95% mg/L	upper 95% mg/L	n	# SAMPLES
	BOD				
A. Sludge	18.47	15.08	22.63	9	696
Aerated	16.16	13.91	18.77	25	401
Ext. Aeration	14.69	10.11	21.35	10	181
RBC	17.46	14.35	21.25	10	252
	TSS				
A. Sludge	11.65	7.76	17.50	9	696
Aerated	18.84	15.95	22.25	25	407
Ext. Aeration	15.28	9.03	25.85	10	178
RBC	11.44	9.70	13.49	10	254
	TKN				
A. Sludge	8.36	5.49	12.74	[illegible]	699
Aerated	14.49	11.50	18.25	5	407
Ext. Aeration	5.37	3.10	9.29	10	179
RBC	6.57	4.75	9.08	10	261
	NH3				
A. Sludge	3.33	1.45	7.61	9	696
Aerated	9.06	6.28	13.06	25	397
Ext. Aeration	1.31	0.44	3.93	10	173
RBC	3.44	1.99	5.95	10	257
	P				
A. Sludge	2.79	1.66	4.69	9	397
Aerated	3.72	2.93	4.72	25	396
Ext. Aeration	3.58	2.88	4.45	10	173
RBC	3.75	3.06	4.60	10	257

Table 3.3 : Mechanical Plant Effluent Quality

	AVE.BOD mg/L	AVE.TSS mg/L	VE.TK mg/L	AVE.NH3 mg/L	AVE.P mg/L
POP. UNDER 1000	14.56	2[illegible].90	8.89	4.39	2.84
POP. OVER 1000	15.41	23.27	9.81	4.45	3.02

Table 3.4 : Effluent Quality for Populations Over and Under 1000

LAGOONS 4S, 2L(or more)										
			FALL DISCHARGE				SPRING DISCHARGE			
Municipality	/ lagoon config	/ storage months	TC count/100mL	Ln(TC)	FC count/100mL	Ln(FC)	TC count/100mL	Ln(TC)	FC count/100mL	Ln(FC)
Barrhead	3S, 2L	7	10	2.30	10 -	2.30	8000 +	8.99	3600	8.19
Beaumont	3S, 2L	12					8000 +	8.99	8000 +	8.99
Boyle	4S, 2L	12	10 -	[illegible]	10 -	2.30				
Camrose	4S, 2L	7			20	3.00				
Clyde	4S, 2L	12					10 -	2.30	10 -	2.30
Fox Creek	4S,4L	7			30	3.40	8000 +	8.99	6900	8.84
Kitscoty	4S,4L	12					120	4.79	10 -	[illegible]
Lamont	4S,2L	7	740	6.61	100	4.61	8000 +	8.99	420	[illegible]
Mundare	4S, 3L	7					10 -	2.30	10 -	2.30
Ponoka	4S, 4L	12					8000 +	8.99	8000 +	8.99
Redwater	4S, 3L	7			8000 +	8.99	8000 +	8.99	8000 +	8.99
Rimbey	4S, 3L	7	80	4.38	10 -	2.30	8000 +	8.99	8000 +	8.99
Spruce Grove	4S, 5L	6					2400 +	7.78	2400 +	7.78
Viking	4S, 2L	6			10 -	2.30	9400	9.15	300	5.70
Wabamun	4S, 3L	7			10 -	2.30	136	4.91	4 -	1.39
Warburg	4S, 3L	12					2400 +	7.78	2400 +	7.78
Westlock	4S, 2L	7					8000 +	8.99	7600	8.94
Breton	4S, 2L	12	20	3.00	10 -	2.30				
Evansburg	4S, 2L	7	170	5.14	4.5	1.50				
Gibbons	4S, 3L	6			10 -	2.30				
Glendon	4S, 2L	12	100	4.61	10 -	2.30				
Hay Lakes	4S, 2L	12			10 -	2.30				
Legal	4S,2L	7			10 -	2.30				
Marwayne	4S, 2L	12			2	0.69				
		MEAN	57	4.05	17	2.83	1627	7.39	666	6.50
		ST. DEV.		1.60		1.84		2.51		2.95
		# samples	7	7	16	16	15	15	15	15

LAGOONS 2S, 2L(or more)										
			FALL DISCHARGE				SPRING DISCHARGE			
Municipality	/ lagoon config	/ storage months	TC count/100mL	Ln(TC)	FC count/100mL	Ln(FC)	TC count/100mL	Ln(TC)	FC count/100mL	Ln(FC)
Ardmore	2S, 2L	12					8000	8.99	10	2.30
Ardrossan	2S, 2L	6	8000 +	8.99	244	5.50	8000 +	8.99	8000 +	8.99
Bawlf	2S, 2L	12					8000 +	8.99	8000 +	8.99
Calmar	2S, 2L	7			700	6.55	2400 +	7.78	2400 +	7.78
Chauvin	2S, 2L	12					2400	7.78	1600	7.38
Lougheed	2S, 2L	12	4.5	1.50	2	0.69				
Josephburg	2S,1L	7	8000 +	8.99	4900	8.50	8000 +	8.99	8000 +	8.99
Waskatenau	2S, 2L	12	10	2.30	10 -	2.30				
Willingdon	2S, 2L	12			10	2.30				
		MEAN	232	5.45	74	4.31	5355	8.59	1643	7.40
		ST. DEV.		4.10		3.00		0.62		2.60
		# samples	4	4	6	6	6	6	6	6

LAGOONS 0S, 1L(or more)										
			FALL DISCHARGE				SPRING DISCHARGE			
Municipality	/ lagoon config	/ storage months	TC count/100mL	Ln(TC)	FC count/100mL	Ln(FC)	TC count/100mL	Ln(TC)	FC count/100mL	Ln(FC)
Alliance	0S, 1L	7			80	4.38	8000 +	8.99	2700	7.90
Bruce	0S, 2L	12					350	5.86	70	4.25
Entwistle	0S, 2L	6			60	4.09				
Fort Kent	0S, 2L	12					8000 +	8.99	680	6.52
Pickardville	0S, 1L	8					8000 +	8.99	8000	8.99
Radway	0S, 1L	6			8000 +	8.99				
Uncas School	0S, 2L	6					14	2.64	1 -	0.00
Alder flats	0S, 2L	12			10 -	2.30				
Clandonald	0S, 1L				5000	8.52				
Cynthia	0S, 1L	7	2400 +	7.78	2400 +	7.78				
Edberg	0S, 1L	12			2700	7.90				
Forestburg	0S, 3L	12			10 -	2.30				
Fultonvale	0S, 2L		8	2.08	4 -	1.39				
Galahad	0S, 2L	12			10 -	2.30				
Islay	0S, 2L	12			2000	7.60				
Neerlandia	0S, 1L	12	120000	11.70	800	6.68				
Winfield	0S, 2L	12	50000	10.82	250	5.52				
		MEAN	3276	8.09	214	5.37	1202	7.09	253	5.53
		ST DEV.		4.35		2.72	17	2.83		[illegible]
		# samples	4	4	13	13	5	5	5	[illegible]
OVERALL		MEAN	245	5.50	56	4.02	2021	7.61	681	6.52
		ST DEV		3.43		2.61		2.28		2.94
		# samples	15	15	35	35	26	26	26	26

Table 3.5 : Summary of Total and Fecal Coliform Data

Comparison of Total Coliform Means (using t-test)										
		TYPE	4S, 2L F	2S, 2L F	0S, 1L F	4S, 2L S	2S, 2L S	0S, 1L S	Overall Fal	Overall Spr
		MEAN	57	232	3276	1627	5355	1202	245	2021
		ST. DEV.	5	61	77	12	2	17	31	10
Type / Discharge	MEAN	# samples	7	4	4	15	6	5	15	26
4S, 2L Fall	57	7	100%	43%	5%	0%	0%	4%	30%	0%
2S, 2L Fall	232	4	43%	100%	41%	24%	9%	50%	98%	12%
0S, 1L Fall	3276	4	5%	41%	100%	68%	79%	69%	22%	73%
0S, 1L Spring	1202	5	4%	50%	69%	82%	24%	100%	36%	66%
Overall Fall	245	15	30%	98%	22%	10%	4%	36%	100%	2%
Overall Spring	2021	26	0%	12%	73%	78%	31%	66%	2%	100%

Comparison of Fecal Coliform Means (using t-test)										
		TYPE	4S, 2L F	2S, 2L F	0S, 1L F	4S, 2L S	2S, 2L S	0S, 1L S	Overall Fal	Overall Spr
		MEAN	17	74	214	666	1643	253	56	681
		ST. DEV.	6	20	15	19	13	35	14	19
Type / Discharge	MEAN	# samples	16	6	13	15	6	5	35	26
4S, 2L Fall	17	16	100%	17%	1%	0%	0%	3%	10%	0%
2S, 2L Fall	74	6	17%	100%	45%	14%	9%	55%	81%	11%
0S, 1L Fall	214	13	1%	45%	100%	30%	14%	92%	12%	24%
4S, 2L Spring	666	15	0%	14%	30%	100%	52%	55%	0%	98%
2S, 2L Spring	1643	6	0%	9%	14%	52%	100%	34%	1%	51%
0S, 1L Spring	253	5	3%	55%	92%	55%	34%	100%	25%	51%
Overall Fall	56	35	10%	81%	12%	0%	1%	25%	100%	0%
Overall Spring	681	26	0%	11%	24%	98%	51%	51%	0%	100%

note: means are in bacterial counts per 100mL

Table 3.6 : Comparison of Coliform Data

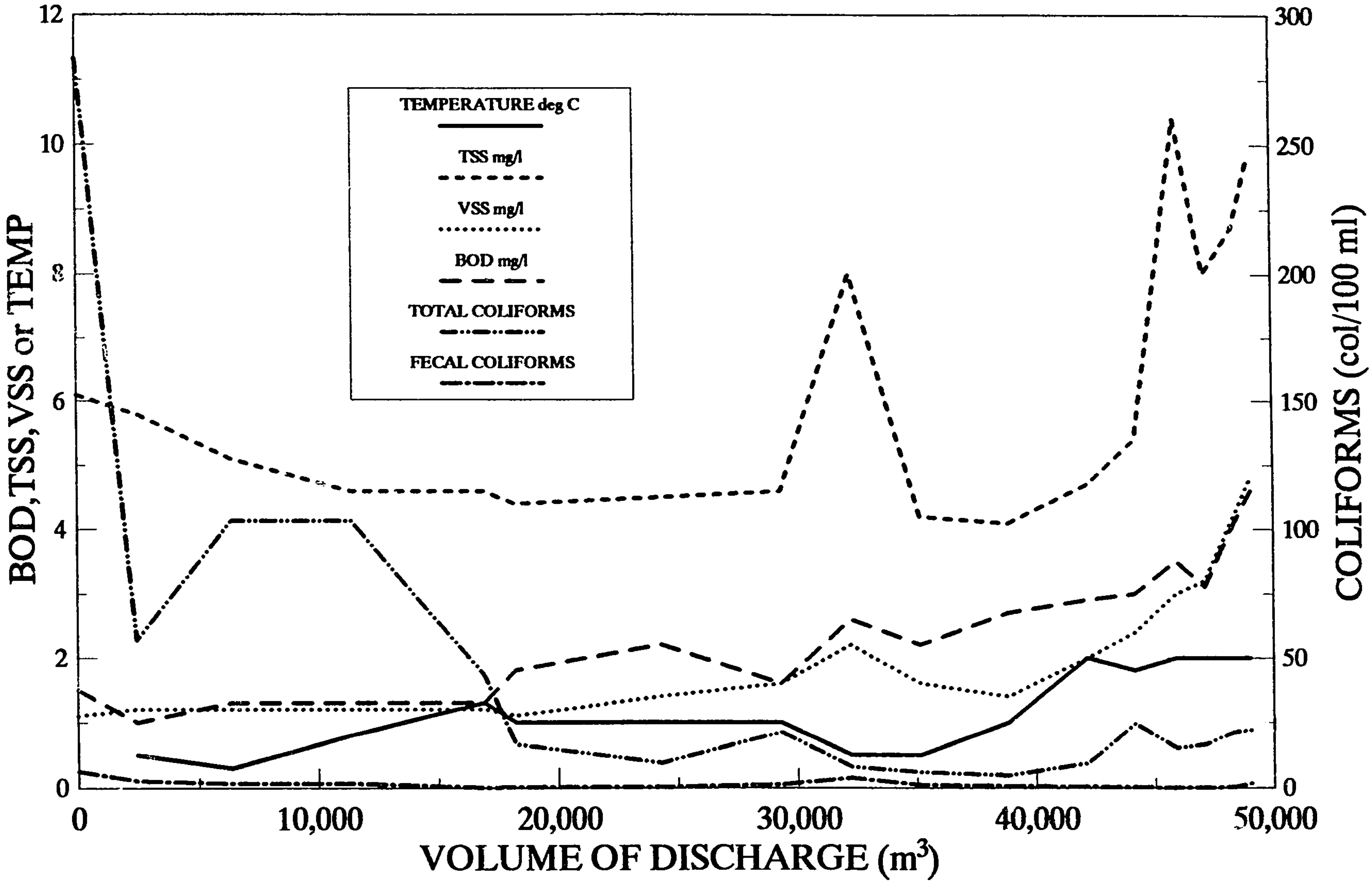


Figure 3.1 : Legal Lagoon Discharge

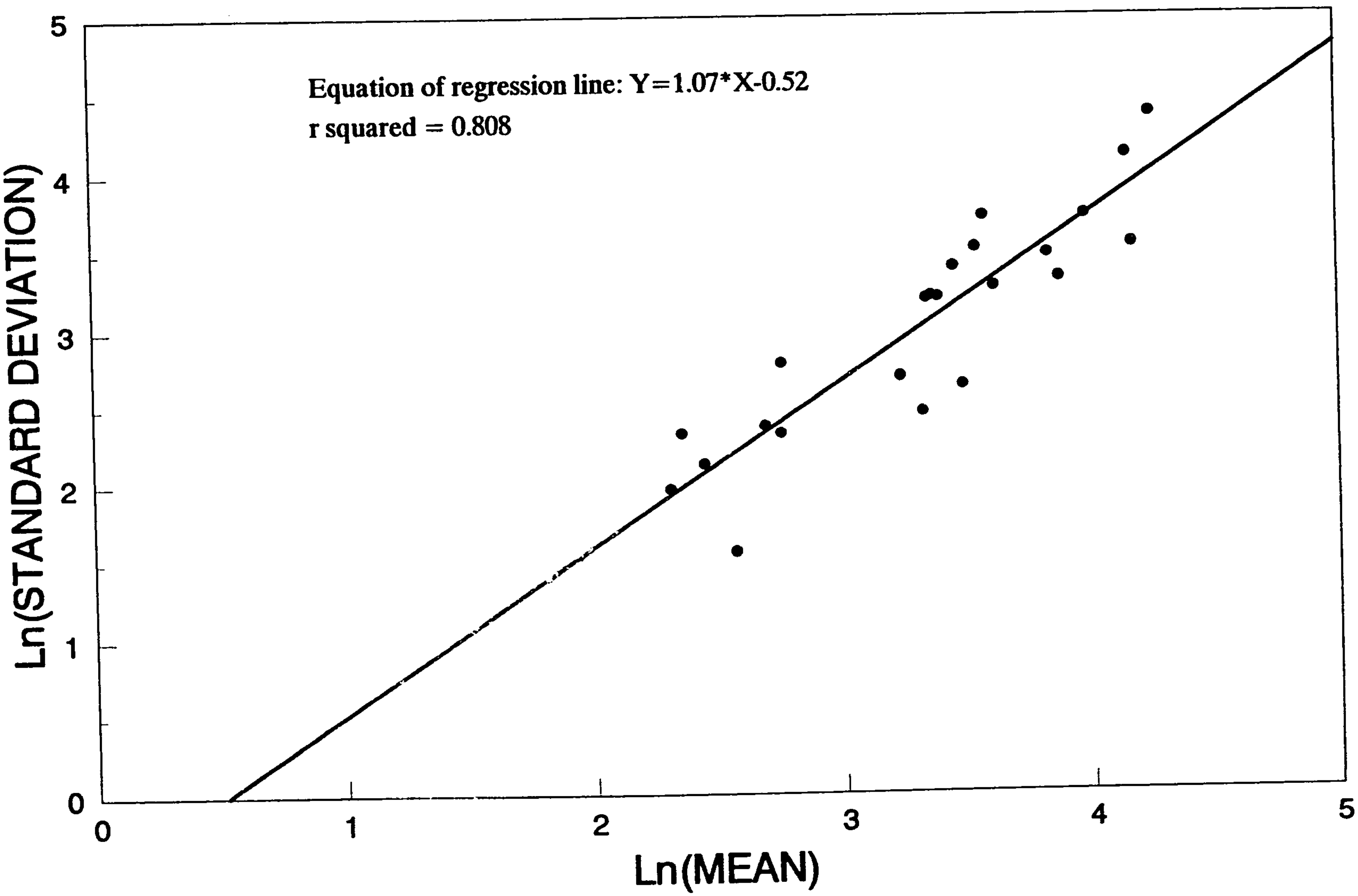


Figure 3.2 : Plot of Ln(Mean) vs Ln(Stdev.) to Investigate Tranformation

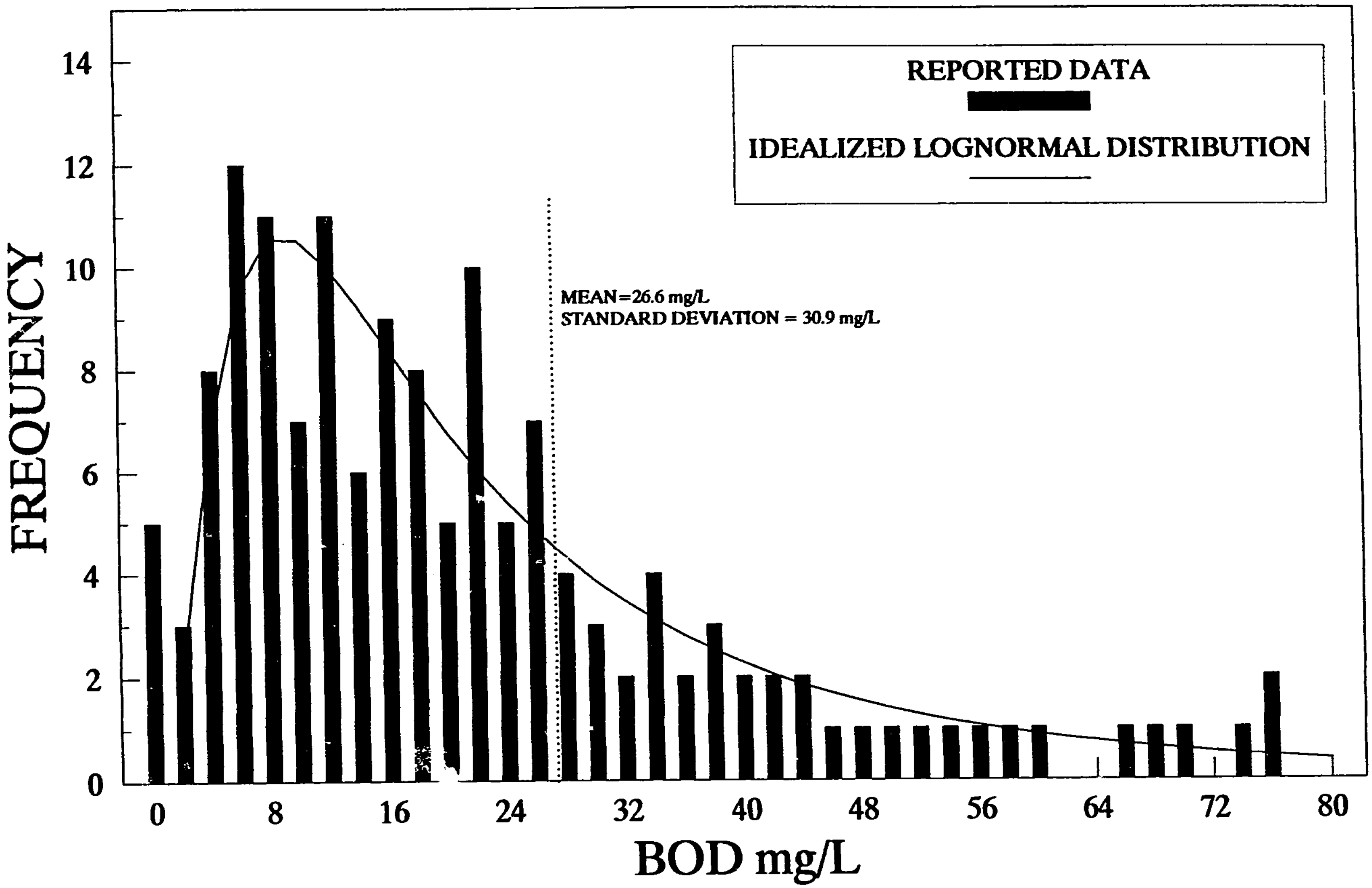
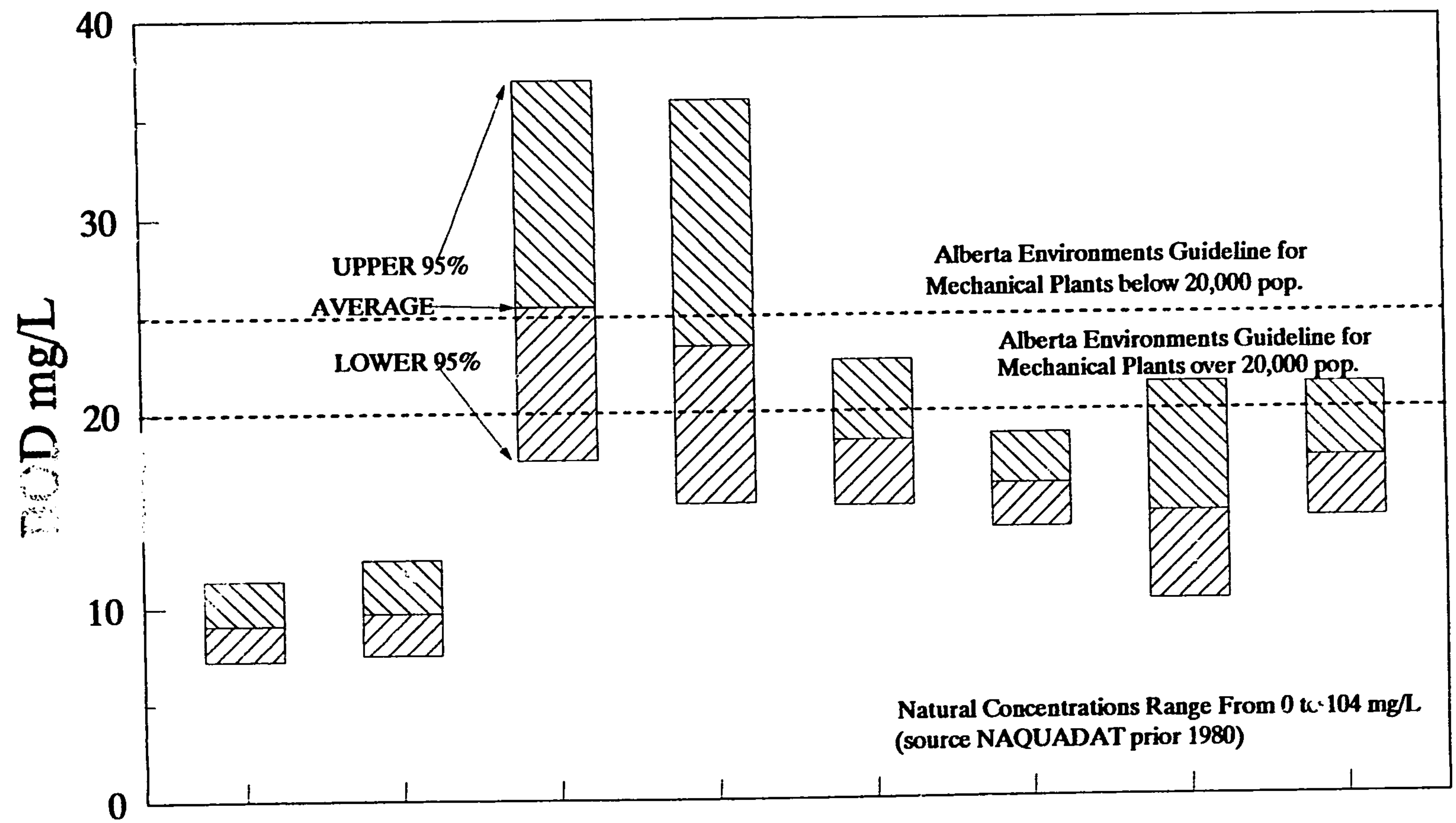
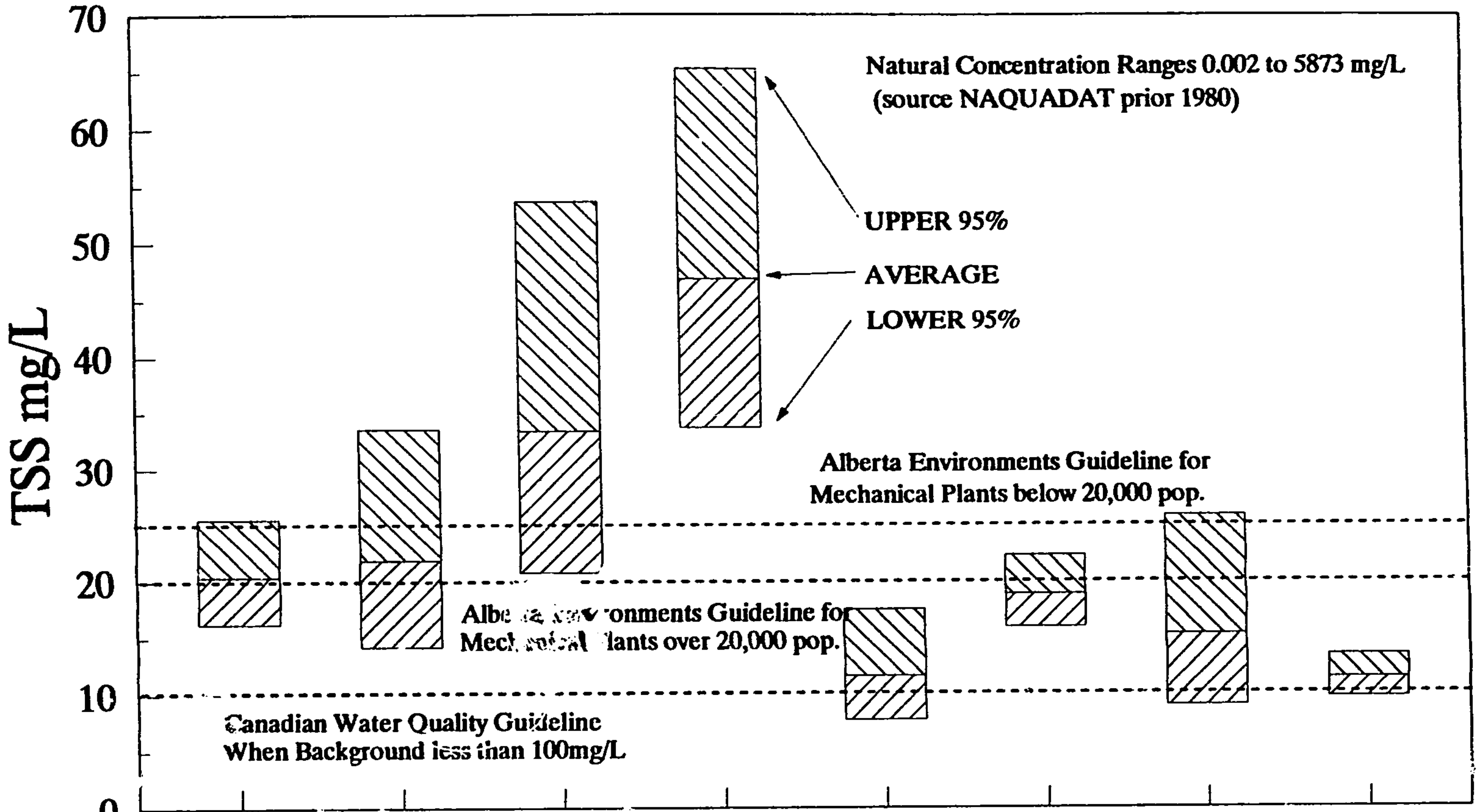


Figure 3.3 : Log-Normal Distribution of Lagoon Data



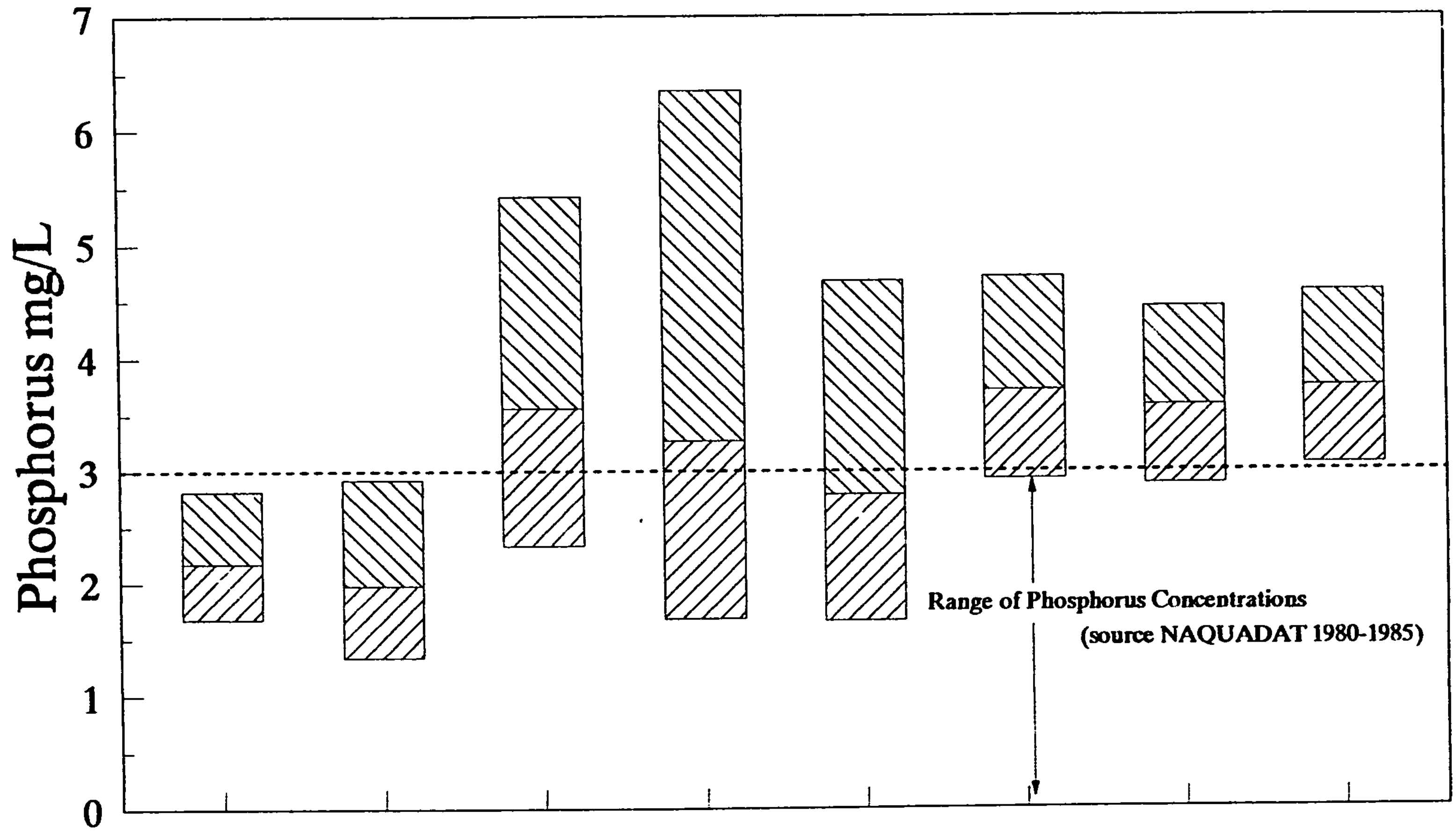
	Lago[illegible] 4S, 2L	Lagoon - 2S, 2L	Lagoon - 0S, 2L	Lagoon - 0S, 1L	A. Sludge	Aerated	Ext. Aeration	RBC
Average	[illegible]	9.7	25.5	23.4	18.5	16.2	14.7	17.5
Upper 95%	[illegible]	12.5	37.0	36.0	22.6	18.8	21.4	21.3
Lower 95%	7.3	7.5	17.5	15.2	15.1	13.9	10.1	14.4
# sites	29	16	13	8	9	25	10	10
# samples	55	26	24	14	696	401	181	252

Figure 3.4 Comparison of BOD Concentrations



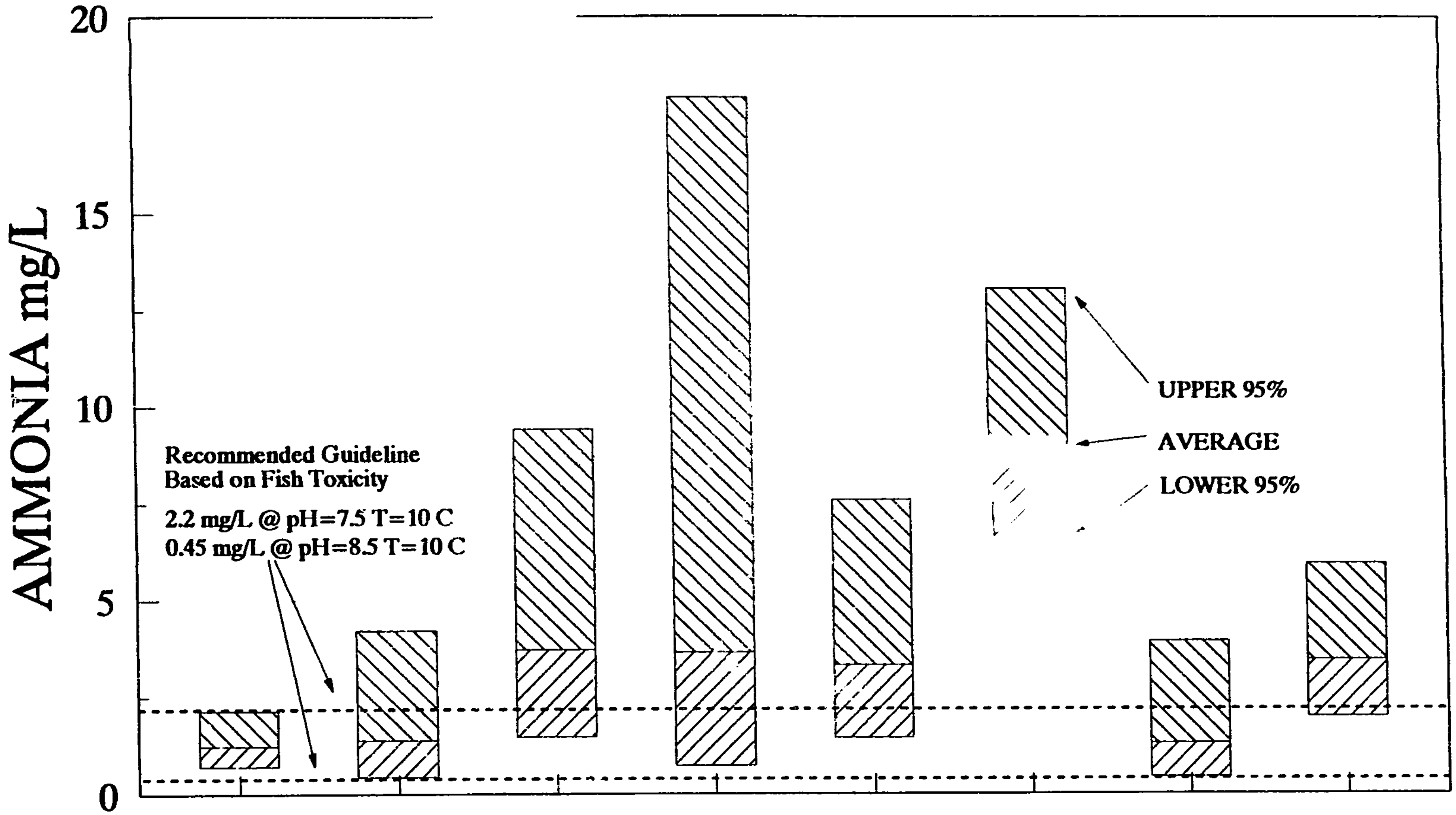
	Lagoon - 4S, 2L	Lagoon - 2S, 2L	Lagoon - 0S, 2L	Lagoon - 0S, 1L	A. Sludge	Aerated	Ext. Aeration	RBC
Average	20.4	21.9	33.4	46.9	11.7	18.8	15.3	11.4
Upper 95%	25.6	33.6	53.6	65.3	17.5	22.3	25.9	13.5
Lower 95%	16.2	14.3	20.8	33.7	7.8	16.0	9.0	9.7
# sites	30	15	13	8	9	25	10	10
# samples	57	25	24	14	696	407	178	254

Figure 3.5 Comparison of TSS Concentrations



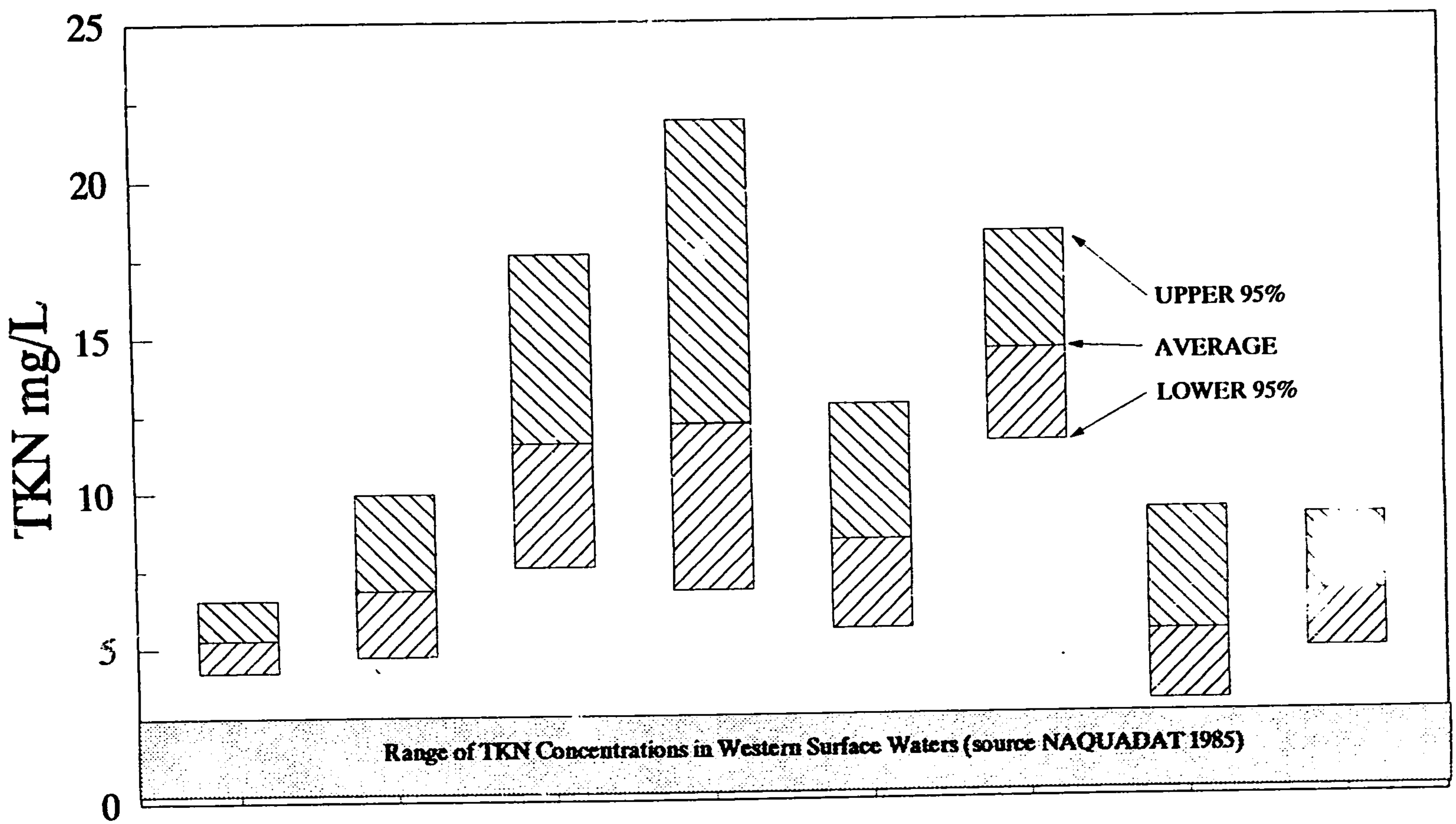
	Lagoon - 4S, 2L	Lagoon - 2S, 2L	Lagoon - 0S, 2L	Lagoon - 0S, 1L	A. Sludge	Aerated	Ext. Aeration	RBC
Average	2.2	2.0	3.6	3.3	2.8	3.7	3.6	3.8
Upper 95%	2.8	2.9	5.4	6.4	4.7	4.7	4.5	4.6
Lower 95%	1.7	1.3	2.3	1.7	1.7	2.9	2.9	3.1
# sites	30	14	13	8	9	25	10	10
# samples	57	24	23	14	697	396	173	257

Figure 3.6 Comparison of Phosphorus Concentrations



	Lagoon - 4S, 2L	Lagoon - 2S, 2L	Lagoon - 0S, 2L	Lagoon - 0S, 1L	A. Sludge	Aerated	Ext. Aeration	RBC
Average	1.3	1.4	3.7	3.7	3.3	9.1	1.3	3.4
Upper 95%	2.2	4.2	9.5	18.0	7.6	13.1	3.9	6.0
Lower 95%	0.7	0.5	1.5	0.7	1.5	6.3	0.4	2.0
# sites	30	15	13	8	9	25	10	10
# samples	56	25	23	14	696	397	173	257

Figure 3.7 Comparison of NH_3 Concentrations



	Lagoon - 4S, 2L	Lagoon - 2S, 2L	Lagoon - 0S, 2L	Lagoon - 0S, 1L	A. Sludge	Aerated	Ext. Aeration	RBC
Average	5.3	6.8	11.5	12.2	8.4	14.5	5.4	6.6
Upper 95%	6.6	9.9	17.6	21.9	12.7	18.3	9.3	9.1
Lower 95%	4.2	4.7	7.5	6.8	5.5	11.5	3.1	4.8
# sites	30	15	13	8	9	25	10	10
# samples	57	25	23	14	699	407	179	261

Figure 3.8 Comparison of TKN Concentrations

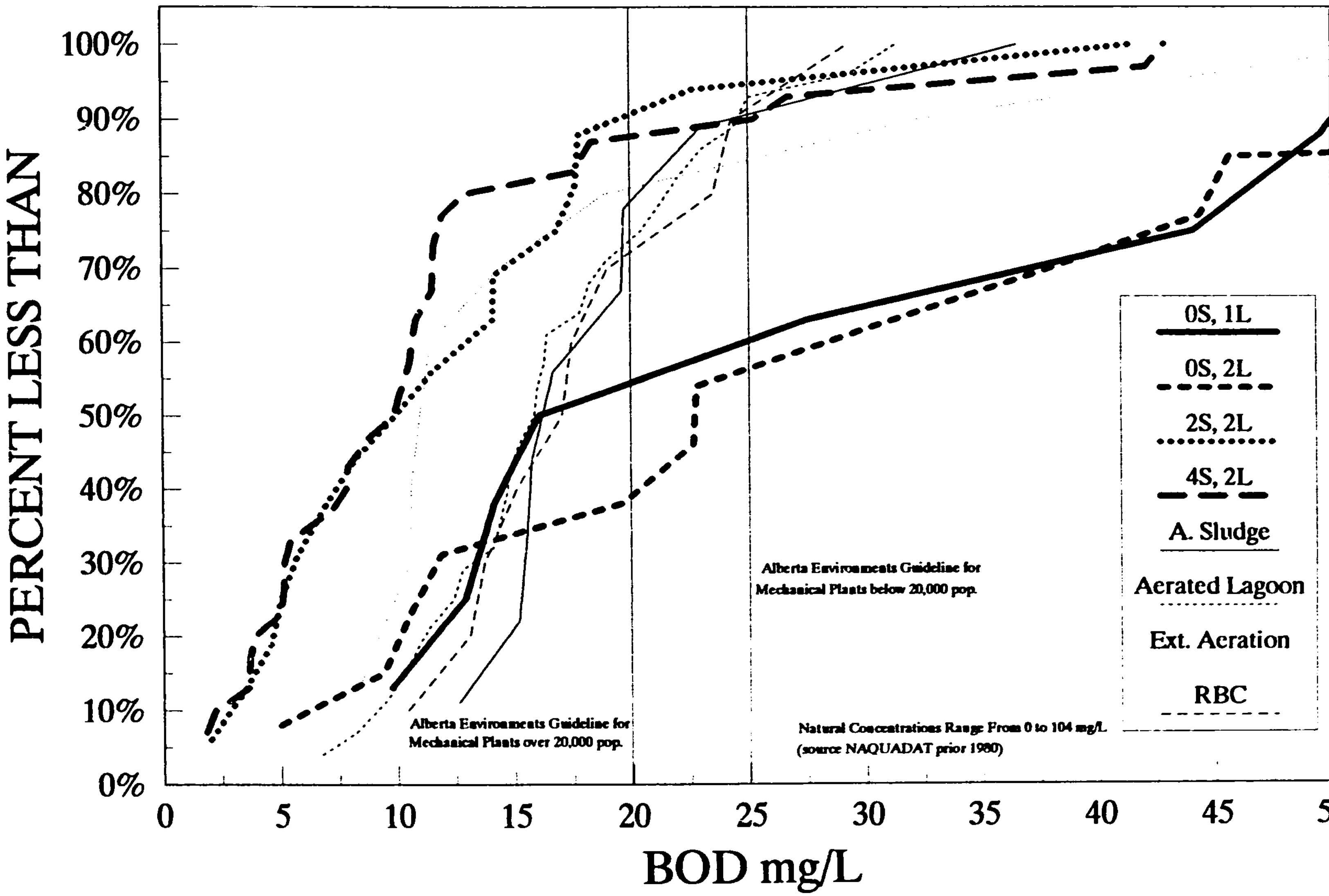


Figure 3.9 : Cumulative Distributions of Lagoons and Plants, BOD

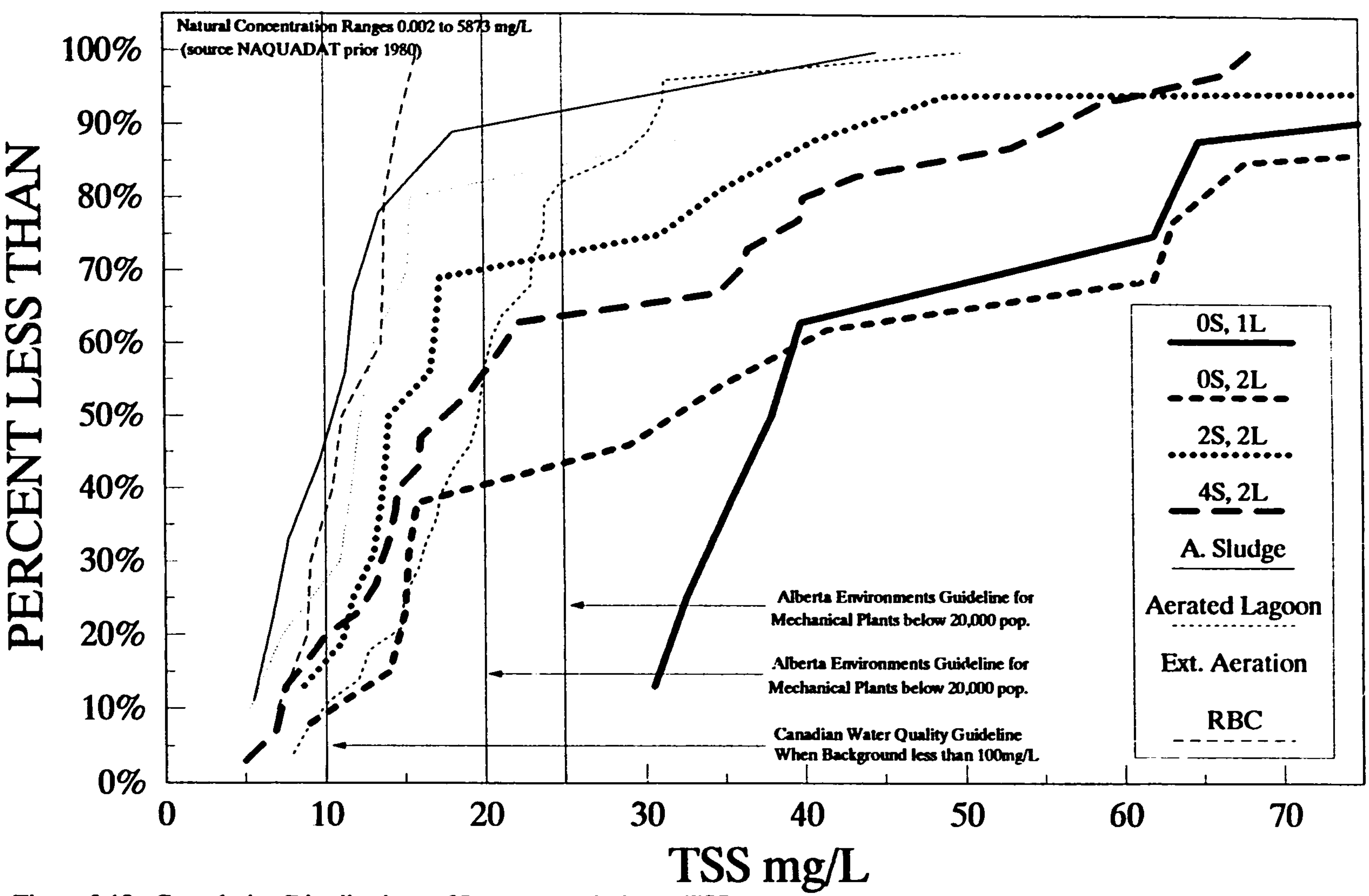


Figure 3.10 : Cumulative Distributions of Lagoons and Plants, TSS

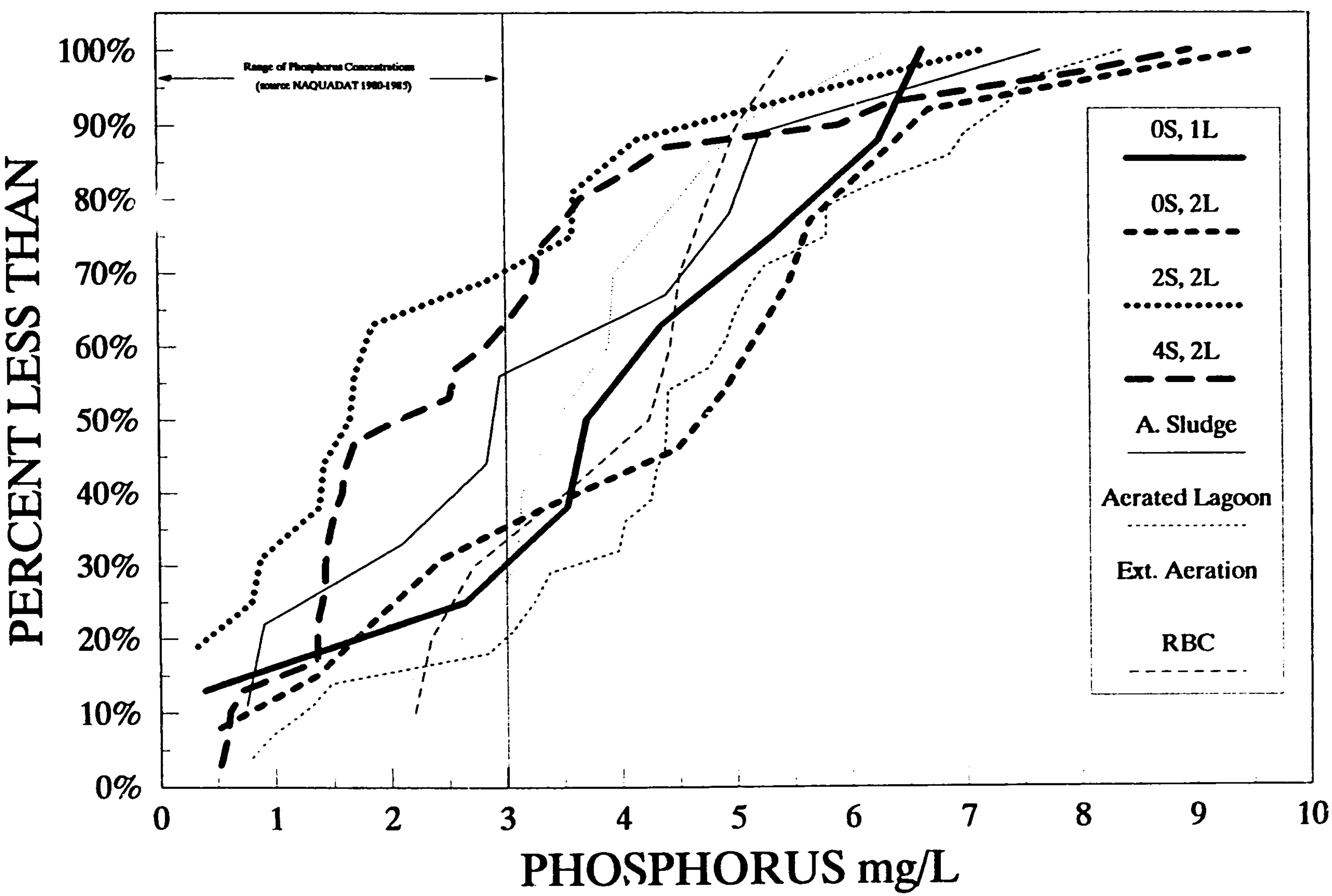


Figure 3.11 : Cumulative Distributions of Lagoons and Plants, P

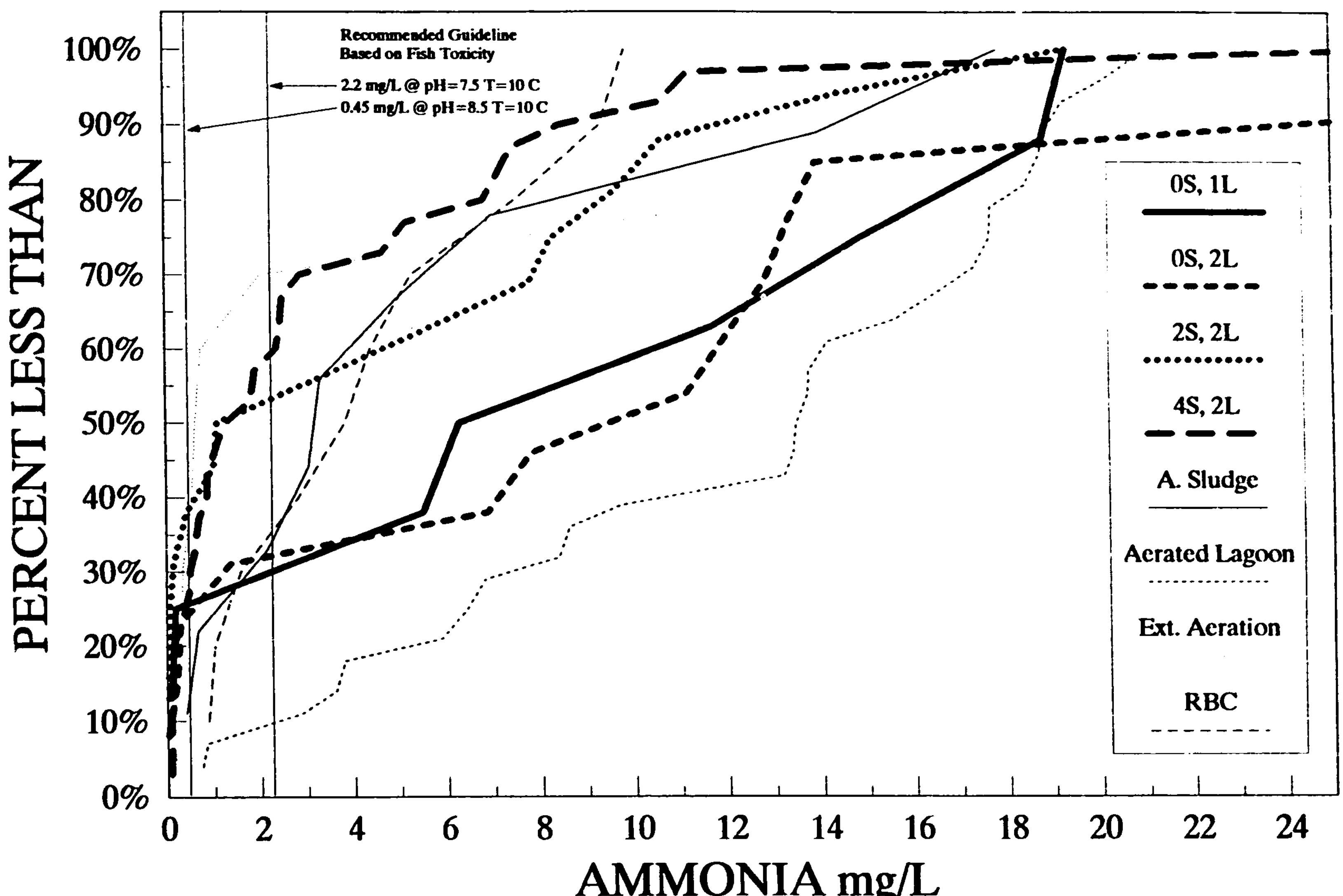


Figure 3.12 : Cumulative Distributions of Lagoons and Plants, Ammonia

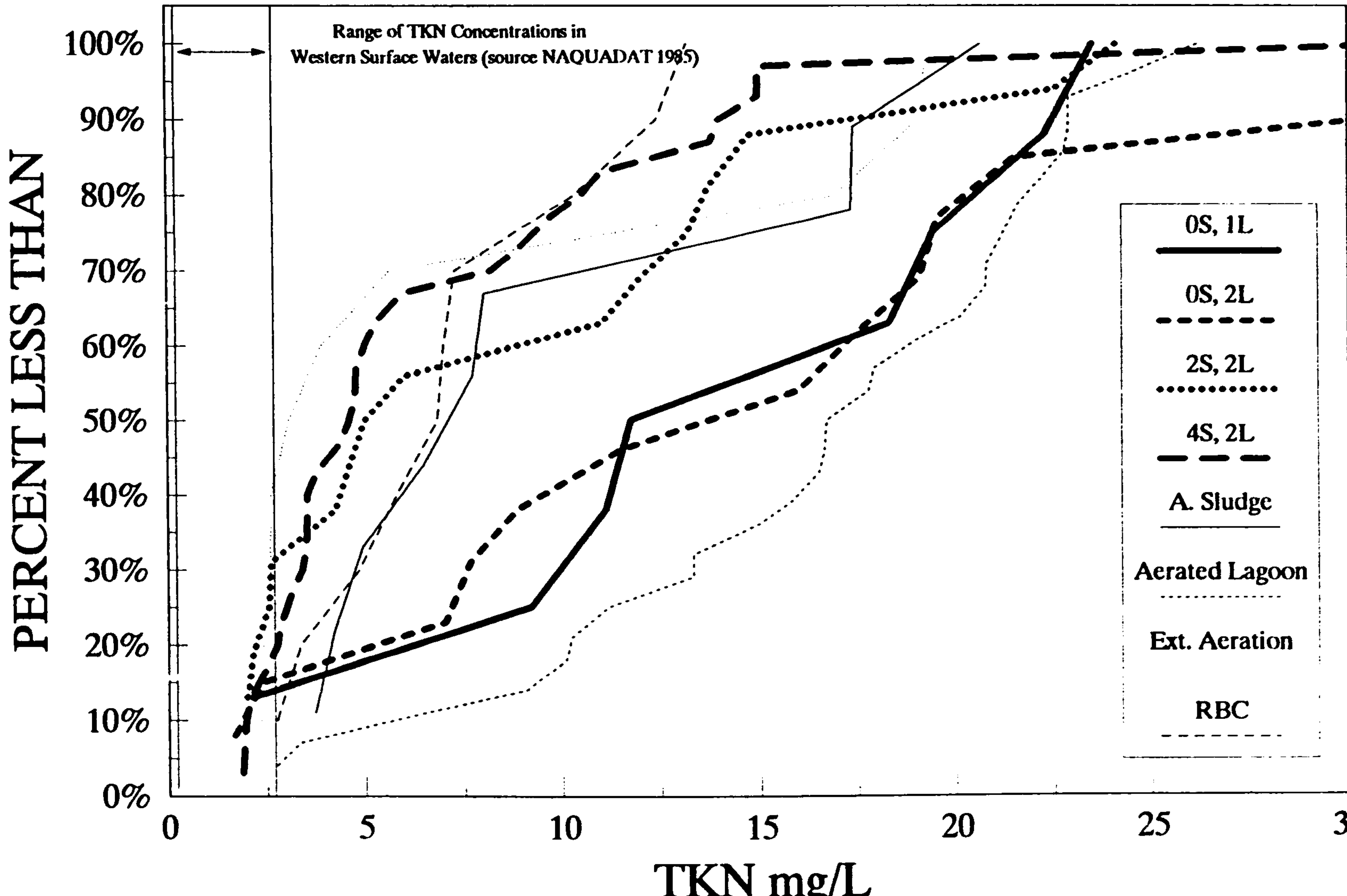


Figure 3.13 : Cumulative Distributions of Lagoons and Plants, TKN

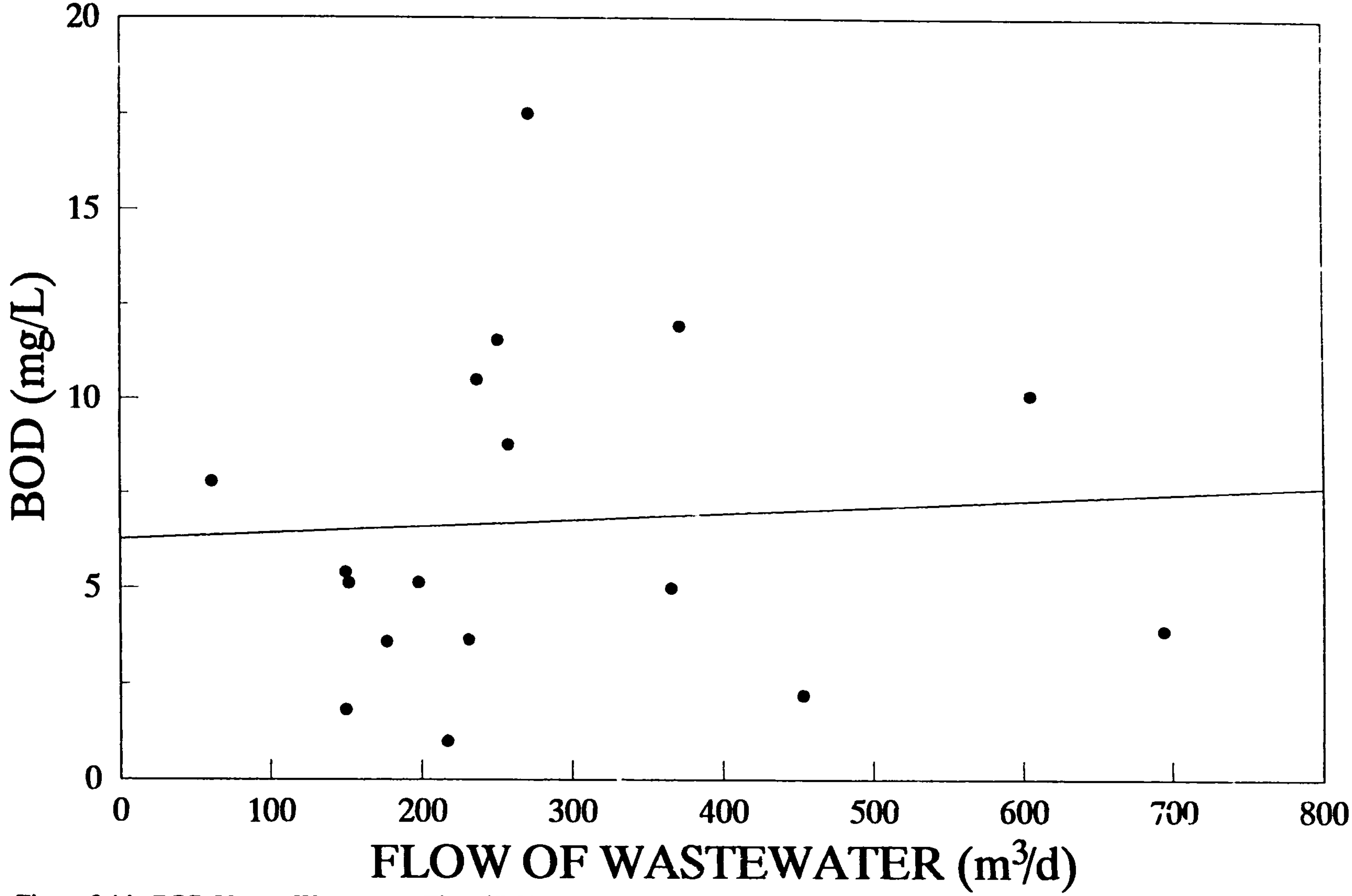


Figure 3.14 : BOD Versus Wastewater Flow 4S-2L

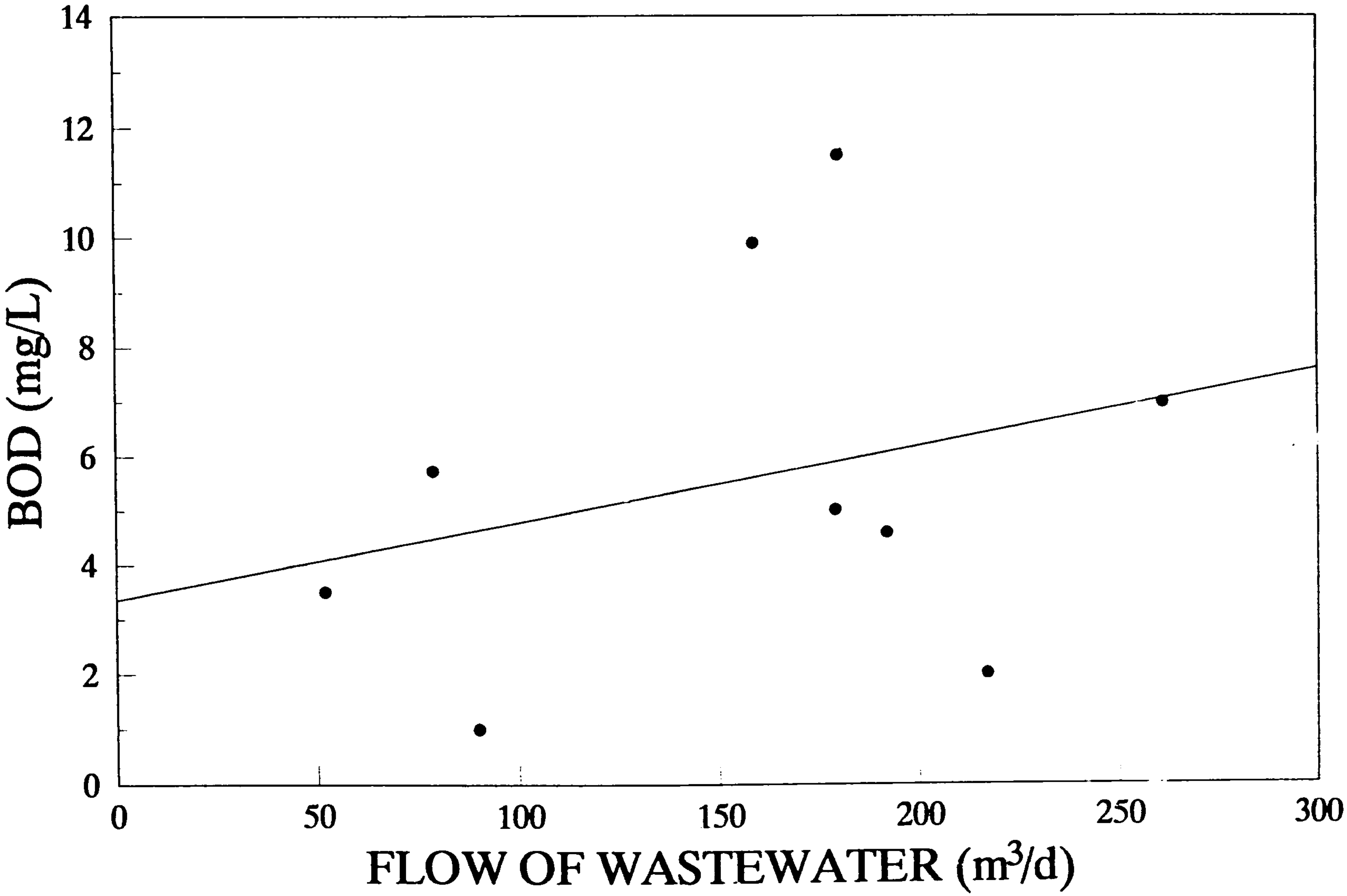


Figure 3.15 : BOD Versus Wastewater Flow 2S-2L

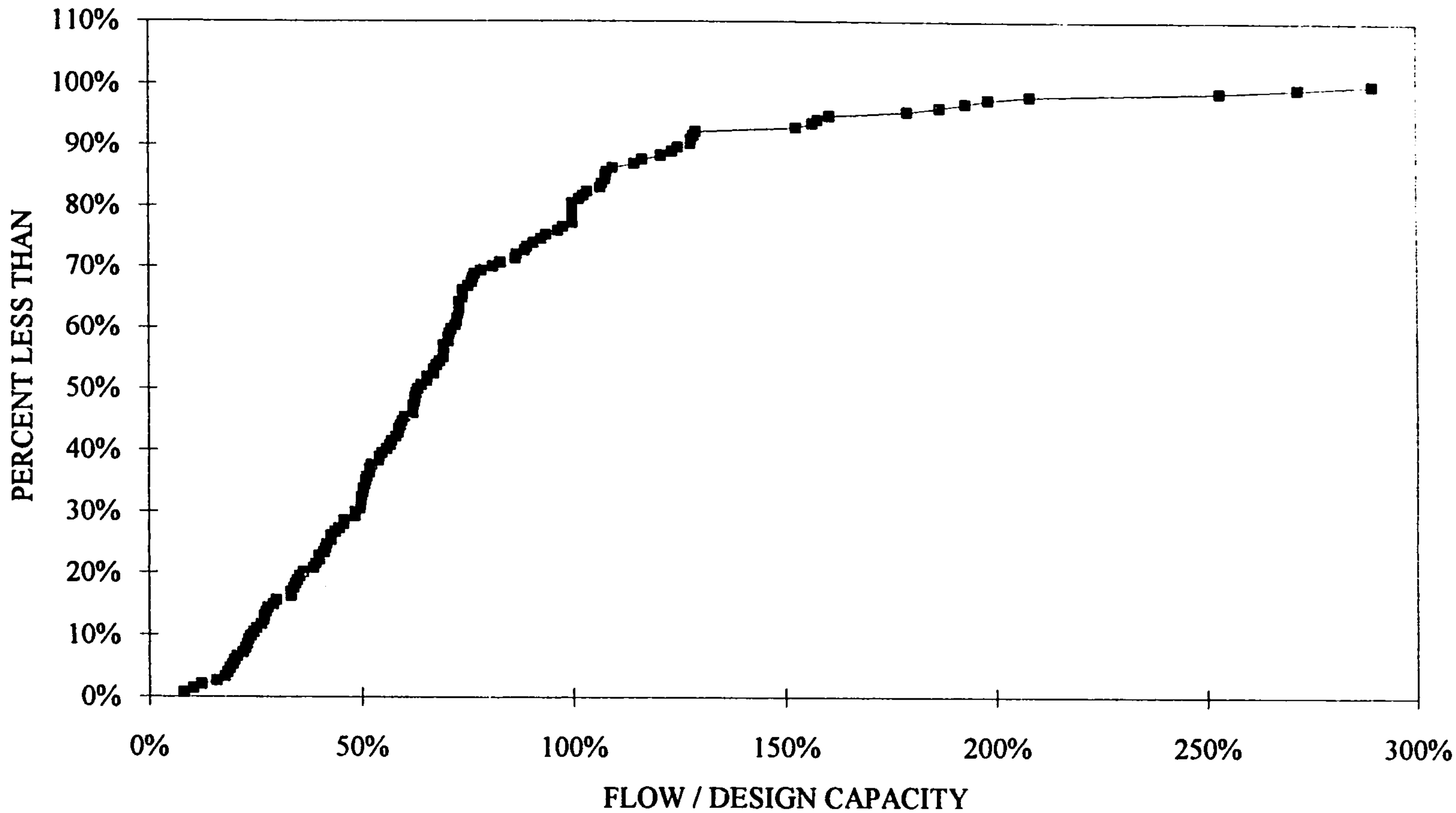
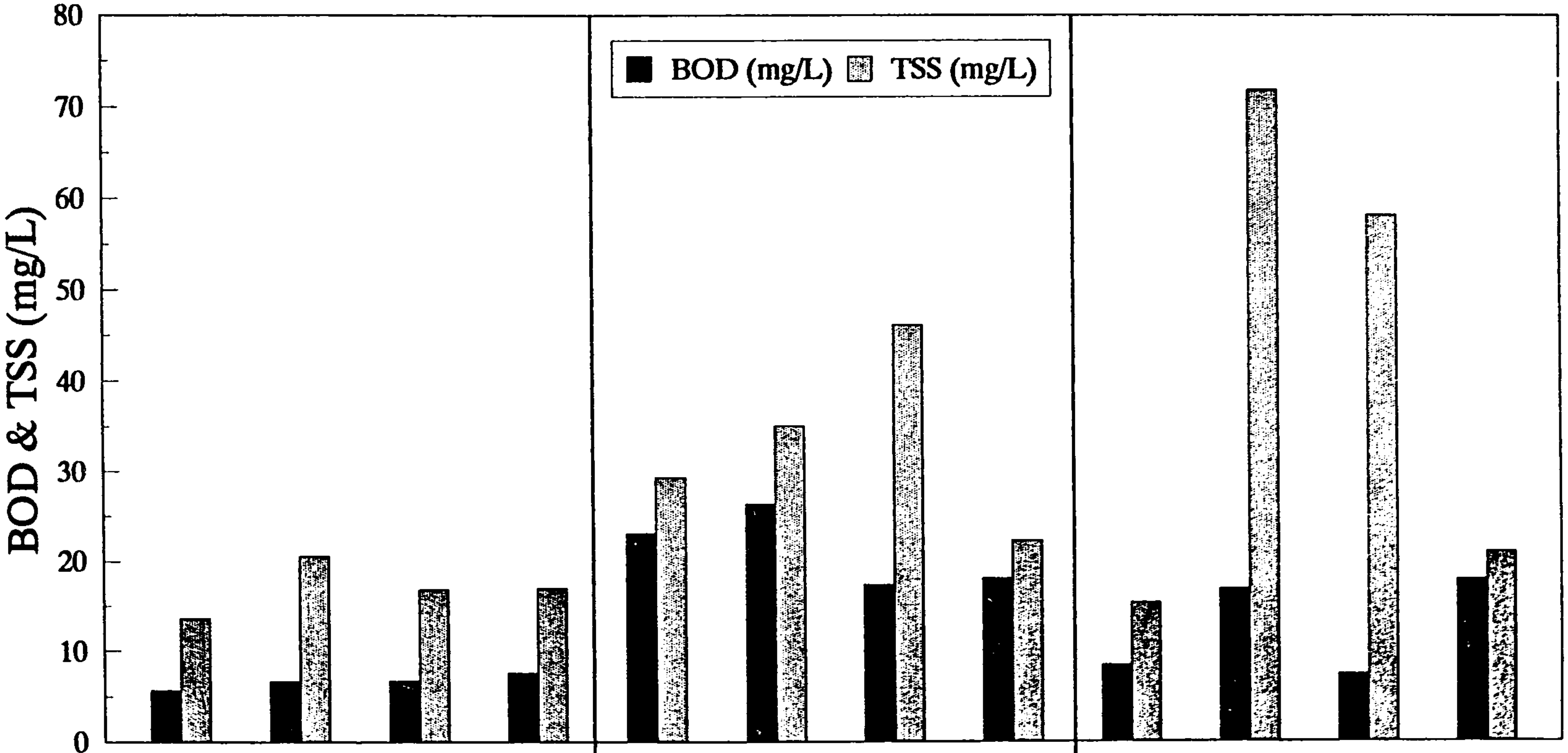


Figure 3.16 : Distribution of Flow/Design Capacity (154 sites)



	FALL DISCHARGE				SPRING DISCHARGE				SUMMER DISCHARGE			
	25% Capacity	50% Capacity	75% Capacity	100% Capacity	25% Capacity	50% Capacity	75% Capacity	100% Capacity	25% Capacity	50% Capacity	75% Capacity	100% Capacity
BOD mean	5.6	6.7	6.7	7.5	23.0	26.3	17.3	18.1	8.4	16.8	7.4	18.0
# Samples	4	9	7	12	3	8	5	10	2	2	1	1
Upper 95%	12.6	11.1	11.3	12.2	48.1	51.6	30.9	33.3	26.4	34.6		
Lower 95%	2.5	4.0	4.0	4.7	11.0	13.4	9.7	9.8	2.7	8.2		
TSS mean	13.6	20.5	16.8	16.9	29.2	35.0	46.1	22.3	15.3	71.8	58.1	21.0
# Samples	4	9	8	12	3	8	5	10	2	2	1	1
Upper 95%	21.7	32.8	26.0	26.1	53.3	62.5	64.2	33.3	25.9	397.7		
Lower 95%	8.5	12.9	10.8	10.9	16.0	19.6	33.2	14.9	9.0	13.0		

Figure 3.17 : % Capacity and Seasonal Variations in Effluent Quality

LAGOON 4S-2L BOD

				Capacity	Fa 25%	Fa 50%	Fa 75%	Fa 100%	Sp 25%	Sp 50%	Sp 75%	Sp 100%	Su 25%	Su 50%	Su 75%	Su 100%
				BOD	5.6	6.7	6.7	7.5	23.0	26.3	17.3	18.1	8.4	16.8	7.4	18.0
				Upper 95%	12.6	11.1	11.3	12.2	48.1	51.6	30.9	33.3	26.4	34.6		
				Lower 95%	2.5	4.0	4.0	4.7	11.0	13.4	9.7	9.8	2.7	8.2		
Capacity	BOD	Upper 95%	Lower 95%	n	4	9	7	12	3	8	5	10	2	2	1	1
Fa 25%	5.64	12.61	2.52	4	50%	36%	36%	28%	3%	1%	3%	3%	30%	9%		
Fa 50%	6.67	11.05	4.03	9	36%	50%	49%	37%	2%	0%	2%	1%	36%	7%		
Fa 75%	6.71	11.32	3.98	7	36%	49%	50%	38%	2%	0%	2%	2%	35%	7%		
Fa 100%	7.55	12.23	4.66	12	28%	37%	38%	50%	3%	0%	4%	2%	43%	12%		
Sp 25%	23.00	48.13	10.99	3	3%	2%	2%	3%	50%	42%	29%	35%	11%	31%		
Sp 50%	26.27	51.60	13.37	8	1%	0%	0%	0%	42%	50%	21%	22%	9%	28%		
Sp 75%	17.29	30.88	9.68	5	3%	2%	2%	4%	29%	21%	50%	47%	14%	48%		
Sp 100%	18.06	33.27	9.80	10	3%	1%	2%	2%	35%	22%	47%	50%	17%	46%		
Su 25%	8.42	26.44	2.68	2	30%	36%	35%	43%	11%	9%	14%	17%	50%	21%		
Su 50%	16.83	34.59	8.19	2	9%	7%	7%	12%	31%	28%	48%	46%	21%	50%		
Su 75%	7.44			1												
Su 100%	17.95			1												

LAGOON 4S-2L TSS

				Capacity	Fa 25%	Fa 50%	Fa 75%	Fa 100%	Sp 25%	Sp 50%	Sp 75%	Sp 100%	Su 25%	Su 50%	Su 75%	Su 100%
				TSS	13.6	20.5	16.8	16.9	29.2	35.0	46.1	22.3	15.3	71.8	58.1	21.0
				Upper 95%	21.7	32.8	26.0	26.1	53.3	62.5	64.2	33.3	25.9	397.7		
				Lower 95%	8.5	12.9	10.8	10.9	16.0	19.6	33.2	14.9	9.0	13.0		
Capacity	TSS	Upper 95%	Lower 95%	n	4	9	8	12	3	8	5	10	2	2	1	1
Fa 25%	13.59	21.75	8.49	4	50%	16%	29%	30%	5%	3%	0%	10%	39%	3%		
Fa 50%	20.54	32.81	12.86	9	16%	50%	27%	28%	23%	9%	2%	40%	30%	4%		
Fa 75%	16.78	26.04	10.81	8	29%	27%	50%	49%	11%	3%	0%	18%	43%	2%		
Fa 100%	16.90	26.08	10.95	12	30%	28%	49%	50%	13%	3%	1%	19%	43%	2%		
Sp 25%	29.23	53.26	16.04	3	5%	23%	11%	13%	50%	37%	10%	26%	12%	16%		
Sp 50%	35.04	62.53	19.64	8	3%	9%	3%	3%	37%	50%	25%	11%	11%	17%		
Sp 75%	46.15	64.19	33.17	5	0%	2%	0%	1%	10%	25%	50%	2%	1%	23%		
Sp 100%	22.28	33.34	14.89	10	10%	40%	18%	19%	26%	11%	2%	50%	23%	3%		
Su 25%	15.30	25.87	9.05	2	39%	30%	43%	43%	12%	11%	1%	23%	50%	12%		
Su 50%	71.84	397.71	12.98	2	3%	4%	2%	2%	16%	17%	23%	3%	12%	50%		
Su 75%	58.15			1												
Su 100%	21.00			1												

Figure 3.18 : T Tests for % Capacity and Season of Discharge

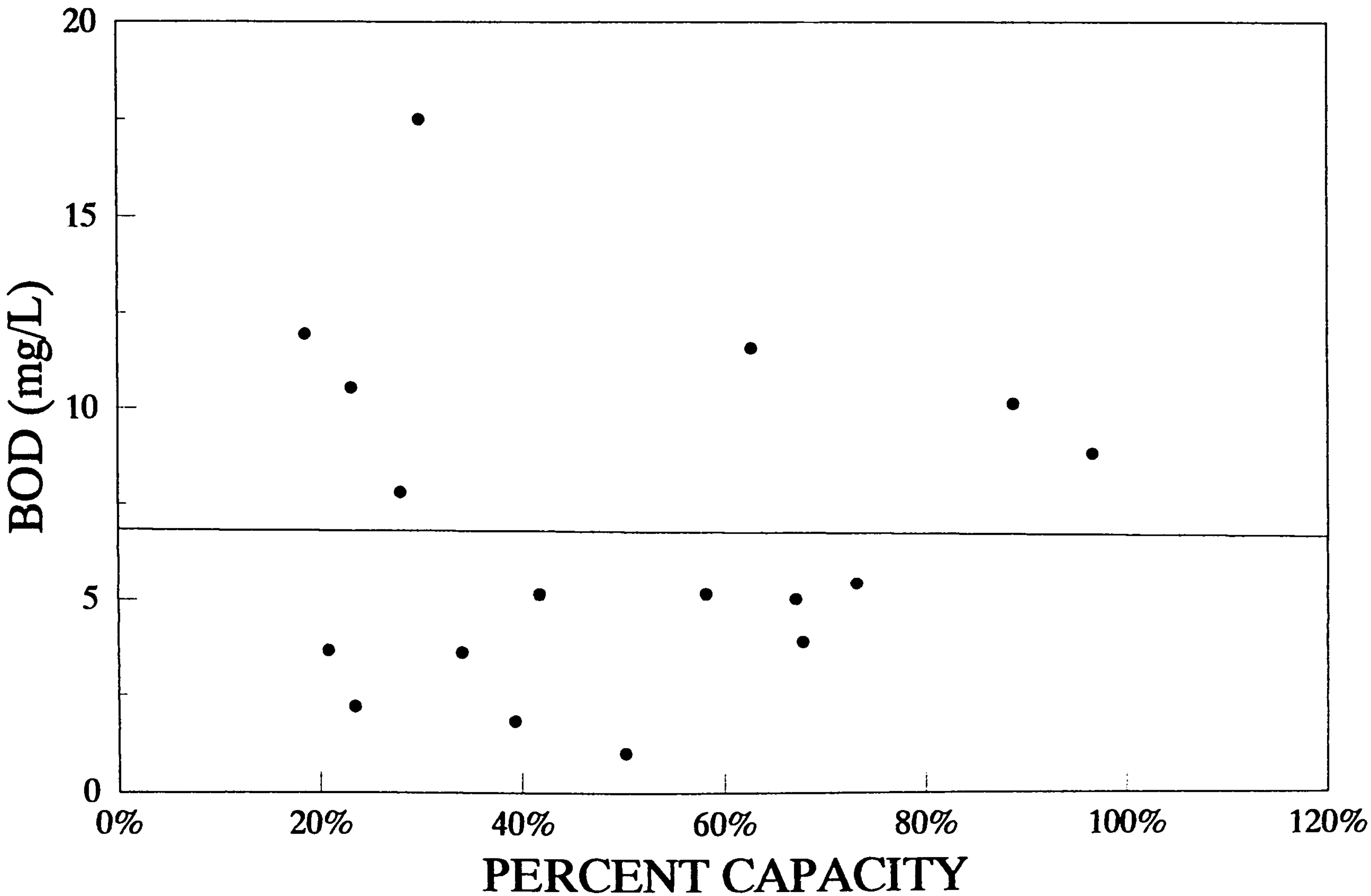


Figure 3.19 : BOD Versus % Capacity

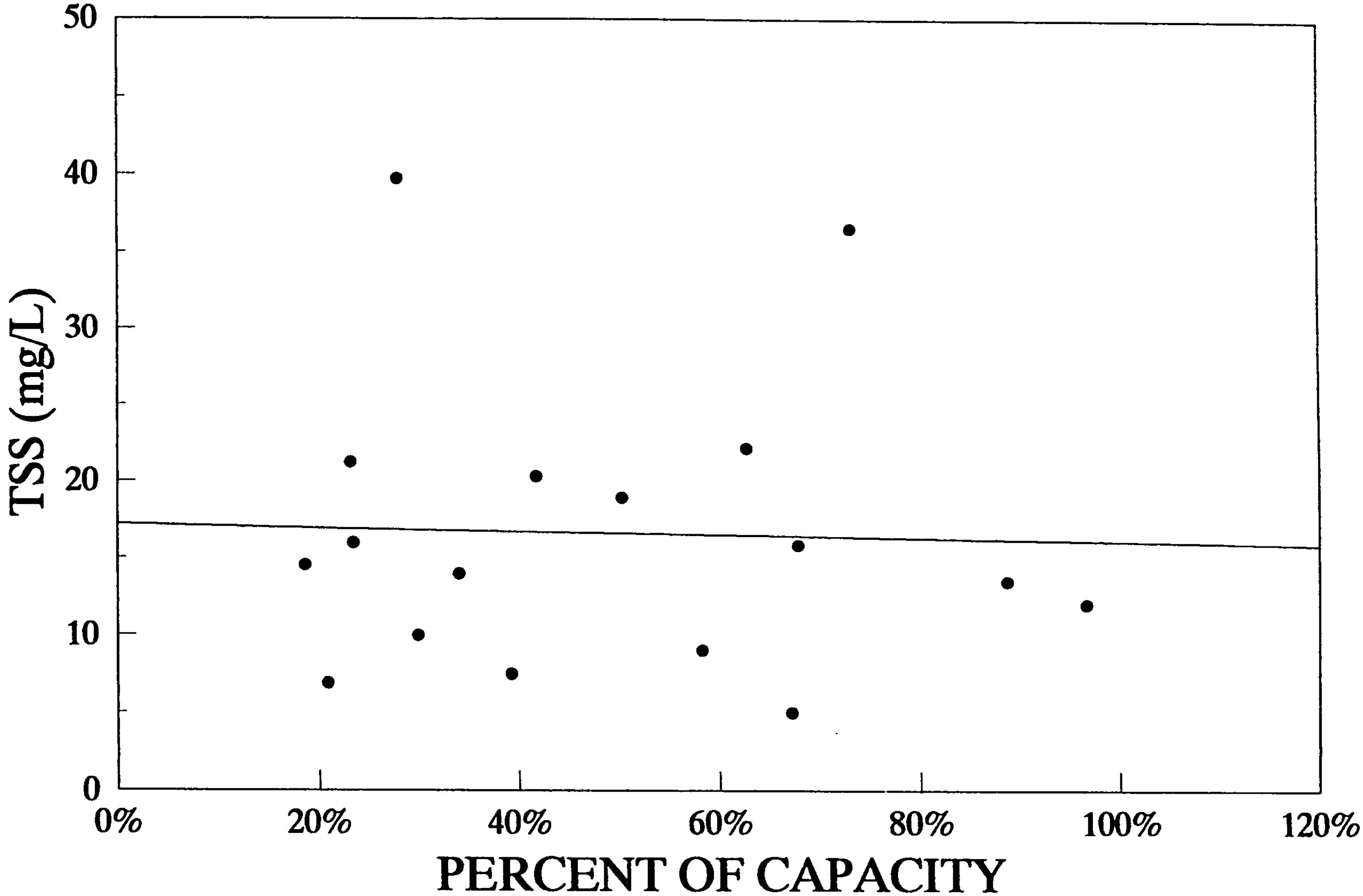


Figure 3.20 : TSS Versus % Capacity

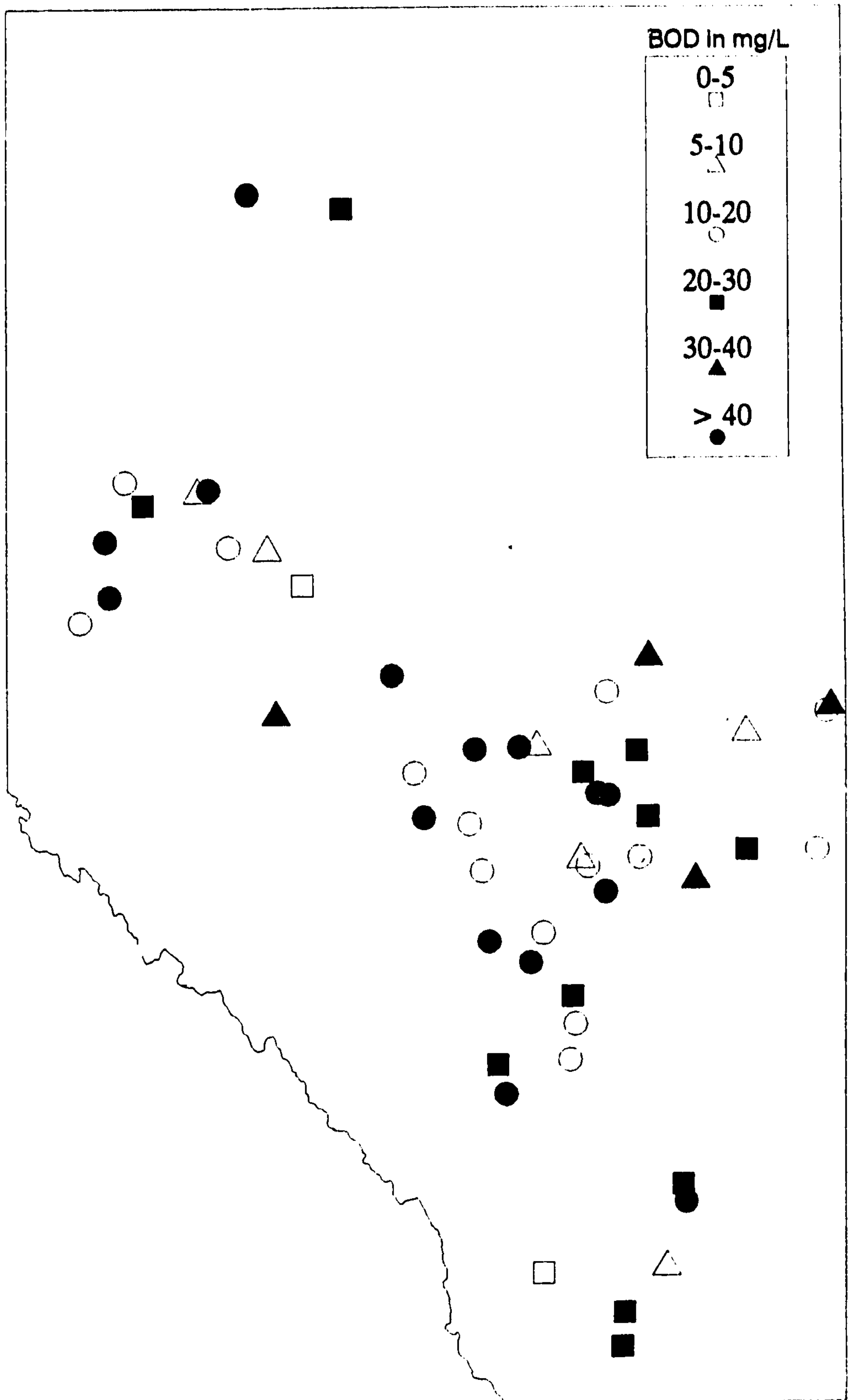


Figure 3.21 : Map of 4S-2L Spring Discharges

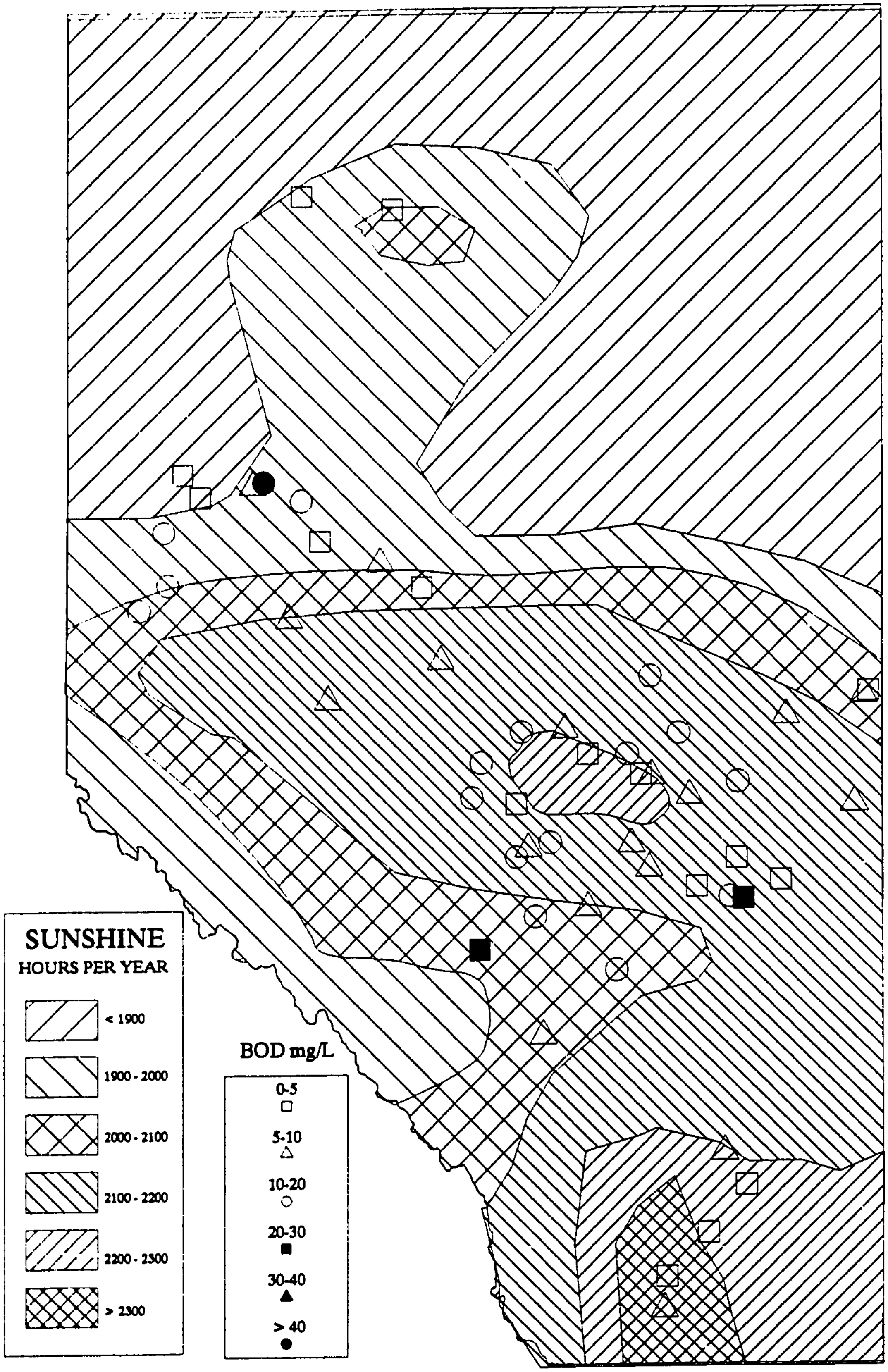


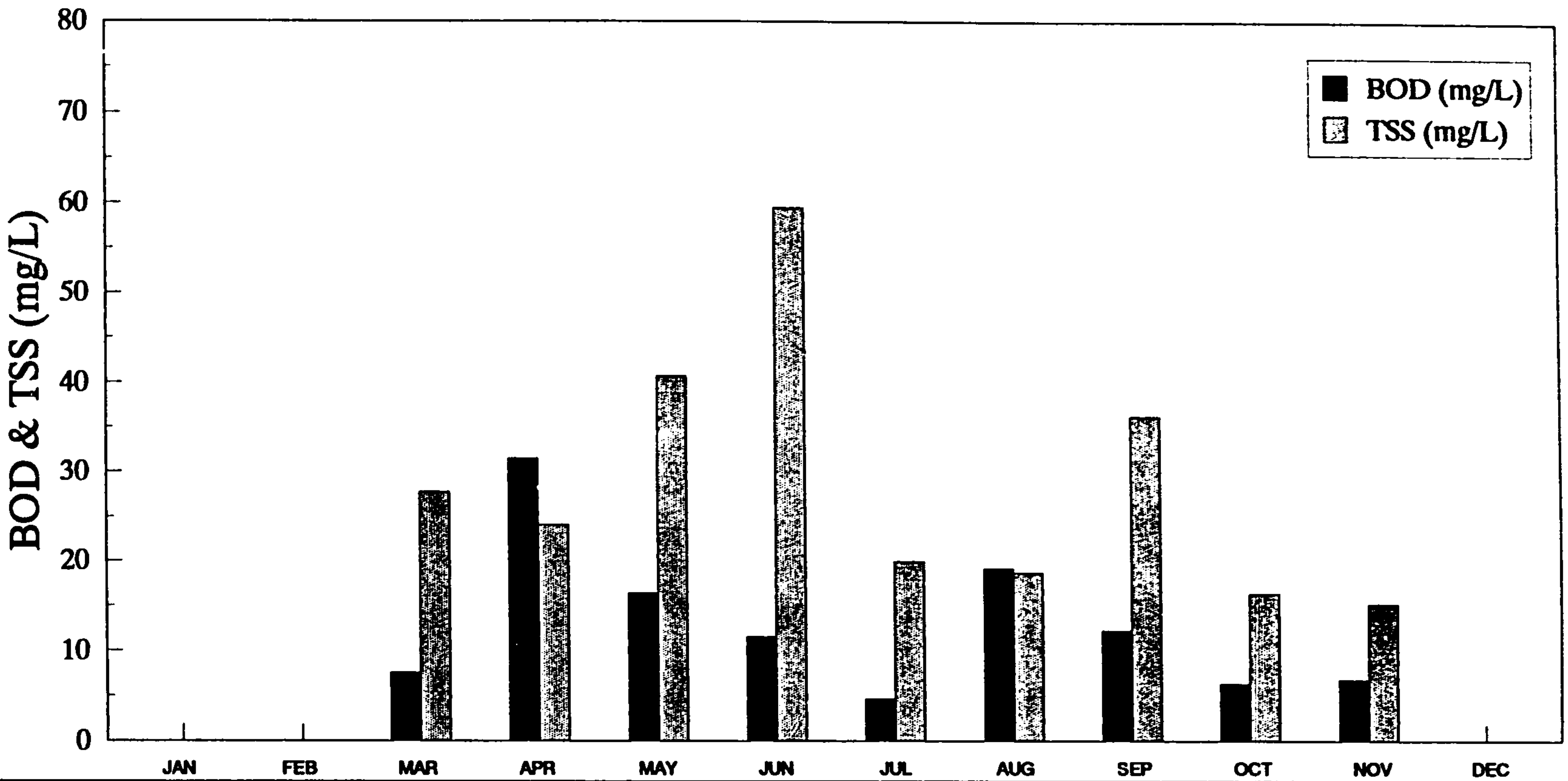
Figure 3.22 : Map of 4S-2L Fall Discharges

				Regoin	1	2	3	4	5	6
				MEAN	2.52	13.36	10.50	9.96	4.67	6.89
				Upper 95%	3.9	22.4	15.6	12.0	6.6	12.6
Sunshine				Lower 95	1.1	4.3	5.4	7.9	2.8	1.1
Regoin	BOD	Upper 95%	Lower 95	n	2	8	9	26	6	2
1	2.52	3.89	1.15	2	50%	15%	10%	3%	14%	14%
2	13.36	22.42	4.31	8	15%	50%	29%	14%	7%	26%
3	10.50	15.61	5.38	9	10%	29%	50%	41%	5%	28%
4	9.96	12.02	7.90	26	3%	14%	41%	50%	1%	22%
5	4.67	6.59	2.75	6	14%	7%	5%	1%	50%	18%
6	6.89	12.63	1.14	2	14%	26%	28%	22%	18%	50%

Figure 3.23 : T Tests for Geographical Distribution of BOD (Lagoons 4S-2L or more)

				Regoin	1	2	3	4	5	6
				MEAN	12.69	21.65	18.43	21.43	18.21	22.00
				Upper 95%	22.9	31.4	25.6	26.6	26.6	43.9
Sunshine				Lower 95	2.5	11.9	11.2	16.2	9.8	0.1
Regoin	TSS	Upper 95%	Lower 95	n	2	8	9	26	6	2
1	12.69	22.88	2.51	2	50%	21%	26%	19%	26%	26%
2	21.65	31.39	11.90	8	21%	50%	30%	48%	31%	49%
3	18.43	25.64	11.22	9	26%	30%	50%	28%	49%	35%
4	21.43	26.62	16.24	26	19%	48%	28%	50%	30%	48%
5	18.21	26.62	9.80	6	26%	31%	49%	30%	50%	35%
6	22.00	43.91	0.09	2	26%	49%	35%	48%	35%	50%

Figure 3.24 : T Tests for Geographical Distribution of TSS (Lagoons 4S-2L or more)



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
BOD mean			7.6	31.5	16.5	11.6	4.7	19.2	12.2	6.3	6.8	
# Samples			2	15	14	3	1	2	10	21	13	
Upper 95%			17.2	46.7	24.7	19.1		30.5	16.2	8.6	12.7	
Lower 95%			3.4	21.3	11.0	7.0		12.0	9.2	4.7	3.6	
TSS mean			27.8	24.1	40.8	59.4	20.0	18.7	36.3	16.3	15.2	
# Samples			2	15	14	3	1	2	10	22	13	
Upper 95%			109.7	36.0	65.7	195.4		47.1	57.6	21.1	20.6	
Lower 95%			7.0	16.2	25.3	18.1		7.4	22.8	12.7	11.2	

Figure 3.25 : Monthly Changes in Effluent Quality, 4S-2L Lagoons

LAGOON 4S-2L BOD

Month	BOD	Upper 95%	Lower 95%	n	1	2	3	4	5	6	7	8	9	10	11	12
				BOD			7.6	31.5	16.5	11.6	4.7	19.2	12.2	6.3	6.8	
				Upper 95%			17.2	46.7	24.7	19.1		30.5	16.2	8.6	12.7	
				Lower 95%			3.4	21.3	11.0	7.0		12.0	9.2	4.7	3.6	
				n			2	15	14	3	1	2	10	21	13	
1																
2																
3	7.58	17.15	3.35	2			50%	1%	10%	21%		10%	11%	36%	45%	
4	31.51	46.70	21.25	15			1%	50%	2%	2%		20%	0%	0%	0%	
5	16.45	24.66	10.98	14			10%	2%	50%	23%		40%	14%	0%	1%	
6	11.59	19.07	7.04	3			21%	2%	23%	50%		14%	43%	8%	23%	
7	4.70			1												
8	19.16	30.53	12.02	2			10%	20%	40%	14%		50%	11%	2%	12%	
9	12.22	16.21	9.21	10			11%	0%	14%	43%		11%	50%	1%	7%	
10	6.31	8.56	4.66	21			36%	0%	0%	8%		2%	1%	50%	41%	
11	6.81	12.71	3.65	13			45%	0%	1%	23%		12%	7%	41%	50%	
12																

LAGOON 4S-2L TSS

Month	TSS	Upper 95%	Lower 95%	n	1	2	3	4	5	6	7	8	9	10	11	12
				TSS			27.8	24.1	40.8	59.4	20.0	18.7	36.3	16.3	15.2	
				Upper 95%			109.7	36.0	65.7	195.4		47.1	57.6	21.1	20.6	
				Lower 95%			7.0	16.2	25.3	18.1		7.4	22.8	12.7	11.2	
				n			2	15	14	3	1	2	10	22	13	
1																
2																
3	27.80	109.69	7.05	2			50%	41%	29%	24%		34%	33%	13%	11%	
4	24.13	35.96	16.19	15			41%	50%	5%	5%		34%	10%	5%	4%	
5	40.78	65.70	25.31	14			29%	5%	50%	27%		13%	37%	0%	0%	
6	59.44	195.41	18.08	3			24%	5%	27%	50%		14%	19%	0%	0%	
7	20.00			1												
8	18.74	47.14	7.45	2			34%	34%	13%	14%		50%	14%	38%	32%	
9	36.25	57.56	22.83	10			33%	10%	37%	19%		14%	50%	0%	0%	
10	16.33	21.05	12.67	22			13%	5%	0%	0%		38%	0%	50%	36%	
11	15.17	20.63	11.16	13			11%	4%	0%	0%		32%	0%	36%	50%	
12																

Figure 3.26 : Monthly Changes in Effluent Quality, T Tests

LAGOON 4S-2L BOD

						12 MONTH												6 MONTH											
					MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
					BOD			7.6	24.1	12.9	9.3	4.7	15.1	11.3	5.5	4.7					37.7	21.0	18.0		24.3	11.7	6.9	9.8	
					Lower 95%			3.4	14.7	9.3	6.0			7.1	4.1	2.7					21.6	10.2				8.2	4.3	2.1	
					Upper 95%			17.2	39.4	17.9	14.4			18.2	7.5	8.1					65.9	43.4				16.6	10.9	45.2	
MONTH	STORAGE	BOD	Lower 95%	Upper 95%	BODN			2	6	7	2	1	1	5	8	8					9	7	1		1	4	13	4	
JAN																													
FEB																													
MAR	12	7.58	3.35	17.15	2			50%	3%	10%	35%			21%	20%	22%					2%	11%				15%	44%	42%	
APR	12	24.06	14.69	39.41	6			3%	50%	3%	5%			3%	0%	0%					14%	39%				4%	0%	12%	
MAY	12	12.87	9.26	17.89	7			10%	3%	50%	19%			33%	0%	1%					0%	12%				36%	4%	33%	
JUN	12	9.31	6.00	14.45	2			35%	5%	19%	50%			33%	8%	14%					3%	15%				24%	32%	49%	
JUL	12	4.70			1																								
AUG	12	15.10			1																								
SEP	12	11.35	7.07	18.22	5			21%	3%	33%	33%			50%	1%	3%					1%	12%				46%	12%	42%	
OCT	12	5.51	4.07	7.48	8			20%	0%	0%	8%			1%	50%	30%					0%	0%				1%	25%	17%	
NOV	12	4.66	2.69	8.08	8			22%	0%	1%	14%			3%	30%	50%					0%	0%				3%	16%	14%	
DEC																													
JAN																													
FEB																													
MAR																													
APR	6	37.71	21.58	65.91	9			2%	14%	0%	3%			1%	0%	0%					50%	11%				1%	0%	3%	
MAY	6	21.04	10.21	43.37	7			11%	39%	12%	15%			12%	0%	0%					11%	50%				14%	1%	17%	
JUN	6	17.95			1																								
JUL																													
AUG	6	24.30			1																								
SEP	6	11.72	8.25	16.65	4			15%	4%	36%	24%			46%	1%	3%					1%	14%				50%	12%	42%	
OCT	6	6.86	4.34	10.85	13			44%	0%	4%	32%			12%	25%	16%					0%	1%				12%	50%	28%	
NOV	6	9.81	2.13	45.20	4			42%	12%	33%	48%			42%	17%	14%					3%	17%				42%	28%	50%	
DEC																													

Figure 3.27 : Monthly Changes in Effluent Quality (Storage Included), T Tests on BOD

LAGOON 4S-2L TSS

MONTH	STORAGE	TSS	Lower 95%	Upper 95%		12 MONTH JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	6 MONTH JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
					MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
					TSS			27.8	21.2	44.2	100.0	20.0	11.7	25.7	16.2	11.5					26.3	37.6	21.0		30.0	66.4	16.4	23.0	
					Lower 95%			7.0	11.3	27.5	34.6			13.0	10.8	8.2					15.3	15.8				58.7	11.7	15.4	
					Upper 95%			109.7	39.7	71.2	289.5			50.7	24.3	16.2					45.1	89.4				75.2	23.1	34.5	
MONTH	STORAGE	TSS	Lower 95%	Upper 95%	n			2	6	7	2	1	1	5	9	8					9	7	1		1	4	13	4	
JAN																													
FEB																													
MAR	12	27.80	7.05	109.69	2			50%	35%	22%	14%			46%	16%	5%					47%	38%				6%	16%	37%	
APR	12	21.17	11.30	39.66	6			35%	50%	4%	3%			35%	24%	5%					31%	17%				1%	23%	43%	
MAY	12	44.24	27.50	71.18	7			22%	4%	50%	8%			11%	0%	0%					10%	38%				13%	0%	5%	
JUN	12	100.01	34.55	289.50	2			14%	3%	8%	50%			5%	0%	0%					3%	16%				15%	0%	2%	
JUL	12	20.00			1																								
AUG	12	11.70			1																								
SEP	12	25.69	13.01	50.73	5			46%	35%	11%	5%			50%	12%	2%					49%	27%				2%	11%	49%	
OCT	12	16.19	10.80	24.26	9			16%	24%	0%	0%			12%	50%	12%					9%	4%				0%	48%	16%	
NOV	12	11.51	8.16	16.23	8			5%	5%	0%	0%			2%	12%	50%					1%	1%				0%	9%	2%	
DEC																													
JAN																													
FEB																													
MAR																													
APR	6	26.32	15.35	45.15	9			47%	31%	10%	3%			49%	9%	1%					50%	24%				3%	7%	38%	
MAY	6	37.58	15.80	89.41	7			39%	17%	39%	16%			27%	4%	1%					24%	50%				18%	3%	22%	
JUN	6	21.00			1																								
JUL																													
AUG	6	30.00			1																								
SEP	6	66.42	58.69	75.17	4			6%	1%	13%	15%			2%	0%	0%					3%	18%				50%	0%	0%	
OCT	6	16.44	11.71	23.07	13			16%	23%	0%	0%			11%	45%	9%					7%	3%				0%	50%	17%	
NOV	6	23.03	15.36	34.54	4			37%	43%	5%	2%			40%	16%	2%					39%	22%				0%	17%	50%	
DEC																													

Figure 3.28 : Monthly Changes in Effluent Quality (Storage Included), T Tests on TSS

						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
					STATION	2L	2L	2L	3L	2L	4L	3L	4L	2L	1L	1L	2L	2L	2L	Aera	2L	erated	1L	2L	RBC	Slud	2L	1L	4L	Stab	2L	3L	3L	1L	2L	1L	2L	4L
					BOD	2.2	5.4	6.0	6.9	7.3	8.5	8.7	8.8	8.9	9.7	10.3	10.8	12.6	14.1	14.7	15.3	16.2	16.8	17.3	17.5	18.5	20.9	24.1	25.4	26.6	28.0	28.1	28.2	32.5	35.9	41.5	46.5	53.1
					n	1	8	16	7	15	1	4	4	4	4	3	11	6	1	10	13	10	4	8	10	9	2	7	3	1	13	10	4	4	8	6	7	4
	STATION	BOD	Lower 95%	Upper 95%	n																																	
1	Lagoon - 0S, 2L SPRING 6	2.16			1																																	
2	Lagoon - 2S, 2L FALL 12	5.40	3.66	7.98	8		50%	36%	24%	19%		12%	7%	9%	7%	9%	1%	1%		0%	0%	0%	0%	0%	0%	0%	1%	0%	0%		0%	0%	0%	0%	0%	0%	0%	0%
3	Lagoon - 4S, 2L FALL 12	5.97	4.37	8.15	16		36%	50%	31%	23%		16%	13%	13%	10%	11%	1%	1%		0%	0%	0%	0%	0%	0%	0%	1%	0%	0%		0%	0%	0%	0%	0%	0%	0%	0%
4	Lagoon - 4S, 3L FALL 12	6.93	3.95	12.16	7		24%	31%	50%	45%		32%	20%	29%	25%	25%	10%	8%		2%	1%	0%	3%	1%	0%	0%	5%	0%	2%		0%	0%	1%	1%	0%	0%	0%	0%
5	Lagoon - 4S, 2L FALL 6	7.26	4.75	11.10	15		19%	23%	45%	50%		35%	-33%	33%	27%	26%	10%	8%		2%	1%	0%	4%	1%	0%	0%	5%	0%	2%		0%	0%	1%	0%	0%	0%	0%	0%
6	Lagoon - 4S, 4L FALL 12	8.46			1																																	
7	Lagoon - 4S, 3L FALL 6	8.72	4.32	17.57	4		12%	16%	32%	35%		50%	49%	49%	42%	40%	29%	21%		9%	7%	1%	7%	3%	-1%	1%	9%	1%	6%		2%	1%	4%	3%	0%	0%	0%	0%
8	Lagoon - 4S, 4L FALL 6	8.80	7.16	10.82	4		7%	13%	20%	-33%		49%	50%	49%	40%	-38%	27%	16%		7%	5%	0%	1%	1%	0%	0%	0%	0%	2%		-2%	0%	-2%	1%	0%	0%	0%	0%
9	Lagoon - 4S, 2L SUMMER 12	8.86	5.35	14.65	4		9%	13%	29%	33%		49%	49%	50%	42%	40%	29%	19%		8%	6%	1%	4%	2%	0%	0%	5%	1%	4%		2%	0%	3%	2%	0%	0%	0%	0%
10	Lagoon - 2S, 1L FALL 6	9.67	4.86	19.24	4		7%	10%	25%	27%		42%	49%	42%	50%	46%	39%	20%		14%	11%	3%	10%	6%	2%	2%	11%	2%	7%		4%	1%	5%	3%	1%	1%	0%	0%
11	Lagoon - 2S, 1L FALL 12	10.26	3.67	28.73	3		9%	11%	25%	26%		40%	-38%	40%	46%	50%	45%	35%		22%	18%	-7%	18%	11%	-6%	-5%	19%	5%	13%		7%	3%	10%	7%	2%	2%	1%	1%
12	Lagoon - 2S, 2L FALL 6	10.81	7.41	15.79	11		1%	1%	10%	10%		29%	27%	29%	39%	45%	50%	32%		14%	9%	2%	11%	5%	-2%	2%	10%	1%	4%		1%	0%	2%	1%	0%	0%	0%	0%
13	Lagoon - 0S, 2L FALL 12	12.60	7.50	21.17	6		1%	1%	8%	8%		21%	16%	19%	20%	35%	32%	50%		32%	27%	13%	22%	15%	10%	7%	17%	4%	10%		5%	2%	7%	4%	1%	1%	0%	0%
14	Lagoon - 0S, 2L FALL 6	14.10			1																																	
15	Ext. Aeration	14.69	10.11	21.35	10		0%	0%	2%	2%		9%	7%	8%	14%	22%	14%	32%		50%	44%	31%	34%	27%	22%	16%	22%	5%	11%		4%	2%	7%	3%	1%	0%	0%	0%
16	Lagoon - 4S, 2L SPRING 12	15.26	11.02	21.14	13		0%	0%	1%	1%		7%	5%	6%	11%	18%	9%	27%		44%	50%	37%	38%	31%	26%	20%	24%	5%	11%		4%	1%	6%	3%	0%	0%	0%	0%
17	Aerated	16.16	13.91	18.77	25		0%	0%	0%	0%		1%	0%	0%	2%	-5%	-1%	11%		29%	36%	50%	42%	34%	29%	18%	18%	2%	-5%		-1%	0%	-2%	0%	0%	0%	0%	0%
18	Lagoon - 0S, 1L FALL 12	16.84	12.08	23.48	4		0%	0%	3%	4%		7%	1%	4%	10%	18%	11%	22%		34%	38%	42%	50%	46%	43%	32%	24%	13%	19%		17%	8%	16%	9%	4%	2%	1%	0%
19	Lagoon - 2S, 2L SPRING 12	17.31	12.59	23.80	8		0%	0%	1%	1%		3%	1%	2%	6%	11%	5%	15%		27%	31%	35%	46%	50%	48%	37%	30%	11%	17%		-11%	5%	12%	5%	1%	1%	0%	0%
20	RBC	17.46	14.35	21.25	10		0%	0%	0%	0%		-1%	0%	0%	2%	-6%	-2%	10%		22%	26%	30%	43%	48%	50%	35%	24%	7%	-11%		-8%	-3%	-7%	-3%	-1%	0%	0%	0%
21	A. Sludge	18.47	15.08	22.63	9		0%	0%	0%	0%		1%	0%	0%	2%	-5%	2%	7%		16%	20%	19%	32%	37%	35%	50%	31%	12%	-16%		-12%	-5%	-11%	-4%	-1%	0%	0%	0%
22	Lagoon - 4S, 2L SUMMER 6	20.89	15.52	28.10	2		1%	1%	5%	5%		9%	0%	5%	11%	19%	10%	17%		22%	24%	19%	24%	30%	24%	31%	50%	37%	38%		35%	27%	34%	25%	17%	12%	9%	4%
23	Lagoon - 0S, 1L FALL 6	24.06	16.27	35.58	7		0%	0%	0%	0%		1%	0%	1%	2%	5%	1%	4%		5%	5%	2%	13%	11%	7%	12%	37%	50%	45%		36%	30%	36%	23%	12%	7%	4%	2%
24	Lagoon - 4S, 4L SPRING 12	25.42	10.27	62.94	3		0%	0%	2%	2%		6%	2%	4%	7%	13%	4%	10%		11%	11%	6%	19%	17%	-11%	-16%	38%	45%	50%		44%	41%	44%	35%	25%	18%	14%	10%
25	Contact Stabilizat'n	26.56			1																																	
26	Lagoon - 4S, 2L SPRING 6	27.99	16.20	48.34	13		0%	0%	0%	0%		2%	-2%	2%	4%	7%	1%	5%		4%	4%	-2%	17%	-11%	-8%	-12%	35%	36%	44%		50%	49%	49%	40%	27%	20%	13%	12%
27	Lagoon - 4S, 3L SPRING 12	28.14	18.83	42.05	10		0%	0%	0%	0%		1%	0%	0%	1%	3%	0%	2%		2%	1%	0%	8%	5%	-3%	-5%	27%	30%	41%		49%	50%	50%	37%	23%	14%	8%	5%
28	Lagoon - 4S, 3L SPRING 6	28.21	11.70	68.05	4		0%	0%	1%	1%		4%	-2%	3%	5%	10%	2%	7%		7%	6%	-3%	16%	12%	-7%	-11%	34%	36%	44%		49%	50%	50%	41%	31%	23%	17%	13%
29	Lagoon - 0S, 1L SPRING 12	32.50	14.75	71.64	4		0%	0%	1%	0%		3%	1%	2%	3%	7%	1%	4%		3%	3%	-1%	9%	5%	-3%	-4%	25%	23%	35%		40%	37%	41%	50%	42%	31%	23%	17%
30	Lagoon - 2S, 2L SPRING 6	35.90	21.84	59.03	8		0%	0%	0%	0%		0%	0%	0%	1%	2%	0%	1%		1%	0%	0%	4%	1%	-1%	-1%	17%	12%	25%		27%	23%	31%	42%	50%	36%	25%	18%
31	Lagoon - 0S, 1L SPRING 6	41.50	23.96	71.87	6		0%	0%	0%	0%		0%	0%	0%	1%	2%	0%	1%		0%	0%	0%	2%	1%	0%	0%	12%	7%	18%		20%	14%	23%	31%	36%	50%	39%	28%
32	Lagoon - 0S, 2L SPRING 12	46.47	27.31	79.09	7		0%	0%	0%	0%		0%	0%	0%	0%	1%	0%	0%		0%	0%	0%	1%	0%	0%	0%	9%	4%	14%		13%	8%	17%	23%	25%	39%	50%	38%
33	Lagoon - 4S, 4L SPRING 6	53.07	32.10	87.74	4		0%	0%	0%	0%		0%	0%	0%	0%	1%	0%	0%		0%	0%	0%	0%	0%	0%	0%	4%	2%	10%		12%	5%	13%	17%	18%	28%	39%	50%

Figure 3.29 : T Tests of Treatment Systems, BOD

						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
					STATION	RBC	Slud	2L	2L	3L	Aera	4L	4L	2L	erate	2L	1L	4L	3L	2L	2L	3L	2L	2L	2L	2L	Stab	2L	2L	3L	4L	1L	1L	2L	2L	1L	1L	1L
					TSS	11.4	11.6	14.4	14.6	15.2	15.3	17.1	17.2	17.5	18.0	21.0	21.6	21.7	22.7	25.1	25.6	26.7	27.0	28.0	28.7	28.9	29.6	31.3	32.0	34.4	34.5	34.6	36.0	39.1	39.9	40.8	44.3	49.6
					TSSN	10	9	17	7	7	10	1	4	1	25	15	4	2	4	2	11	10	1	8	7	13	1	8	13	4	4	7	5	4	6	3	4	4
	STATION	TSS	Lower 95%	Upper 95%	TSSN																																	
1	RBC	11.44	9.70	13.49	10	50%	-47%	-11%	9%	-17%	-16%		3%		0%	-1%	-1%	0%	-1%	0%	-1%	0%		0%	0%	0%		-1%	0%	0%	0%	0%	0%	0%	0%	-1%	0%	0%
2	A. Sludge	11.65	7.76	17.50	9	-47%	50%	19%	22%	24%	22%		15%		1%	3%	7%	-10%	6%	7%	2%	0%		1%	2%	0%		2%	0%	1%	0%	0%	0%	2%	0%	-3%	0%	0%
3	Lagoon - 4S, 2L FALL 12	14.44	11.09	18.80	17	-11%	19%	50%	49%	43%	42%		29%		4%	6%	11%	-16%	9%	9%	3%	0%		1%	2%	0%		-1%	0%	1%	0%	0%	0%	-1%	0%	-2%	0%	0%
4	Lagoon - 2S, 2L FALL 12	14.55	10.52	20.14	7	9%	22%	49%	50%	46%	45%		28%		8%	13%	13%	-13%	12%	7%	8%	1%		2%	5%	1%		-5%	1%	1%	1%	1%	1%	-4%	1%	-6%	0%	0%
5	Lagoon - 4S, 3L FALL 12	15.17	7.99	28.78	7	-17%	24%	43%	46%	50%	49%		40%		-18%	19%	25%	-30%	23%	23%	13%	4%		7%	10%	4%		9%	3%	7%	6%	4%	5%	8%	3%	11%	3%	1%
6	Ext. Aeration	15.28	9.03	25.85	10	-16%	22%	42%	45%	49%	50%		40%		-17%	17%	24%	-29%	22%	22%	10%	3%		6%	8%	3%		7%	2%	6%	5%	3%	4%	6%	2%	9%	2%	1%
7	Lagoon - 4S, 4L FALL 12	17.10			1																																	
8	Lagoon - 4S, 4L FALL 6	17.17	10.99	26.84	4	3%	15%	29%	28%	40%	40%		50%		35%	32%	29%	-26%	27%	17%	22%	10%		11%	16%	9%		16%	7%	6%	3%	6%	6%	12%	5%	17%	2%	0%
9	Lagoon - 8S, 2L SPRING 6	17.50			1																																	
10	Aerated	18.04	15.95	22.25	25	0%	1%	4%	8%	-10%	-17%		35%		50%	-29%	29%	-32%	23%	18%	-9%	2%		3%	-4%	1%		-3%	0%	1%	1%	0%	0%	-1%	0%	-2%	0%	0%
11	Lagoon - 4S, 2L FALL 6	20.99	14.14	31.14	15	-1%	3%	6%	13%	19%	17%		32%		-29%	50%	47%	-48%	43%	30%	28%	17%		20%	21%	13%		16%	8%	13%	12%	9%	9%	11%	5%	13%	5%	2%
12	Lagoon - 2S, 1L FALL 6	21.65	11.20	41.85	4	-1%	7%	11%	13%	25%	24%		29%		29%	47%	50%	-50%	46%	39%	37%	20%		28%	30%	23%		27%	10%	10%	14%	16%	16%	21%	13%	25%	8%	3%
13	Lagoon - 4S, 4L SPRING 12	21.74	21.36	22.13	2	0%	-10%	-16%	-13%	-30%	-29%		-26%		-32%	-48%	-50%	50%	-47%	25%	-41%	-33%		-32%	-35%	-29%		-33%	-24%	-20%	-11%	-22%	-19%	-27%	-18%	-31%	-10%	1%
14	Lagoon - 4S, 3L FALL 6	22.72	10.85	47.58	4	-1%	6%	9%	12%	23%	22%		27%		23%	43%	46%	-47%	50%	44%	41%	33%		32%	34%	28%		30%	21%	22%	19%	20%	19%	24%	15%	27%	11%	5%
15	Lagoon - 4S, 2L SUMMER 6	25.10	17.70	35.60	2	0%	7%	9%	7%	23%	22%		17%		18%	38%	39%	25%	44%	50%	49%	45%		42%	43%	39%		39%	33%	28%	20%	29%	27%	32%	24%	35%	15%	2%
16	Lagoon - 2S, 2L FALL 6	25.58	14.77	44.30	11	-1%	2%	3%	8%	13%	10%		22%		-9%	28%	37%	-41%	41%	49%	50%	44%		41%	40%	36%		33%	26%	29%	28%	24%	24%	24%	17%	26%	15%	10%
17	Lagoon - 4S, 3L SPRING 12	26.72	18.12	39.41	10	0%	1%	1%	2%	7%	6%		11%		3%	21%	29%	-33%	34%	45%	45%	50%		44%	43%	39%		35%	27%	26%	24%	23%	21%	22%	14%	-24%	10%	4%
18	Lagoon - 0S, 2L FALL 6	27.00			1																																	
19	Lagoon - 2S, 2L SPRING 6	27.95	17.47	44.73	8	0%	1%	1%	2%	7%	6%		11%		3%	20%	28%	-32%	32%	42%	41%	44%		50%	48%	46%		40%	34%	31%	29%	29%	27%	27%	19%	29%	14%	7%
20	Lagoon - 0S, 2L SPRING 12	28.70	14.58	56.50	7	0%	2%	2%	5%	10%	8%		16%		-4%	21%	30%	-35%	34%	43%	40%	41%		48%	50%	49%		43%	39%	37%	36%	34%	33%	32%	26%	33%	21%	14%
21	Lagoon - 4S, 2L SPRING 6	28.87	20.03	41.61	13	0%	0%	0%	1%	4%	3%		9%		1%	13%	23%	-29%	28%	39%	36%	37%		46%	49%	50%		42%	36%	33%	31%	29%	27%	26%	19%	-27%	14%	7%
22	Contact Stabilizat'n	29.56			1																																	
23	Lagoon - 2S, 2L SPRING 12	31.31	14.84	66.03	8	-1%	2%	-1%	-5%	9%	7%		16%		-3%	16%	27%	-33%	30%	39%	33%	32%		40%	43%	42%		50%	48%	44%	43%	42%	40%	38%	33%	38%	28%	21%
24	Lagoon - 4S, 2L SPRING 12	32.01	21.56	47.50	13	0%	0%	0%	1%	3%	2%		7%		0%	8%	18%	-24%	21%	33%	26%	23%		36%	39%	36%		48%	50%	43%	43%	41%	38%	34%	28%	34%	22%	13%
25	Lagoon - 4S, 3L SPRING 6	34.39	18.39	64.29	4	0%	1%	1%	1%	7%	6%		6%		1%	13%	18%	-20%	22%	28%	29%	24%		31%	37%	33%		44%	43%	50%	50%	50%	46%	43%	38%	42%	29%	17%
26	Lagoon - 4S, 4L SPRING 6	34.46	22.95	51.76	4	0%	0%	0%	1%	6%	5%		3%		1%	12%	14%	-11%	19%	20%	28%	23%		29%	36%	31%		43%	43%	50%	50%	50%	46%	42%	38%	42%	26%	12%
27	Lagoon - 8S, 1L FALL 6	34.56	19.85	60.14	7	0%	0%	0%	1%	4%	3%		6%		0%	9%	16%	-22%	20%	29%	24%	20%		29%	34%	29%		42%	41%	50%	50%	50%	46%	42%	37%	41%	29%	19%
28	Lagoon - 8S, 1L SPRING 6	35.96	19.29	67.03	5	0%	0%	0%	1%	5%	4%		6%		0%	9%	16%	-19%	19%	27%	24%	19%		27%	33%	27%		40%	38%	46%	46%	45%	50%	45%	41%	44%	33%	21%
29	Lagoon - 4S, 2L SUMMER 12	39.11	12.17	125.70	4	0%	2%	-1%	-4%	8%	6%		12%		-1%	11%	21%	-27%	24%	32%	24%	18%		27%	32%	26%		38%	34%	43%	42%	42%	45%	50%	49%	48%	43%	-36%
30	Lagoon - 0S, 2L FALL 12	39.90	20.79	76.59	6	0%	0%	0%	1%	3%	2%		5%		0%	5%	13%	-18%	15%	24%	17%	11%		19%	26%	19%		33%	28%	38%	38%	37%	41%	49%	50%	49%	42%	31%
31	Lagoon - 2S, 1L FALL 12	40.82	6.94	240.18	3	-1%	-3%	-2%	-6%	11%	9%		17%		-2%	13%	25%	-31%	27%	35%	26%	-20%		29%	33%	-27%		38%	34%	42%	42%	41%	44%	48%	49%	50%	46%	-41%
32	Lagoon - 8S, 1L FALL 12	44.35	24.35	80.75	4	0%	0%	0%	0%	3%	2%		2%		0%	5%	8%	-10%	12%	15%	15%	8%		14%	21%	14%		20%	22%	29%	26%	29%	33%	43%	42%	46%	50%	37%
33	Lagoon - 8S, 1L SPRING 12	49.64	37.59	65.55	4	0%	0%	0%	0%	1%	1%		0%		0%	2%	3%	1%	5%	2%	10%	4%		7%	24%	7%		21%	13%	17%	10%	19%	21%	-36%	31%	-41%	37%	50%

Figure 3.30 : T Tests of Treatment Systems, TSS

						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
					STATION	2L	2L	2L	2L	2L	2L	1L	3L	4L	3L	4L	2L	2L	1L	Stab	Slud	2L	2L	2L	4L	1L	1L	Aera	erate	RBC	1L	3L	1L	2L	2L	2L	3L	4L
					P	1.1	1.3	1.6	1.6	1.8	1.9	1.9	1.9	2.3	2.4	2.4	2.7	2.7	2.8	2.8	2.3	2.8	2.8	3.0	3.2	3.3	3.4	3.6	3.7	3.7	3.9	4.1	4.3	4.4	4.6	4.6	5.0	7.5
					PN	2	7	1	15	17	1	3	4	1	6	2	6	11	4	1	9	13	13	7	4	4	7	10	25	10	4	6	6	13	7	8	10	6
	STATION	P	Lower 95%	Upper 95%	PN																																	
1	Lagoon - 4S, 2L SUMMER 6	..05	0.03	31.87	2	50%	-41%		-20%	-22%		35%	-31%		22%	-34%	21%	-13%	27%		-15%	-5%	-11%	-15%	-10%	20%	-13%	-5%	-2%	-4%	-15%	17%	-9%	-4%	-6%	-4%	-2%	-7%
2	Lagoon - 2S, 2L FALL 12	1.30	0.76	2.24	7	-41%	50%		26%	16%		24%	10%		9%	-15%	8%	3%	12%		3%	0%	2%	3%	2%	4%	2%	0%	0%	0%	1%	2%	0%	0%	0%	0%	0%	0%
3	Lagoon - 0S, 2L SPRING 6	1.58			1																																	
4	Lagoon - 4S, 2L FALL 6	1.65	1.10	2.46	15	-20%	26%		50%	38%		39%	36%		17%	-26%	13%	6%	16%		7%	1%	4%	5%	6%	7%	3%	0%	0%	0%	3%	3%	1%	0%	0%	0%	0%	0%
5	Lagoon - 4S, 2L FALL 12	1.79	1.29	2.48	17	-22%	16%		38%	50%		44%	42%		20%	-28%	14%	7%	18%		7%	2%	5%	6%	6%	7%	3%	0%	0%	0%	2%	3%	1%	0%	0%	0%	0%	0%
6	Lagoon - 0S, 2L FALL 6	1.88			1																																	
7	Lagoon - 2S, 1L FALL 12	1.91	0.74	4.93	3	35%	24%		39%	44%		50%	50%		35%	-37%	32%	25%	35%		25%	14%	22%	21%	15%	20%	16%	4%	3%	-3%	9%	15%	7%	6%	4%	2%	1%	1%
8	Lagoon - 4S, 3L FALL 6	1.92	1.29	2.86	4	-31%	18%		36%	42%		50%	50%		31%	25%	27%	21%	31%		20%	9%	18%	15%	5%	12%	10%	1%	2%	0%	2%	9%	2%	3%	1%	0%	0%	0%
9	Lagoon - 4S, 4L FALL 12	2.28			1																																	
10	Lagoon - 4S, 3L FALL 12	2.39	1.27	4.52	6	22%	9%		17%	20%		35%	31%		50%	-50%	42%	38%	42%		36%	28%	33%	30%	25%	28%	22%	-9%	7%	-7%	15%	18%	9%	7%	6%	3%	1%	1%
11	Lagoon - 4S, 4L SPRING 12	2.40	2.35	2.46	2	-34%	-15%		-26%	-28%		-37%	25%		-50%	50%	-45%	-42%	-45%		-40%	34%	-39%	-35%	17%	-30%	-28%	8%	-16%	5%	9%	-23%	-12%	-15%	-8%	4%	2%	0%
12	Lagoon - 0S, 2L FALL 12	2.66	1.22	5.79	6	21%	8%		13%	14%		32%	27%		42%	-45%	50%	48%	48%		46%	-43%	44%	40%	36%	37%	31%	-19%	15%	-16%	24%	25%	16%	12%	12%	9%	-4%	-4%
13	Lagoon - 2S, 2L FALL 6	2.71	1.73	4.24	11	-13%	3%		6%	7%		25%	21%		38%	-42%	48%	50%	49%		47%	43%	44%	38%	33%	34%	27%	-15%	10%	-11%	19%	20%	11%	7%	7%	5%	2%	1%
14	Lagoon - 0S, 1L SPRING 12	2.75	0.77	9.85	4	27%	12%		16%	18%		35%	31%		42%	-45%	48%	49%	50%		49%	-48%	48%	44%	41%	41%	37%	-27%	-22%	-24%	31%	32%	24%	19%	19%	-16%	-10%	-9%
15	Contact Stabilizat'n	2.76			1																																	
16	A. Sludge	2.79	1.66	4.69	9	-15%	3%		7%	7%		25%	20%		36%	-40%	46%	47%	49%		50%	48%	48%	42%	37%	37%	31%	-19%	14%	-15%	23%	23%	14%	10%	9%	6%	3%	2%
17	Lagoon - 4S, 2L SUMMER 12	2.82	1.72	4.62	4	-22%	5%		11%	11%		24%	14%		36%	35%	46%	46%	49%		49%	50%	49%	44%	34%	38%	33%	16%	20%	11%	17%	25%	14%	15%	9%	5%	2%	1%
18	Lagoon - 4S, 2L SPRING 12	2.83	1.87	4.30	13	-11%	2%		4%	5%		22%	18%		33%	-39%	44%	44%	48%		48%	49%	50%	43%	37%	38%	31%	-19%	12%	-15%	22%	22%	13%	8%	8%	6%	2%	1%
19	Lagoon - 2S, 2L SPRING 12	3.02	1.74	5.26	7	-15%	3%		5%	6%		21%	15%		30%	-35%	40%	38%	44%		42%	39%	43%	50%	44%	44%	39%	-27%	23%	-22%	20%	20%	19%	16%	13%	10%	5%	2%
20	Lagoon - 4S, 4L FALL 6	3.23	2.27	4.60	4	-18%	2%		6%	6%		15%	5%		25%	17%	36%	33%	41%		37%	31%	37%	44%	50%	49%	45%	32%	33%	24%	25%	32%	21%	24%	15%	9%	5%	0%
21	Lagoon - 2S, 1L FALL 6	3.26	1.61	6.58	4	20%	4%		7%	7%		20%	12%		28%	-30%	37%	34%	41%		37%	32%	38%	44%	49%	50%	46%	37%	35%	31%	34%	36%	26%	26%	20%	15%	9%	3%
22	Lagoon - 0S, 1L FALL 6	3.41	1.93	6.02	7	-13%	2%		3%	3%		16%	10%		22%	-28%	31%	27%	37%		31%	23%	31%	39%	45%	46%	50%	-43%	38%	-37%	38%	37%	28%	25%	21%	18%	10%	4%
23	Ext. Aeration	3.58	2.88	4.45	10	-5%	0%		0%	0%		4%	1%		-9%	8%	-19%	-15%	-27%		-19%	10%	-19%	-27%	32%	37%	-43%	50%	43%	39%	35%	-35%	23%	-23%	14%	9%	3%	0%
24	Aerated	3.72	2.93	4.72	25	-2%	0%		0%	0%		5%	2%		7%	-16%	15%	10%	-22%		14%	6%	12%	23%	33%	35%	38%	43%	50%	49%	45%	40%	31%	24%	21%	18%	8%	2%
25	RBC	3.75	3.06	4.60	10	-4%	0%		0%	0%		-3%	0%		-7%	5%	-16%	-11%	-24%		-15%	6%	-15%	-22%	24%	31%	-37%	39%	49%	50%	43%	-40%	28%	-28%	18%	13%	5%	0%
26	Lagoon - 0S, 1L FALL 12	3.89	2.67	5.67	4	-15%	1%		3%	2%		9%	2%		15%	9%	24%	19%	31%		23%	12%	22%	28%	25%	34%	38%	35%	45%	43%	50%	47%	39%	39%	31%	25%	16%	1%
27	Lagoon - 4S, 3L SPRING 6	4.06	1.72	9.56	4	17%	2%		3%	3%		15%	9%		18%	-23%	25%	20%	32%		23%	13%	22%	28%	32%	36%	37%	-35%	40%	-40%	47%	50%	45%	44%	39%	36%	27%	11%
28	Lagoon - 0S, 1L SPRING 6	4.29	2.67	6.88	6	-9%	0%		1%	1%		7%	2%		9%	-12%	16%	11%	24%		14%	5%	13%	19%	21%	26%	28%	23%	31%	28%	39%	45%	50%	48%	42%	39%	27%	6%
29	Lagoon - 4S, 2L SPRING 6	4.37	2.87	6.66	13	-4%	0%		0%	0%		6%	3%		7%	-15%	12%	7%	19%		10%	3%	8%	16%	24%	26%	25%	-23%	24%	-28%	39%	44%	48%	50%	45%	42%	31%	10%
30	Lagoon - 0S, 2L SPRING 12	4.58	3.01	6.96	7	-6%	0%		0%	0%		4%	1%		6%	-8%	12%	7%	19%		9%	2%	8%	13%	15%	20%	21%	14%	21%	18%	31%	39%	42%	45%	50%	48%	36%	7%
31	Lagoon - 2S, 2L SPRING 6	4.63	3.44	6.24	8	-4%	0%		0%	0%		2%	0%		3%	4%	9%	5%	-16%		6%	7.	6%	10%	9%	15%	18%	9%	10%	13%	25%	36%	39%	42%	48%	50%	35%	3%
32	Lagoon - 4S, 3L SPRING 12	5.01	3.86	6.50	10	-2%	0%		0%	0%		1%	0%		1%	2%	-4%	2%	-10%		3%	0%	2%	5%	5%	9%	10%	3%	8%	5%	16%	27%	27%	31%	36%	35%	50%	5%
33	Lagoon - 4S, 4L SPRING 6	7.53	5.92	9.58	4	-7%	0%		0%	0%		1%	0%		1%	0%	-4%	1%	-9%		2%	0%	1%	2%	0%	3%	4%	0%	2%	0%	1%	11%	6%	10%	7%	3%	5%	50%

Figure 3.31 : T Tests of Treatment Systems, Phosphorus

						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
					STATION	1L	3L	2L	2L	2L	2L	2L	4L	Aera	3L	4L	2L	1L	1L	2L	4L	2L	2L	2L	Slud	RBC	Stab	2L	1L	1L	erate	2L	2L	3L	2L	1L	3L	4L
					NH3	0.4	0.5	0.6	0.7	0.8	0.9	1.2	1.2	1.3	1.5	2.0	2.2	2.5	2.8	2.9	2.9	3.0	3.1	3.2	3.3	3.4	3.6	3.6	3.7	5.2	9.1	11.8	12.0	12.4	13.7	15.9	16.1	19.7
					NH3N	3	7	7	17	6	2	15	1	10	4	4	5	4	4	13	2	10	8	11	9	10	1	1	7	4	25	13	8	10	7	6	4	4
	STATION	NH3	Lower 95%	Upper 95%	NH3N																																	
1	Lagoon - 2S, 1L FALL 12	0.45	0.08	2.62	3	50%	44%	45%	31%	36%	38%	18%		18%	14%	13%	11%	16%	13%	7%	10%		9%	4%	2%	1%			3%	9%	0%	0%	0%	0%	0%	0%	0%	0%
2	Lagoon - 4S, 3L FALL 12	0.54	0.14	2.05	7	44%	50%	49%	38%	36%	38%	16%		17%	17%	13%	10%	12%	10%	4%	12%		5%	2%	2%	1%			2%	5%	0%	0%	0%	0%	0%	0%	0%	0%
3	Lagoon - 2S, 2L FALL 12	0.55	0.10	2.98	7	45%	49%	50%	-40%	38%	40%	19%		20%	22%	17%	14%	16%	13%	5%	18%		8%	3%	3%	-2%			4%	7%	0%	0%	0%	0%	0%	0%	1%	-1%
4	Lagoon - 4S, 2L FALL 12	0.66	0.37	1.17	17	31%	38%	-40%	50%	-39%	-37%	13%		12%	11%	7%	4%	5%	4%	1%	5%		1%	0%	0%	0%			0%	1%	0%	0%	0%	0%	0%	0%	0%	0%
5	Lagoon - 0S, 2L FALL 12	0.82	0.11	5.88	6	36%	36%	38%	-39%	50%	48%	35%		33%	33%	27%	23%	24%	22%	12%	26%		15%	9%	0%	-6%			9%	13%	0%	0%	-1%	0%	-1%	-1%	-2%	-2%
6	Lagoon - 4S, 2L SUMMER 6	0.95	0.01	160.11	2	38%	38%	40%	-37%	48%	50%	44%		42%	40%	36%	33%	35%	32%	25%	35%		27%	21%	-19%	-14%			20%	25%	-1%	-2%	-4%	-2%	-3%	-3%	-8%	-7%
7	Lagoon - 4S, 2L FALL 6	1.19	0.51	2.76	15	18%	16%	19%	13%	35%	44%	50%		45%	39%	29%	24%	23%	20%	10%	23%		12%	7%	6%	4%			7%	8%	0%	0%	0%	0%	0%	0%	0%	0%
8	Lagoon - 4S, 4L FALL 12	1.22			1																																	
9	Ext. Aeration	1.31	0.44	3.93	10	18%	17%	20%	12%	33%	42%	45%		50%	44%	34%	29%	29%	25%	16%	27%		18%	12%	10%	-7%			11%	12%	0%	0%	0%	0%	0%	0%	1%	-1%
10	Lagoon - 4S, 3L FALL 6	1.52	0.48	4.75	4	14%	17%	22%	11%	33%	40%	39%		44%	50%	39%	36%	35%	31%	27%	25%		27%	20%	16%	9%			15%	18%	0%	0%	0%	0%	0%	0%	1%	0%
11	Lagoon - 4S, 4L FALL 6	2.02	0.43	9.56	4	13%	13%	17%	7%	27%	36%	29%		34%	39%	50%	47%	44%	40%	37%	38%		36%	31%	28%	21%			26%	26%	1%	1%	1%	0%	-1%	-1%	2%	-2%
12	Lagoon - 4S, 2L SUMMER 12	2.22	0.52	9.47	5	11%	10%	14%	4%	23%	33%	24%		29%	36%	47%	50%	46%	43%	40%	43%		38%	34%	31%	25%			28%	26%	1%	1%	2%	-1%	-1%	-1%	3%	-2%
13	Lagoon - 0S, 1L FALL 12	2.54	0.26	25.02	4	16%	12%	16%	5%	24%	35%	23%		29%	35%	44%	46%	50%	48%	46%	47%		44%	42%	39%	-36%			37%	34%	-3%	-4%	-6%	-3%	-5%	-5%	9%	-7%
14	Lagoon - 2S, 1L FALL 6	2.80	0.39	20.25	4	13%	10%	13%	4%	22%	32%	20%		25%	31%	40%	43%	48%	50%	49%	49%		47%	45%	43%	-39%			39%	35%	-3%	4%	5%	-3%	-4%	-4%	7%	-5%
15	Lagoon - 4S, 2L SPRING 12	2.87	1.03	7.96	13	7%	4%	5%	1%	12%	25%	10%		16%	27%	37%	40%	46%	49%	50%	49%		46%	44%	42%	-39%			38%	30%	-1%	1%	-3%	-1%	-2%	-2%	5%	-3%
16	Lagoon - 4S, 4L SPRING 12	2.94	1.92	4.50	2	10%	12%	10%	5%	26%	35%	23%		27%	25%	38%	41%	47%	49%	49%	50%		48%	47%	45%	41%			41%	38%	5%	5%	3%	1%	0%	0%	1%	0%
17	Lagoon - 0S, 2L SPRING 6	3.05			1																																	
18	Lagoon - 2S, 2L SPRING 12	3.13	0.72	13.53	8	9%	5%	8%	1%	15%	27%	12%		10%	27%	36%	38%	44%	47%	46%	48%		50%	49%	47%	-45%			43%	35%	-2	-4%	-6%	-3%	-5%	-5%	8%	-6%
19	Lagoon - 2S, 2L FALL 6	3.17	1.27	7.88	11	4%	2%	3%	0%	9%	21%	7%		12%	20%	31%	34%	42%	45%	44%	47%		49%	50%	47%	44%			42%	31%	-1%	1%	2%	-1%	-1%	-1%	3%	-2%
20	A. Sludge	3.33	1.45	7.61	9	2%	2%	3%	0%	8%	-19%	6%		10%	16%	28%	31%	39%	43%	42%	45%		47%	47%	50%	47%			44%	32%	1%	1%	1%	1%	1%	-1%	2%	1%
21	RBC	3.44	1.99	5.95	10	1%	1%	-2%	0%	-6%	-14%	4%		-7%	9%	21%	25%	-36%	-39%	-39%	41%		-45%	44%	47%	50%			45%	-31%	0%	0%	0%	0%	0%	0%	0%	0%
22	Contact Stabilizat'n	3.64			1																																	
23	Lagoon - 0S, 2L FALL 6	3.65			1																																	
24	Lagoon - 0S, 1L FALL 6	3.69	1.37	9.92	7	3%	2%	4%	0%	9%	20%	7%		11%	15%	26%	28%	37%	39%	38%	41%		43%	42%	44%	45%			50%	37%	2%	2%	3%	1%	2%	-1%	3%	2%
25	Lagoon - 0S, 1L SPRING 12	5.25	0.57	48.18	4	9%	5%	7%	1%	13%	25%	8%		12%	18%	26%	26%	34%	35%	30%	38%		35%	31%	32%	-31%			37%	50%	-20%	16%	-19%	-14%	-15%	-13%	19%	-15%
26	Aerated	9.06	6.28	13.06	25	0%	0%	0%	0%	0%	-1%	0%		0%	0%	1%	1%	-3%	-3%	-1%	5%		-3%	-1%	1%	0%			2%	-20%	50%	22%	23%	17%	14%	8%	12%	6%
27	Lagoon - 4S, 2L SPRING 6	11.76	6.54	21.14	13	0%	0%	0%	0%	0%	-2%	0%		0%	0%	1%	1%	-4%	4%	1%	5%		-4%	1%	1%	0%			2%	16%	22%	50%	40%	44%	37%	26%	29%	19%
28	Lagoon - 2S, 2L SPRING 6	11.97	6.56	21.84	8	3%	0%	0%	0%	-1%	-4%	0%		0%	0%	1%	2%	-6%	5%	-3%	3%		-6%	2%	1%	0%			3%	-19%	23%	40%	50%	46%	37%	24%	28%	15%
29	Lagoon - 4S, 3L SPRING 12	12.43	8.27	18.70	10	0%	0%	0%	0%	0%	-2%	0%		0%	0%	0%	-1%	-3%	-3%	-1%	1%		-3%	-1%	1%	0%			1%	-14%	17%	44%	46%	50%	38%	22%	25%	11%
30	Lagoon - 0S, 2L SPRING 12	13.66	9.01	20.72	7	0%	0%	0%	0%	-1%	-3%	0%		0%	0%	-1%	-1%	-5%	-4%	-2%	0%		-5%	-1%	1%	0%			2%	-15%	14%	37%	37%	38%	50%	30%	33%	14%
31	Lagoon - 0S, 1L SPRING 6	15.93	11.02	23.02	6	0%	0%	0%	0%	-1%	-3%	0%		0%	0%	-1%	-1%	-5%	-4%	-2%	0%		-5%	-1%	-1%	0%			-1%	-13%	8%	26%	24%	22%	30%	50%	40%	23%
32	Lagoon - 4S, 3L SPRING 6	16.14	9.01	28.91	4	0%	0%	1%	0%	-2%	-8%	0%		1%	1%	2%	3%	9%	7%	5%	1%		8%	3%	2%	0%			3%	19%	12%	29%	28%	25%	33%	40%	50%	35%
33	Lagoon - 4S, 4L SPRING 6	19.65	13.86	27.86	4	0%	0%	-1%	0%	-2%	-7%	0%		-1%	0%	-2%	-2%	-7%	-5%	-3%	0%		-6%	-2%	[illegible]	0%			2%	-15%	6%	19%	15%	11%	14%	23%	30%	50%

Figure 3.32 : T Tests of Treatment Systems, Ammonia

#	STATION	TKN	Lower 95%	Upper 95%	n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
					STATION	4L	3L	2L	2L	1L	2L	Aera	3L	2L	4L	2L	RBC	2L	4L	2L	Slud	2L	Stab	1L	2L	2L	1L	2L	1L	1L	Aerate	2L	3L	2L	2L	3L	1L	4L
					TKN	2.8	3.6	3.7	4.2	5.3	5.3	5.4	5.6	5.9	6.0	6.4	6.6	6.7	7.1	7.7	8.4	8.4	9.4	9.6	10.4	10.5	10.9	12.1	12.1	12.2	14.5	17.0	17.8	18.2	19.0	19.9	20.7	25.7
					n	1	7	17	7	3	15	10	4	1	4	6	10	1	2	11	9	13	1	4	5	8	7	2	4	4	25	13	10	8	7	4	6	4
	STATION	TKN	Lower 95%	Upper 95%	n																																	
1	Lagoon - 4E, 4L FALL 12	2.76			1																																	
2	Lagoon - 4E, 3L FALL 12	3.60	1.96	6.62	7		50%	-47%	37%	25%	15%	18%	19%		18%	14%	4%		-15%	3%	2%	1%		4%	3%	1%	1%	12%	4%	1%	0%	0%	0%	0%	0%	0%	0%	0%
3	Lagoon - 4E, 2L FALL 12	3.67	2.97	4.55	17		-47%	50%	-32%	12%	-5%	-0%	7%		6%	-4%	0%		7%	0%	0%	0%		0%	0%	0%	0%	-2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
4	Lagoon - 2E, 2L FALL 12	4.17	2.24	7.75	7		37%	-32%	50%	34%	25%	28%	28%		25%	20%	9%		-21%	6%	4%	3%		7%	4%	2%	1%	15%	5%	2%	0%	0%	0%	0%	0%	0%	0%	0%
5	Lagoon - 2E, 1L FALL 12	5.31	2.44	11.59	3		25%	12%	34%	50%	50%	49%	46%		42%	39%	29%		-31%	22%	16%	18%		17%	14%	0%	6%	20%	16%	4%	1%	1%	0%	1%	1%	2%	0%	0%
6	Lagoon - 4E, 2L FALL 6	5.34	3.58	7.97	15		15%	-5%	25%	50%	50%	49%	46%		40%	33%	24%		-31%	12%	6%	6%		10%	6%	3%	2%	-14%	6%	3%	0%	0%	0%	0%	0%	0%	0%	0%
7	Ext. Aeration	5.37	3.10	9.29	10		18%	-8%	28%	49%	48%	50%	47%		41%	35%	27%		-34%	16%	12%	9%		14%	9%	5%	4%	-19%	9%	5%	0%	0%	0%	0%	0%	1%	0%	0%
8	Lagoon - 4E, 3L FALL 6	5.59	3.07	10.16	4		19%	7%	28%	46%	46%	47%	50%		45%	40%	31%		-31%	23%	16%	17%		15%	12%	7%	5%	27%	14%	3%	0%	0%	0%	0%	0%	1%	0%	0%
9	Lagoon - 0E, 2L SPRING 6	5.85			1																																	
10	Lagoon - 4E, 4L FALL 6	6.02	2.58	14.00	4		18%	6%	25%	42%	40%	41%	45%		50%	46%	41%		-41%	30%	23%	23%		22%	18%	12%	10%	30%	18%	9%	1%	1%	0%	1%	1%	3%	1%	-1%
11	Lagoon - 0E, 2L FALL 12	6.45	2.89	14.37	6		14%	-4%	20%	39%	33%	35%	40%		46%	50%	48%		-45%	34%	27%	26%		26%	21%	15%	13%	29%	19%	13%	1%	1%	-1%	1%	2%	4%	1%	-1%
12	RBC	6.57	4.75	9.08	10		4%	0%	9%	29%	24%	27%	31%		41%	48%	50%		42%	29%	19%	19%		15%	10%	5%	4%	-20%	9%	2%	0%	0%	0%	0%	0%	0%	0%	0%
13	Lagoon - 0E, 2L FALL 6	6.70			1																																	
14	Lagoon - 4E, 4L SPRING 12	7.10	6.91	7.29	2		-15%	3%	-21%	-31%	-31%	-34%	-31%		-41%	-45%	42%		50%	-44%	-37%	-39%		-31%	-28%	-22%	18%	-39%	-29%	3%	5%	-5%	3%	2%	2%	2%	0%	0%
15	Lagoon - 2E, 2L FALL 6	7.66	5.00	11.73	11		3%	0%	6%	22%	12%	16%	23%		30%	34%	29%		-44%	50%	39%	38%		30%	23%	17%	14%	-28%	18%	12%	0%	1%	0%	1%	1%	2%	0%	0%
16	A. Sludge	8.36	5.49	12.74	9		2%	0%	4%	16%	8%	12%	16%		23%	27%	19%		-37%	39%	50%	50%		37%	29%	24%	20%	-33%	23%	15%	1%	1%	0%	1%	1%	2%	0%	0%
17	Lagoon - 4E, 2L SPRING 12	8.39	5.48	12.85	13		2%	0%	4%	19%	7%	11%	18%		24%	27%	20%		-39%	39%	50%	50%		38%	31%	25%	22%	-32%	24%	19%	1%	1%	1%	1%	1%	3%	1%	1%
18	Contact Stabilizat'n	9.39			1																																	
19	Lagoon - 2E, 1L FALL 6	9.64	4.54	20.44	4		4%	0%	7%	17%	10%	14%	15%		22%	26%	15%		-31%	30%	37%	38%		50%	44%	42%	38%	43%	38%	29%	11%	8%	3%	6%	6%	8%	3%	2%
20	Lagoon - 4E, 2L SUMMER 12	10.42	5.07	21.43	5		3%	0%	4%	14%	6%	9%	12%		18%	21%	10%		-28%	23%	29%	30%		44%	50%	49%	45%	45%	41%	37%	15%	10%	5%	8%	8%	11%	5%	4%
21	Lagoon - 2E, 2L SPRING 12	10.48	6.69	16.44	8		1%	0%	2%	8%	3%	5%	7%		12%	15%	5%		-22%	17%	24%	24%		42%	49%	50%	45%	-44%	39%	34%	10%	6%	3%	4%	4%	6%	2%	1%
22	Lagoon - 0E, 1L FALL 6	10.94	7.11	16.84	7		1%	0%	1%	6%	2%	4%	5%		10%	13%	4%		18%	14%	20%	21%		38%	45%	45%	50%	-46%	42%	37%	14%	8%	3%	5%	4%	6%	2%	1%
23	Lagoon - 4E, 2L SUMMER 6	12.05	0.43	337.72	2		12%	-2%	15%	30%	-14%	-19%	27%		30%	29%	-20%		-39%	-28%	-33%	-31%		43%	45%	-44%	-46%	50%	50%	-50%	-37%	-32%	-20%	-30%	-30%	-34%	-27%	-26%
24	Lagoon - 0E, 1L SPRING 12	12.13	3.88	37.85	4		4%	0%	5%	16%	6%	9%	14%		18%	19%	9%		-29%	18%	23%	22%		38%	41%	39%	42%	50%	50%	-50%	-31%	23%	-18%	20%	20%	23%	-16%	-13%
25	Lagoon - 0E, 1L FALL 12	12.17	9.15	16.19	4		1%	0%	2%	4%	3%	5%	3%		9%	13%	2%		3%	12%	15%	18%		29%	37%	34%	37%	-50%	-50%	50%	29%	18%	6%	9%	8%	7%	2%	0%
26	Aerated	14.49	11.50	18.25	25		0%	0%	0%	1%	0%	0%	0%		1%	1%	0%		5%	0%	1%	1%		11%	15%	10%	14%	-37%	-31%	29%	50%	23%	16%	17%	14%	16%	0%	3%
27	Lagoon - 4E, 2L SPRING 6	16.98	11.85	24.33	13		0%	0%	0%	1%	0%	0%	0%		1%	1%	0%		-5%	1%	1%	1%		0%	10%	6%	0%	-32%	23%	10%	23%	50%	43%	40%	35%	33%	25%	12%
28	Lagoon - 4E, 3L SPRING 12	17.75	13.84	22.77	10		0%	0%	0%	0%	0%	0%	0%		0%	-1%	0%		1%	0%	0%	0%		3%	5%	3%	3%	-20%	-10%	6%	16%	43%	50%	45%	39%	33%	23%	6%
29	Lagoon - 2E, 2L SPRING 6	18.23	12.69	26.18	8		0%	0%	0%	1%	0%	0%	0%		1%	1%	0%		2%	1%	1%	1%		6%	0%	4%	5%	-38%	20%	9%	17%	40%	45%	50%	44%	39%	31%	12%
30	Lagoon - 0E, 2L SPRING 12	18.97	12.79	28.15	7		0%	0%	0%	1%	0%	0%	0%		1%	2%	0%		2%	1%	1%	1%		6%	0%	4%	4%	-30%	20%	8%	14%	35%	39%	44%	50%	44%	37%	16%
31	Lagoon - 4E, 3L SPRING 6	19.91	12.26	32.33	4		0%	0%	0%	2%	0%	1%	1%		3%	4%	0%		2%	2%	2%	2%		0%	11%	6%	6%	-34%	23%	7%	10%	33%	33%	39%	44%	50%	44%	19%
32	Lagoon - 0E, 1L SPRING 6	20.73	15.22	28.23	6		0%	0%	0%	0%	0%	0%	0%		1%	1%	0%		0%	0%	0%	1%		3%	5%	2%	2%	-27%	-16%	2%	8%	25%	23%	31%	37%	44%	50%	17%
33	Lagoon - 4E, 4L SPRING 6	25.68	20.85	31.62	4		0%	0%	0%	0%	0%	0%	0%		-1%	-1%	0%		0%	0%	0%	1%		2%	4%	1%	1%	-26%	-13%	0%	3%	12%	6%	12%	16%	19%	17%	50%

Figure 3.33 : T Tests of Treatment Systems, TKN

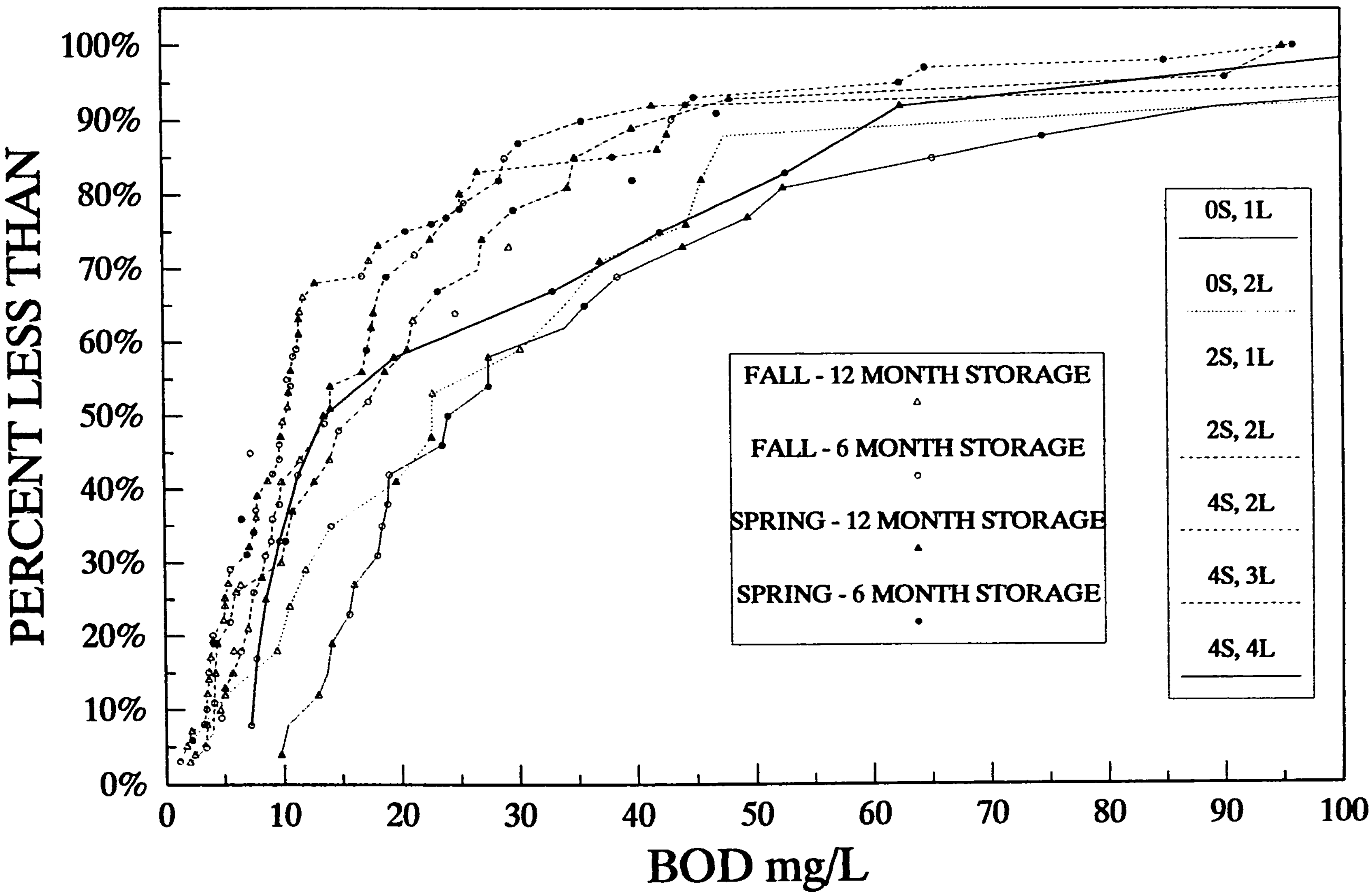


Figure 3.34 : Cumulative Distributions of Lagoon Systems, BOD

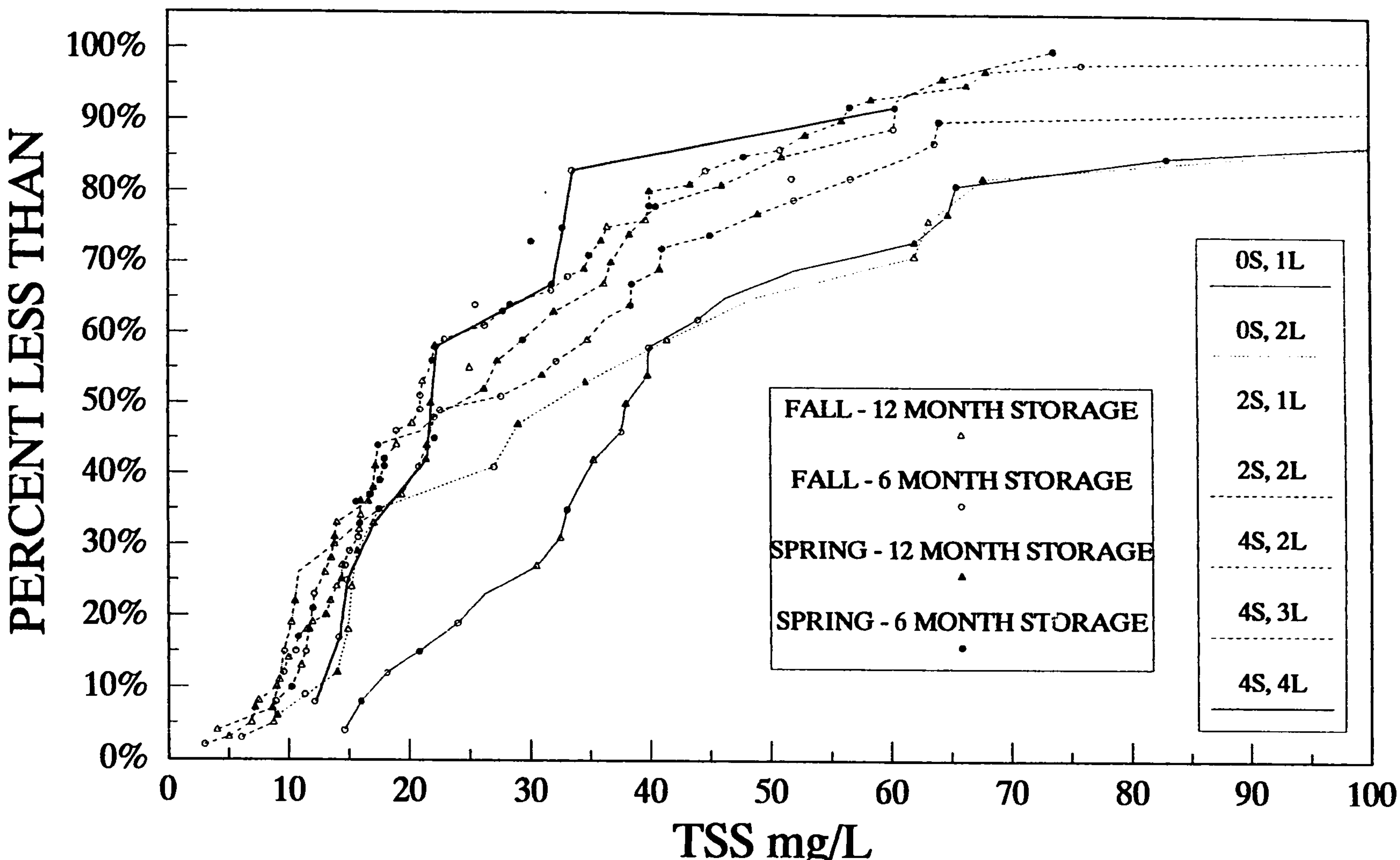


Figure 3.35 : Cumulative Distributions of Lagoon Systems, TSS

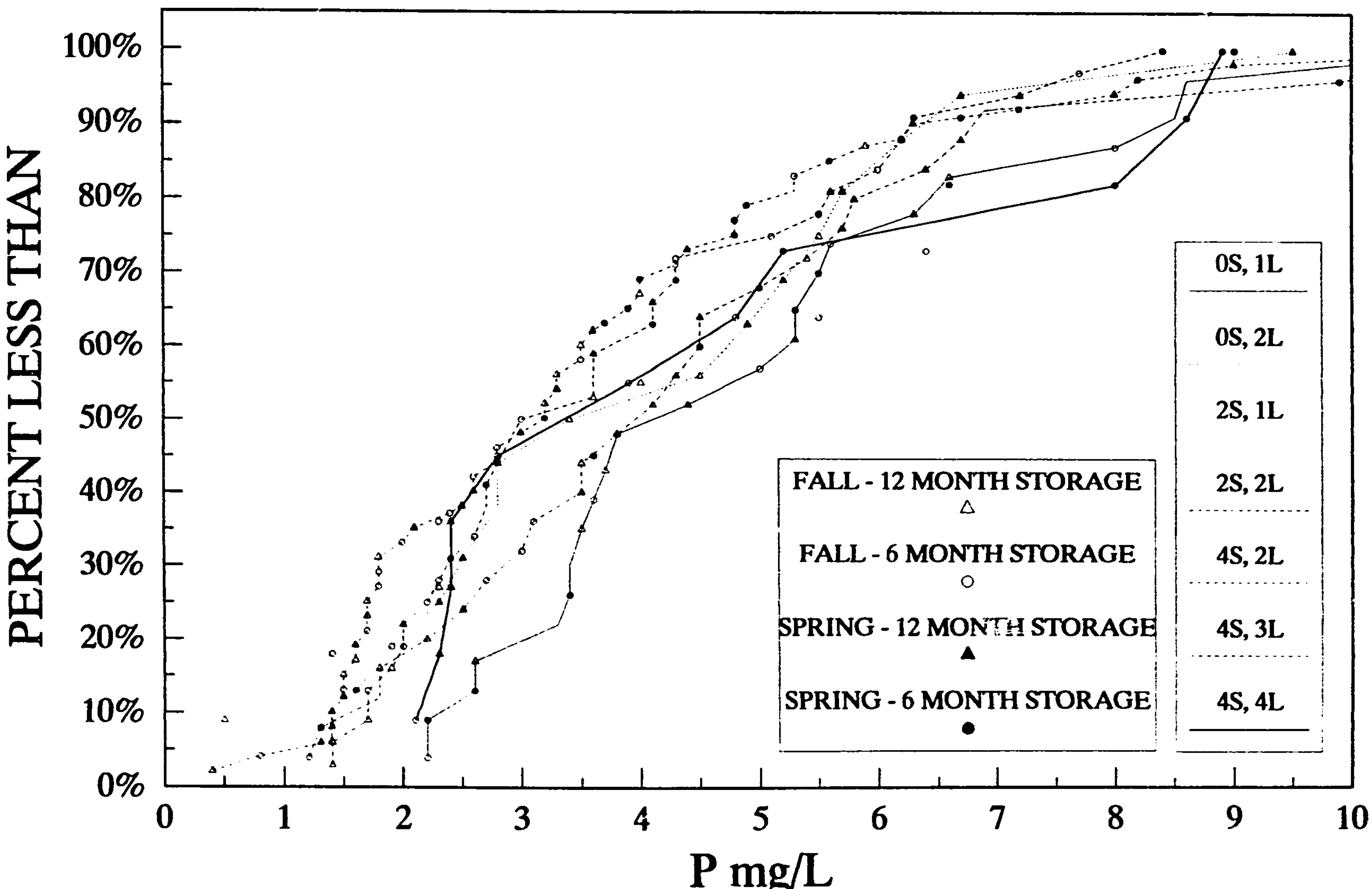


Figure 3.36 : Cumulative Distributions of Lagoon Systems, P

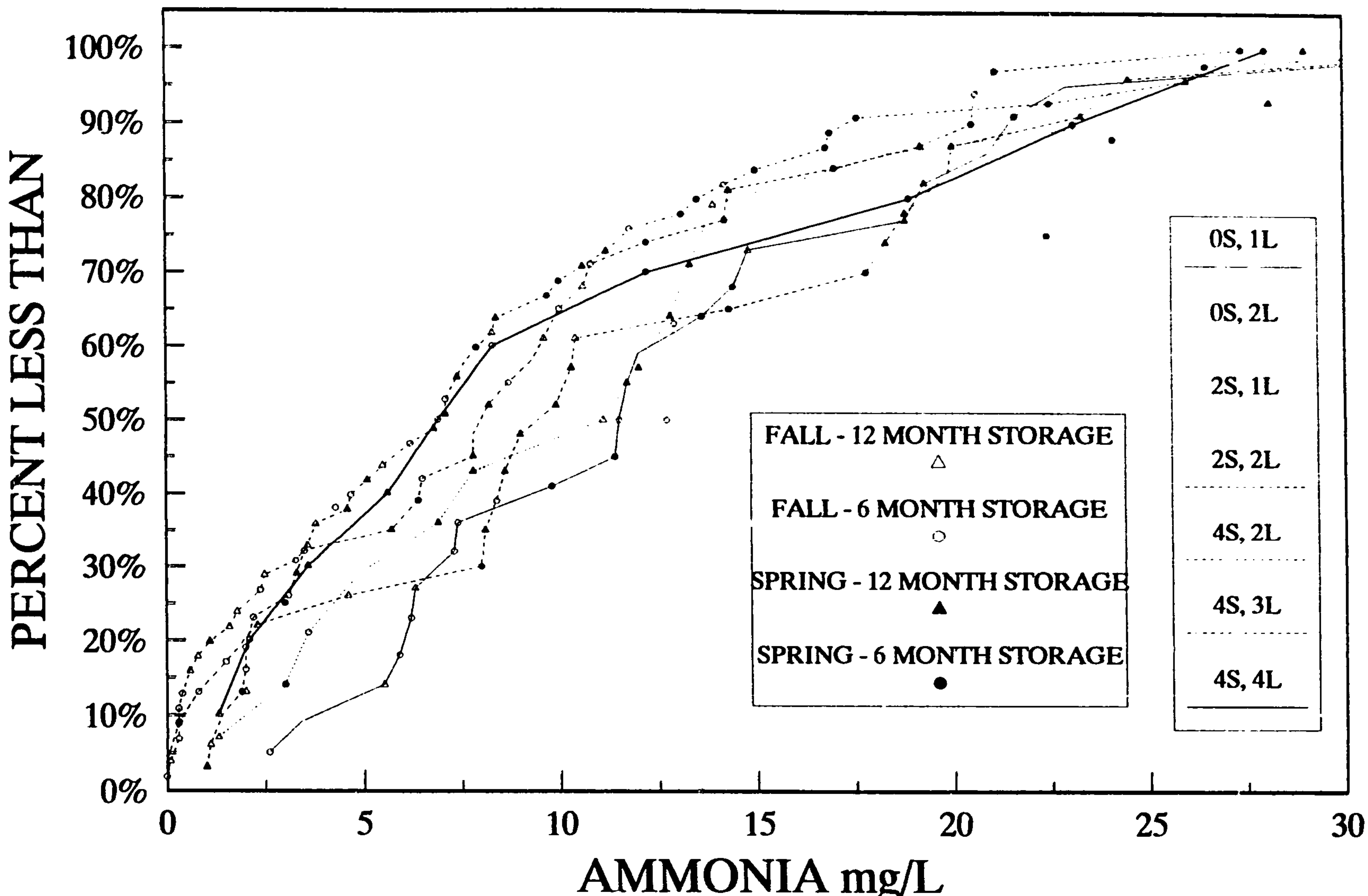


Figure 3.37 : Cumulative Distributions of Lagoon Systems, AMMONIA

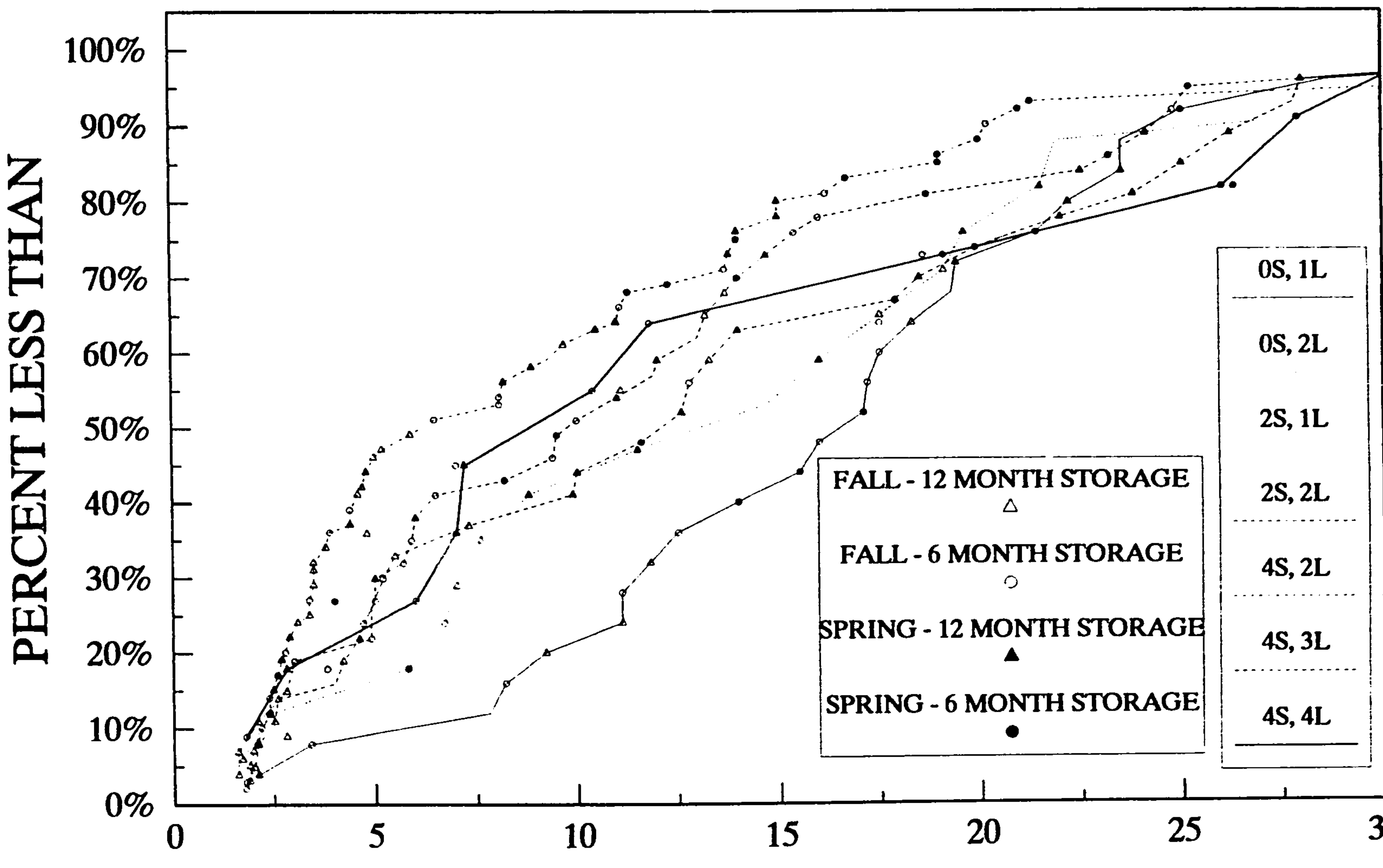


Figure 3.38 : Cumulative Distributions of Lagoon Syste.ns, TKN

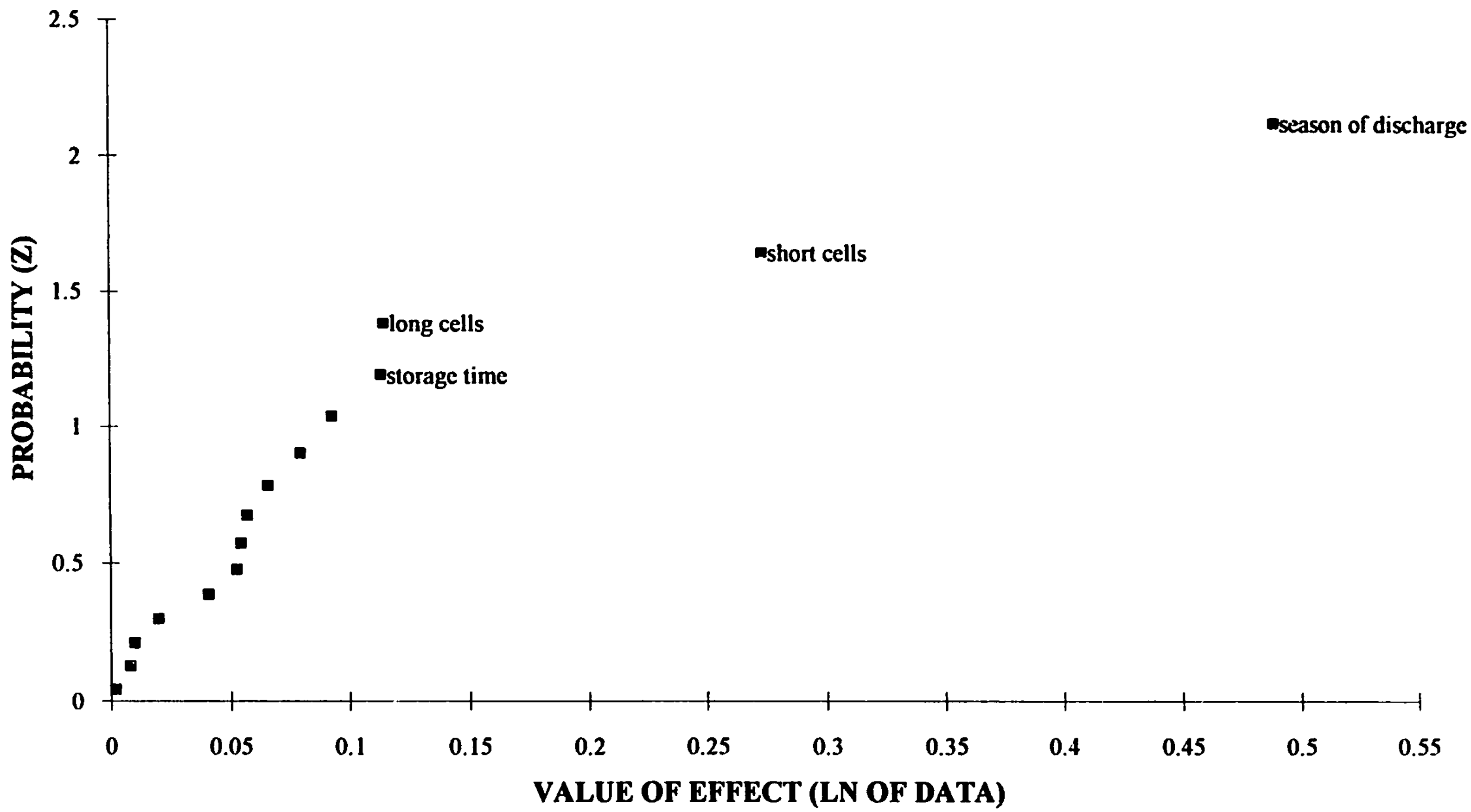


Figure 3.39 : Half- Normal Plot for BOD

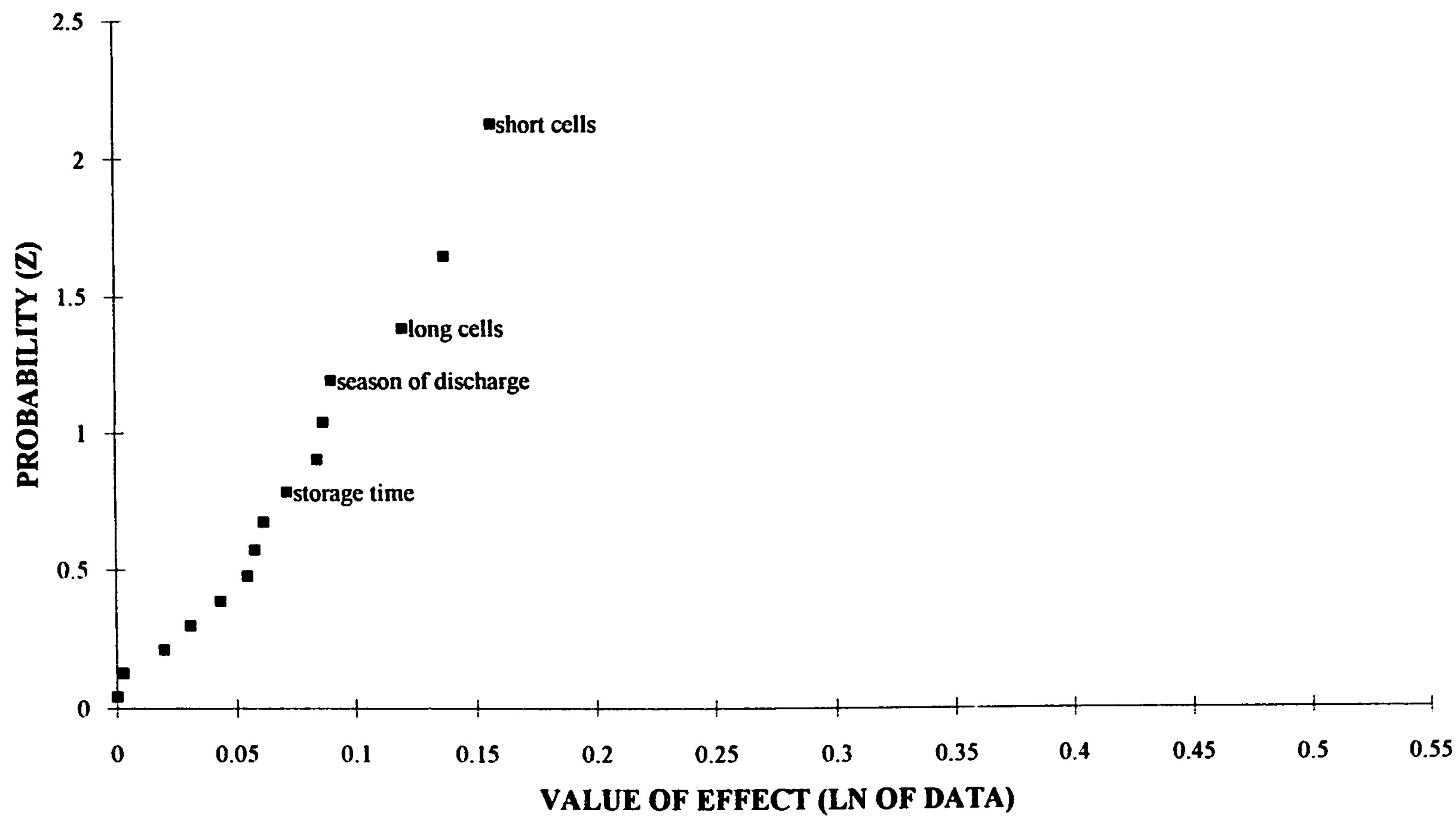


Figure 3.40 : Half-Normal Plot for TSS

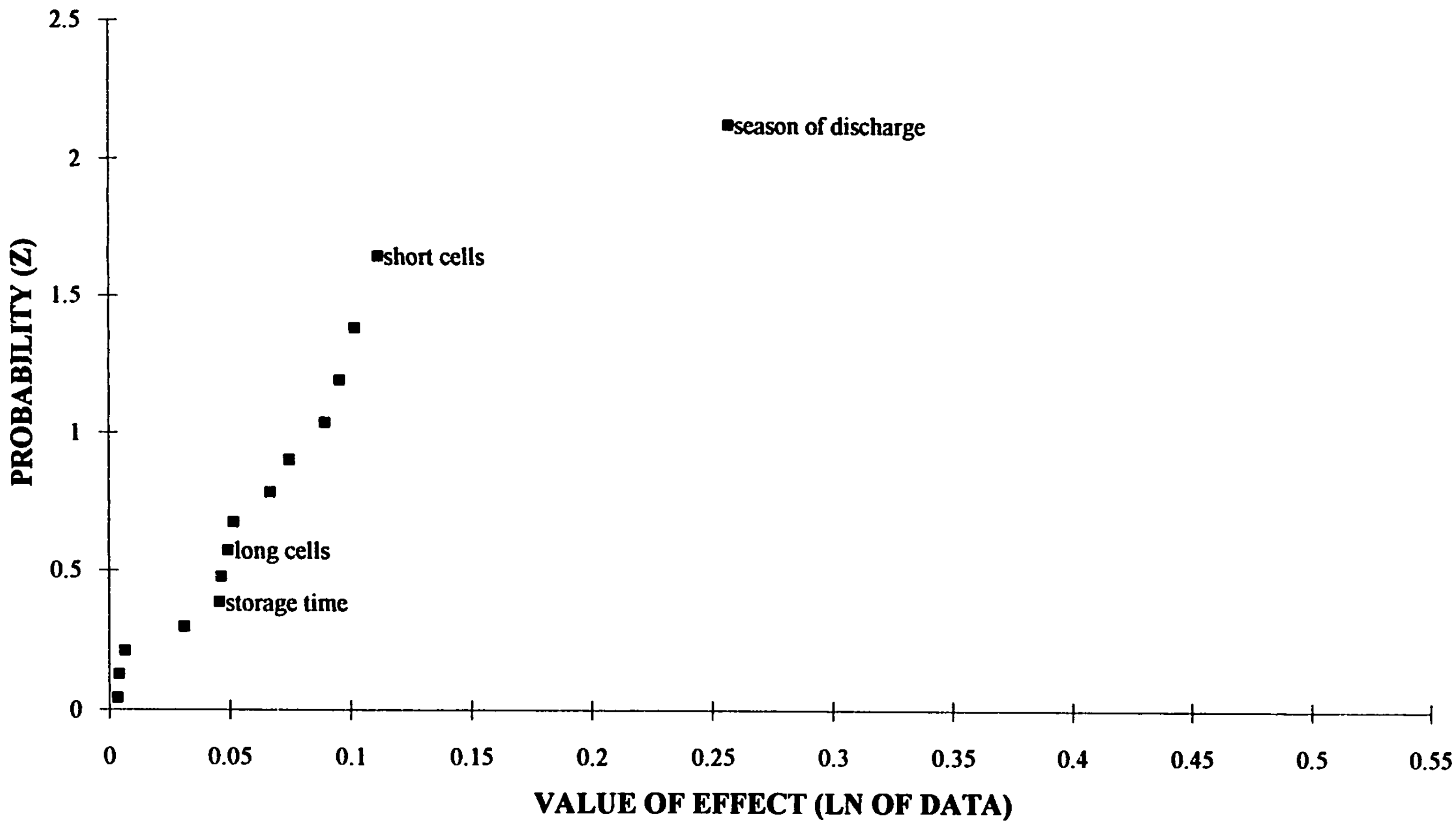


Figure 3.41 : Half-Normal Plots for Phosphorus

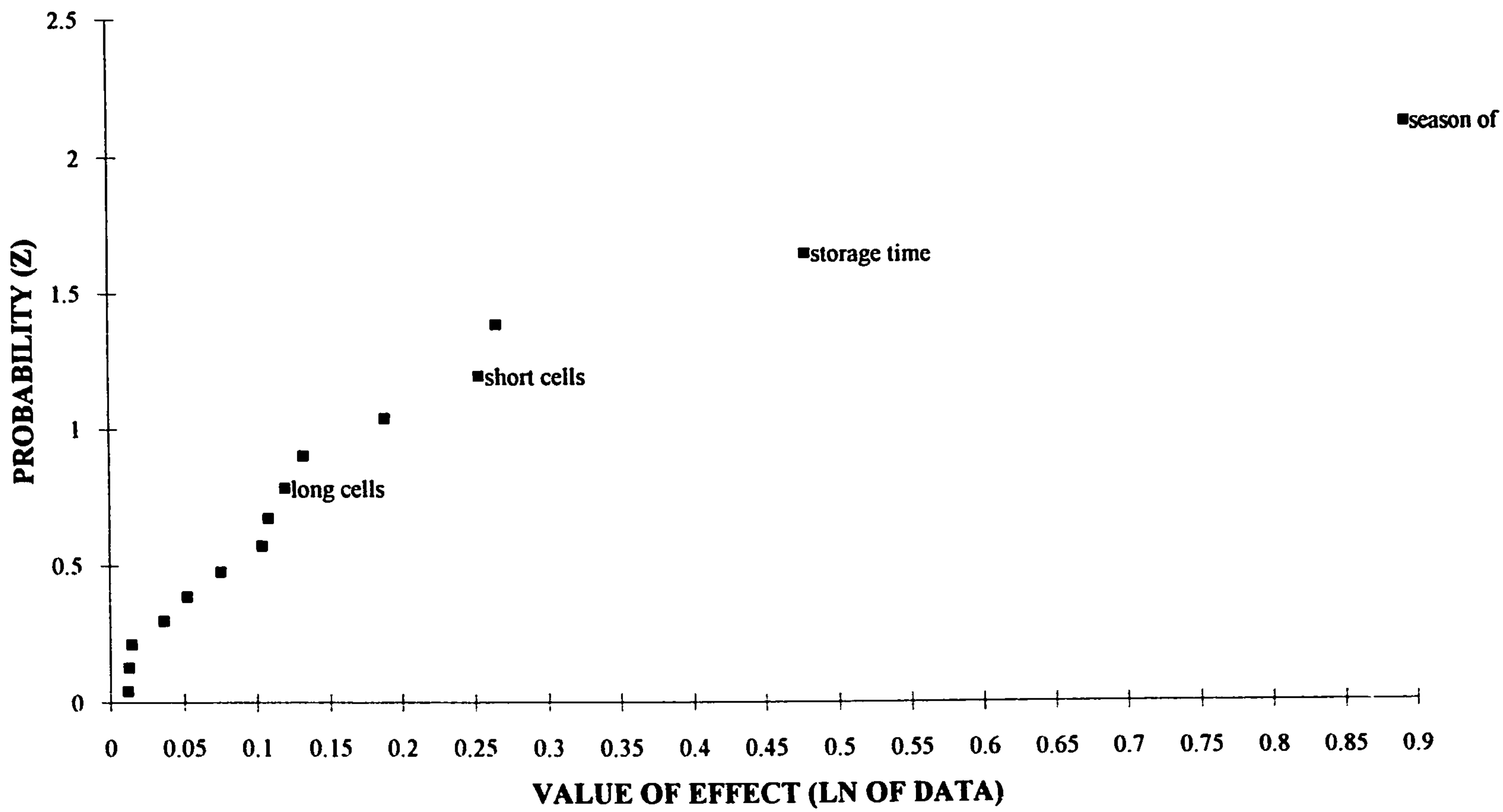


Figure 3.42 : Half-Normal Plot for Ammonia

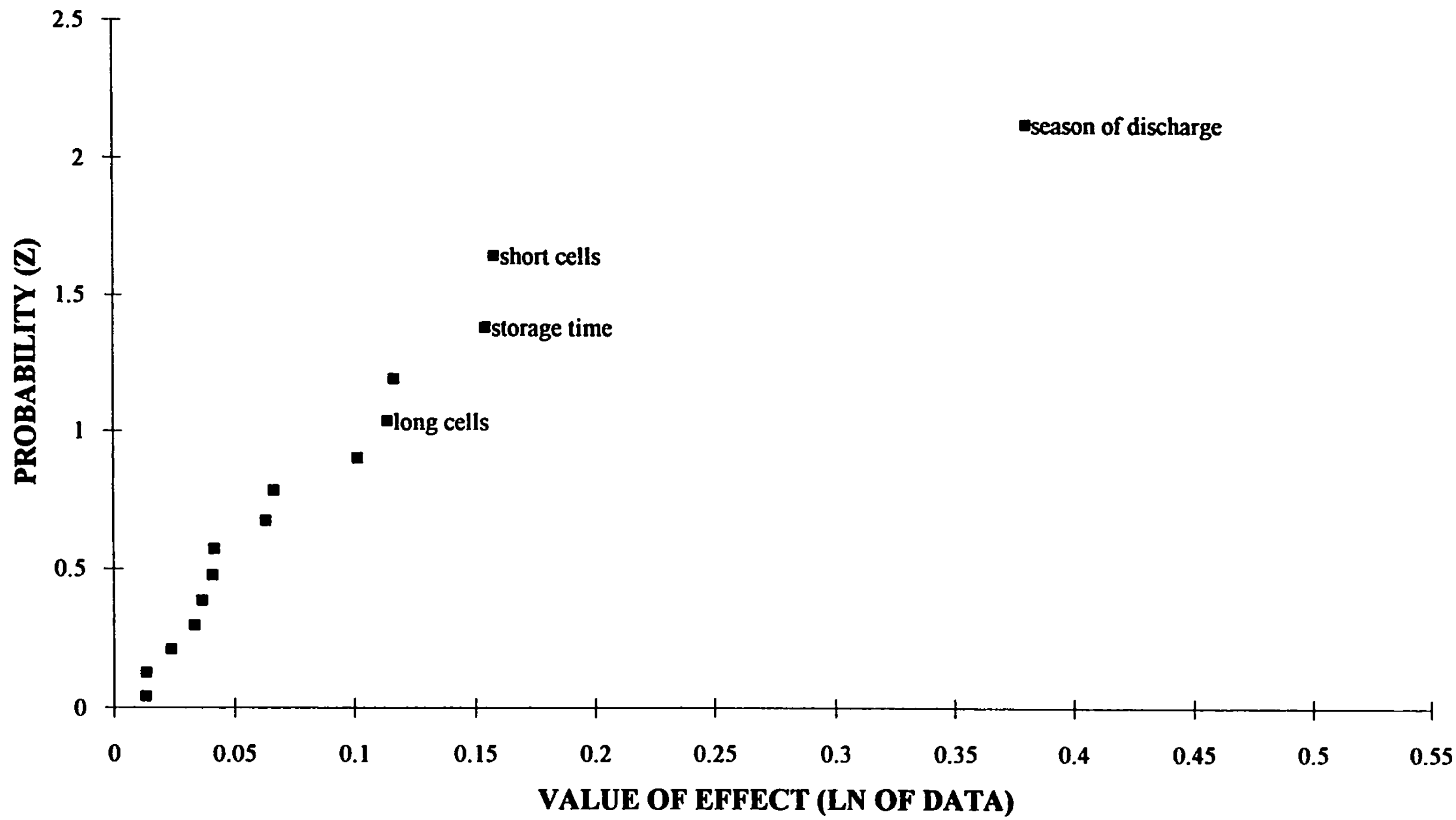


Figure 3.43 : Half-Normal Plot for TKN

4.0 IMPACTS OF LAGOON TREATED EFFLUENT

4.1 Introduction

The discussion of the impact of lagoon treated municipal wastewater is not too different from any treatment applied to municipal wastewater except that there is not a continuous discharge. The earlier chapter on effluent quality has demonstrated that lagoons meeting the Alberta Environmental Protection's design guideline produced effluents which were comparable or superior to other common treatment options for most effluent quality parameters. In situations where effluent quality governs the impact, lagoon effluents will be comparable or superior to other treatment options.

This chapter deals with the impacts of lagoon treated effluent in terms of; public health and wildlife, adjacent properties and ground water, fall versus spring discharge, and suitability for land application.

4.2 Public Health and Wildlife

The level of impact of any effluent discharge to a water course is dependent on the dilution ratio (discharge flow rate/water course flow rate), the quality of effluent, the sensitivity and assimilative capacity of the receiving water, and the down stream uses of the receiving water.

4.2.1 Dilution Ratio

The volume of flow of the receiving body and the volume of flow of the lagoon discharge are the factors that determine the dilution ratio. The distance required for any discharge to become completely mixed across the receiving channel is roughly 200 to 300 channel widths down stream depending on stream characteristics. This discussion deals with the completely mixed dilution ratio.

The flow of rivers and streams varies seasonally and depending on the size and nature of the catchment. Figure 4.1 (Bow River at Banff) shows the variation in the normal and extreme discharge at this site. This figure demonstrates the common characteristics of rivers which are at peak flow during the spring runoff period and lower flows in the early spring and fall. The spring runoff varies in timing and intensity depending on the river and the catchment. Rivers fed by mountain snowpacks seem to get high spring discharges in May-June-July while rivers fed by lower elevation snowpacks and spring rain peak in April-May-June (Environment Canada, 1990). The rivers fed by mountain snowpacks tend not to have as extreme spring runoff peaks and low fall discharges as the rivers fed by spring rains and lower snow packs. It is not uncommon for many streams to stop flowing in the fall (Environment Canada, 1990, Kellerhal *et al.*, 1972).

The discharge rate from lagoons is roughly 10 to 20 times the wastewater inflow into the facility assuming 36 to 18 day discharge duration respectively and 12 months of storage. There are tradeoffs when considering the benefits of controlled discharge facilities versus continuous discharge facilities. Controlled discharge has the benefit of avoiding seasons of poor assimilative capacity or high recreational use of the receiving water while the disadvantage is the discharge rate is much higher.

To maximize the dilution ratio of a lagoon discharge the timing of the discharge must coincide with the high discharge period of the receiving stream and the duration of the discharge maximized.

4.2.2 Effluent Quality

The effluent quality parameters used in assessing the impact of lagoon effluents on public heath and wildlife are BOD, TSS, P, ammonia, nitrate/nitrite, TDS (total dissolved solids), and total and fecal coliforms.

A brief discussion of the ways these effluent quality parameters affect the receiving water follows.

4.2.2.1 BOD

The major impact of BOD on a receiving water is the depletion of dissolved oxygen (DO) that occurs in the receiving water as the effluent is stabilized. The consumption of the DO by the microorganisms stabilizing the effluent decreases the DO concentration while reaeration and photosynthesis replenished the oxygen consumed. The natural DO concentrations of the receiving water are determined by a balance between the oxygen sinks and sources. The natural DO concentration of the receiving water varies seasonally with temperature fluctuations and natural organic loading due to non-point sources. The sag in DO concentrations after a point source discharge like a lagoon upsets the natural balance that has been established and the natural process of oxygen transfer adds oxygen to the water to restore the balance. A simple model first presented by Streeter and Phelps (Krenkel and Novotny, 1980) illustrates the effect these processes have on the DO concentrations in a stream or river (see Figure 4.2). It is important to note that this is a simple representation of a very complex process, predicting the rate that the BOD of an effluent will be exerted in the natural environment depends on many site specific factors. Greenfield and Elder (1926) stated that there was an initial lag phase in the exerted BOD incubated at 2° to 6° C probably due to an inadequate population of microbes acclimatized to these temperatures. Figure 4.2 is intended to demonstrate the general trends of the DO sag curve and should not be taken as complete. The figure shows the DO levels decrease as the BOD is exerted and then it flattens off and returns to the previously assumed levels due to oxygen transfer. A problem occurs if the BOD is too high in the wastewater and the natural oxygen transfer processes cannot meet the rate the BOD is being exerted and the DO concentrations drop below the levels that are required by the aquatic biota in the receiving body. The DO concentration necessary for most fish is established at 6.0 mg/L and 5.0 mg/L for later and earlier stages of life respectively (Canadian Council of Resource and Environment Ministers, 1987). In situations where there is ice cover the natural reaeration processes cannot function and the DO concentrations will remain at lower levels without being replenished. Hickey (1989) suggested a receiving water criterion of 5 mg/L BOD_5 for maintaining DO levels for fish.

4.2.2.2 TSS

The Canadian Council of Resource and Environment Ministers (1987, hereafter CCREM, 1987) describe the impact of TSS on the receiving environment as having a significant effect on organism succession due to shading, abrasive action, habitat alteration, and sedimentation. The limits set by CCREM (1987) to ensure fish suffer no ill effects are 10 mg/L added to background concentrations unless the background TSS is greater than 100 mg/L when the limit is 10% of background. Lagoon TSS is mostly algae (Hickey *et al.*, 1989) which is naturally occurring in the receiving waters while TSS from mechanical plants is composed of matter of wastewater origin that did not settle out in the clarification process.

4.2.2.3 Phosphorus

Phosphorus is an element that is essential for plants to grow and the absence of phosphorus will limit the amount of plant growth in water as well as land. Middlebrooks *et al.* (1978) explains that phosphorus is often the limiting nutrient in aquatic systems simply because the ratio of phosphorus to other nutrients in the cell material greatly exceeds the ratio found in water and land masses. If phosphorus is the limiting nutrient and it is then added to a water body by wastewater effluent discharges or from non-point sources like runoff from agricultural operations where it is being used in fertilizers, then the water body could sustain increased weed and algae growth. Receiving water limits for phosphorus are not set by CCREM (1987) because the impacts are sites specific. When phosphorus removal is a requirement in wastewater treatment the guideline is 1 mg/L.

4.2.2.4 Nitrogen

Nitrogen can cause problems in receiving water in four ways; first, nitrogen in the form of nitrate can be a limiting nutrient and the addition of it can cause eutrofication of the water body, second, nitrogen in the form of unionized ammonia and nitrate is toxic to fish at low concentrations, third, oxygen is consumed through nitrification where ammonia is oxidized to nitrate and then to nitrite, and fourth, nitrates may produce a condition known as methemoglobinemia (blue babies) in infants under 6 months of age (Krenkel and Novotny, 1980).

The portion of total ammonia in the toxic unionized form is dependent on the concentration of ammonia, temperature, and pH. Yake and James (1983) proposed the setting of ammonia limits taking into account probabilistic pH and temperature conditions in the receiving stream. The rate of volatilization of ammonia is greater in streams than ponds due to mixing and Stratton (1968) predicts the half-life of ammonia discharges to streams to be 11 hours at pH 8.5 and temperature of 20°C. The ammonia receiving water quality guideline for the protection of fish is 1.37 mg/L at pH of 8.0 and temperature of 10°C (CCREM, 1987).

As with phosphorus, a guideline for algae growth is not set for nitrate concentrations in the receiving water because it is a site specific value however, CCREM

(1987) stipulates that concentrations that stimulate prolific weed growth should be avoided. The drinking water guideline for nitrate and nitrite is 10 mg/L and 1 mg/L (as N) and combined nitrate/nitrite is 10 mg/L (CCREM, 1987). The guideline for stock watering is 100 mg/L combined nitrate/nitrite (CCREM, 1987).

4.2.2.5 TDS

The TDS guideline for drinking water is 500 mg/L and is based primarily on aesthetic consideration (CCREM, 1987). Water with high TDS consumed in large amounts can cause physiological upset and ultimate death in most animals. The TDS guideline for stock watering is 3000 mg/L and waters with 10,000 mg/L are unsuitable for livestock. For irrigation, if the TDS levels do not exceed 1000 mg/L then salination should not be a problem (CCREM, 1987). Depending on the type of soil and crop grown waters with TDS of up to 3500 mg/L are suitable for irrigation (CCREM, 1987).

4.2.2.6 Total and Fecal Coliforms

The coliform group of bacteria are a useful indicator of the bacteriological quality of water. Generally only some of the fecal coliform are considered pathogenic but because they are present in the intestinal tract of warm blooded animals in great numbers (1×10^9 organism per gram of feces), they are a good indication of the possible presence of other pathogenic organisms. *Enterococci* and *Escherichia coli* are better indicators than total and fecal coliforms for water quality for swimmers and recreational uses however the only data available is total and fecal coliforms. The CCREM (1987) stipulates a guideline for bathing and recreational use as an average of 200 fecal coliforms per 100 mL while the guideline for irrigation is 100 fecal and 1000 total coliforms per 100 mL.

4.2.3 Lagoon Effluent Impacts

Tables 4.1, 4.2, and 4.3 are summaries of the mean and 95th percentile values of the previously discussed parameters for the lagoon configurations 0S-2L, 2S-2L, and 4S-2L with 12 month storage respectively. Table 4.4 shows the data for AS plants. The tables also include the dilution ratio required to achieve the desirable receiving water concentrations for various uses. Some 95 percentile values are excessively high because of the limited number of samples used to estimate the value.

The various lagoon configurations were evaluated in terms of the dilution ratio necessary to meet receiving water criterion of the quality parameters. The mean values were discussed primarily because some 95 percentile numbers are misleading.

4.2.3.1 Lagoon 0S-2L

Table 4.1 indicates that the mean fall discharge of a 0S-2L lagoon required a dilution of 1 to 3 in order to meet the receiving water criterion for TSS. In the spring the average dilution necessary was 1 to 9 and is dictated by the ammonia levels although the fecal coliform requirement would probably have been 1 to several hundred.

4.2.3.2 Lagoon 2S-2L

The largest dilution ratio required for the average 2S-2L lagoon with fall discharge was 1 to 1.1 for TDS concentration for drinking water. The governing spring dilution ratio was 1 to 15 for fecal coliform levels (see Table 4.2).

4.2.3.3 Lagoon 4S-2L

The ratio of only 1 to 0.8 was required for the average fall 4S-2L discharge to meet the criterion for phosphorus and TDS (drinking water). The spring dilution necessary was 1 to 5.7 for the fecal coliform requirement (see Table 4.3).

4.2.3.4 Activated Sludge Plants

The average dilution ratio required by AS plant effluents was 1 to 2.7 and 1 to 1000 for BOD and coliforms respectively (see Table 4.4).

4.2.4 Summary

This evaluation has demonstrated that with reasonable dilution ratios the average lagoon effluents have met receiving water quality criterion for the protection of public health and wildlife. Once again this analysis shows the superiority of the lagoon configurations with short detention cells. Increased dilution ratios are required in the spring to compensate for poorer effluent quality. The dilution ratio required by AS plants was two orders of magnitude greater than the 4S-2L lagoons and was governed by the total and fecal coliform counts.

The 95 percentile dilution ratios in the spring were high in a few parameters especially in terms of coliforms which are a concern for recreational use of the receiving water. This indicates that some of the lagoon sites in the spring may have trouble meeting receiving water criterion. To minimize the impact of lagoon effluents, spring discharges should be planned for maximum duration within the window of highest effluent quality (month of discharge), highest receiving water flow, and lowest recreational use.

4.3 Spring Versus Fall Discharge

While effluent quality in some fall discharges does not require any dilution to meet receiving water criterion, discharging a lagoon to a dry river bed or an almost stagnant stream is not desirable. The fall flow conditions in some water courses is such that spring discharge should be considered.

The effluent quality varied greatly from spring to fall discharges as was previously discussed and is evident in Tables 4.1 to 4.3. The spring discharges were of lower quality than fall with BOD roughly 3 times greater, TSS 2 times, phosphorus 2 times, ammonia 5 to 10 times, nitrate/nitrite and TDS no change, and coliforms counts were as much as 15 times greater in the spring. Lagoon discharges were also more variable in the spring than the fall (see 95 % values) as chapter 3 demonstrated, spring effluent quality varied greatlv with month of discharge. Coliform data showed a large degree of variance with the 95% values 3 orders of magnitude above the average.

The peak spring flow of a river or stream is often 10 or more times the fall flow rates (Figure 4.1) and in some cases higher spring flows may be of poorer water quality. The higher flow rates in the spring could possibly provide the necessary dilution to make up for the lower effluent quality for all the parameters but the erratic coliform data is reason for concern. The high 95% counts indicate that sufficient dilution may not be available and the receiving water criterion for coliforms may be exceeded.

The analysis indicates that spring discharges may be a reasonable alternative in terms of all effluent quality parameters. The decision of spring versus fall discharge should be based on site specific factors of seasonal receiving water flow and local lagoon performance (due to variability in the spring effluent quality).

4.4 Suitability for Land Application

The suitability of lagoon effluent for irrigation is discussed for the impact on public health and livestock and impact on the farming operation.

Bell (1976) studied the dieoff rate of fecal coliforms on alfalfa irrigated with sewage lagoon effluent and found that exposure to sunlight for 10 hours resulted in complete dieoff of the coliforms and suggested that the two days of sunlight will adequately protect livestock from salmonella and enteropathogenic *E. coli* infection. Bell and Bole (1978) also studied fecal coliform dieoff in the soil due to irrigation with sewage lagoon effluent and interpreted the results as indicating that the soil no longer constitutes a serious public health hazard for entric diseases two weeks after irrigation with sewage lagoon effluent. Both of these studies where done near Lethbridge, Alberta.

CCREM (1987) states that the guideline of total and fecal coliform counts for irrigation is 1000 and 100 per 100 mL respectively. Tables 4.1 to 4.3 show that average fall discharges of lagoons with short detention cells met the guideline for irrigation. The spring discharges require some dilution but irrigation is usually not necessary in the spring. There is no coliform data available for Alberta lagoons in the summer which is the common irrigation period. Summer time coliform counts are likely low based on the high rate of treatment and the long hours of sunlight in the early spring, and the examples of spring discharges with low counts (see Table 3.5, chp. 3).

The guidelines for the impact of irrigation water quality on the farming operation depend on the soil and crop types (CCREM, 1987). The discussion of soil conditions concludes that sandy soils are more tolerant to higher concentrations of the major ions of concern. The major ions of concern for irrigation are bicarbonate, chloride, sodium, and TDS. The salinity or TDS of irrigation water is an extremely important factor because an increase in salinity in the soil solution increases the osmotic pressure which reduces the amount of water available for plant consumption. Excess water must be applied to move a portion of the salts out of the root zone in order to avoid salt accumulation. Guidelines for TDS are in Table 4.5 and the chloride guideline is 100 mg/L for sensitive crops and 700 mg/L for tolerant crops. Table 4.5 and the average TDS concentrations for lagoons in Tables 4.1 to 4.3 indicate that lagoon effluents are suitable for most crops grown in Alberta. The average concentration of chloride in the three lagoon configurations is below 100 mg/L. The sodium guideline based on a calculation with hardness and numerical guidelines for bicarbonate are not given.

This analysis indicates that with average conditions lagoon effluents are suitable for use in irrigation. Manuals are available that give detailed instructions on the operation of wastewater irrigation (see Environment Canada, 1984).

4.5 Conclusions

The impacts of municipal treated effluents are minimized by lagoon treatment. The advantage of controlled discharge avoiding ice covered receiving waters out weighs the disadvantage of higher discharge rates. Lagoons with short detention cells have better effluent quality and require less dilution than lagoons without short detention cells. The fall discharges of 2S-2L and 4S-2L lagoons require roughly 1 to 1 dilution to meet the receiving water criterion for all the parameters investigated. AS plants require much higher dilution ratios due to the higher coliform counts in the effluent. Spring discharges required increased dilution but the increase is similar to the increased spring flows of receiving waters. The question of fall versus spring discharge should be evaluated on site specific criteria of seasonal receiving water flow rates and local effluent quality. Effluent quality and specifically coliform counts may be a concern in spring discharges and if spring discharges are necessary upgrading the effluent quality may be required. Irrigation water quality is based on the type of soil and crop but lagoon effluent is suitable in average conditions for most crops.

Variable	Effluent Concentration						Receiving Water Criterion mg/L	Reason for Criterion	Dilution Ratio Required			
	Fall			Spring					Fall		Spring	
	Mean mg/L	95 percentile mg/L	No of Samples	Mean mg/L	95 percentile mg/L	No of Samples			Mean	95 percentile	Mean	95 percentile
BOD	12.6	76.3	6	46.5	294.1	7	5.0	fish DO maintenance (Hickey 1989)	1.5	14	8.3	58
TSS	39.9	383.3	6	28.7	301.1	7	10	fish impact (CWQG)	3.0	37	1.9	29
Phosphorus	2.7	39.5	6	4.6	19.6	7	1.0	algal growth *	1.7	38	3.6	19
Ammonia	0.8	758.4	6	13.7	57.9	7	1.4	fish toxicity ** (CWQG)	0.0	553	9.0	41
Nitrate / Nitrite	0.4	2185.3	3	0.2	112651.4	3	10	drinking water (CWQG)	0.0	218	0.0	11264
							100	stock watering (CWQG)	0.0	21	0.0	1126
TDS	1627.3	5540.2	6	1164.8	4934.5	7	500	drinking water (CWQG)	2.3	10	1.3	8.9
							3000	stock watering (CWQG)	0.0	0.8	0.0	0.6
							500-3500	irrigation **** (CWQG)	0.0	0.6	0.0	0.4
Total Coliforms org./100 ml	***	***		***	***		1000	irrigation (CWQG)				
Fecal Coliforms org./100 ml	2.1E+02	8.6E+04	13	***	***		100	irrigation (CWQG)	1.1	854		
							200	bathing / recreation (CWQG)	0.1	427		

Table 4.1 : Dilution Required of 0S-2L Lagoon Discharges to Achieve Desired Receiving Water Concentrations

Format of figure taken from Hickey, 1989

* effluent limit when P removal required

** pH=8.0, 10 deg C (79)

*** note : Coliform data is missleading, many samples exceeded the range of analysis of 8000 org/100 ml, see data table in Chp. 3

**** depends on crop and soil type, 3500 mg/l used for dilution calculation

note : Dilution Ratio = (Effluent quality / Criterion) - 1

Variable	Effluent Concentration						Receiving Water Criterion mg/L	Reason for Criterion	Dilution Ratio Required			
	Fall			Spring					Fall		Spring	
	Mean mg/L	95 percentile mg/L	No of Samples	Mean mg/L	95 percentile mg/L	No of Samples			Mean	95 percentile	Mean	95 percentile
BOD	5.4	21.4	8	17.3	53.3	8	5.0	fish DO maintenance (Hichey 1989)	0.1	3	2.5	10
TSS	14.6	44.9	7	31.3	436.7	8	10	fish impact (CWQG)	0.5	3	2.1	43
Phosphorus	1.3	8.6	7	3.0	20.7	7	1.0	algal growth *	0.3	8	2.0	20
Ammonia	0.6	192.8	7	3.1	551.4	8	1.4	fish toxicity ** (CWQG)	0.0	140	1.3	401
Nitrate / Nitrite	0.4	1.6	7	0.6		2	10 100	drinking water (CWQG) stock watering (CWQG)	0.0 0.0	0 0	0.0 0.0	
TDS	1069.7	8073.7	7	1197.7	5359.5	8	500 3000 500-3500	drinking water (CWQG) stock watering (CWQG) irrigation **** (CWQG)	1.1 0.0 0.0	15 1.7 1.3	1.4 0.0 0.0	9.7 0.8 0.5
Total Coliforms org./100 ml	2.3E+02	1.1E+10 ***	4	5.4E+03 ***	3.0E+04 ***	6	1000	irrigation (CWQG)	0.0	10671989.9	4.4	29.1
Fecal Coliforms org./100 ml	7.4E+01	3.1E+05	6	1.6E+03 ***	2.2E+06 ***	6	100 200	irrigation (CWQG) bathing / recreation (CWQG)	0.0 0.0	3084 1541	15.4 7.2	22327.1 11163.1

Table 4.2 : Dilution Required of 2S-2L Lagoon Discharges to Achieve Desired Receiving Water Concentrations

Format of figure taken from Hickey, 1989

* effluent limit when P removal required

** pH=8.0, 10 deg C (79)

*** note : Coliform data is missleading, many samples exceeded the range of analysis of 8000 org/100 ml, see data table in Chp. 3

**** depends on crop and soil type, 3500 mg/l used for dilution calculation

note : Dilution Ratio = (Effluent quality / Criterion) - 1

Variable	Effluent Concentration: Fall Mean mg/L	Fall 95 percentile mg/L	Fall No of Samples	Spring Mean mg/L	Spring 95 percentile mg/L	Spring No of Samples	Receiving Water Criterion mg/L	Reason for Criterion	Dilution Ratio Required: Fall Mean	Fall 95 percentile	Spring Mean	Spring 95 percentile
BOD	6.0	23.4	16	15.3	57.1	13	5.0	fish DO maintenance (Hichey 1989)	0.2	4	2.1	10
TSS	14.4	47.1	17	32.0	158.3	13	10	fish impact (CWQG)	0.4	4	2.2	15
Phosphorus	1.8	7.7	17	2.8	15.4	13	1.0	algal growth *	0.8	7	1.8	14
Ammonia	0.7	8.8	17	2.9	179.4	13	1.4	fish toxicity ** (CWQG)	0.0	5	1.1	130
Nitrate / Nitrite	0.5	18.3	15	0.3	9.9	7	10	drinking water (CWQG)	0.0	1	0.0	0
							100	stock watering (CWQG)	0.0	0	0.0	0
TDS	893.6	3482.5	17	838.6	4952.1	13	500	drinking water (CWQG)	0.8	6	0.7	8.9
							3000	stock watering (CWQG)	0.0	0.2	0.0	0.7
							500-3500	irrigation **** (CWQG)	0.0	0.0	0.0	0.4
Total Coliforms org./100 ml	5.7E+01	3.5E+03	7	1.6E+03 ***	3.7E+05 ***	15	1000	irrigation (CWQG)	0.0	2.5	0.6	365.8
Fecal Coliforms org./100 ml	1.7E+01	8.8E+02	16	6.7E+02 ***	3.9E+05 ***	15	100	irrigation (CWQG)	0.0	8	5.7	3895.8
							200	bathing / recreation (CWQG)	0.0	3	2.3	1947.4

Table 4.3 : Dilution Required of 4S-2L Lagoon Discharges to Achieve Desired Receiving Water Concentrations

Format of figure taken from Hickey, 1989

* effluent limit when P removal required

** pH=8.0, 10 deg C (79)

*** note : Coliform data is missleading, many samples exceeded the range of analysis of 8000 org/100 ml, see data table in Chp. 3

**** depends on crop and soil type, 3500 mg/l used for dilution calculation

note : Dilution Ratio = (Effluent quality / Criterion) - 1

Variable	Effluent Concentration						Receiving Water Criterion mg/L	Reason for Criterion	Dilution Ratio Required			
	Fall			Spring					Fall		Spring	
	Mean mg/L	95 percentile mg/L	No of Samples	Mean mg/L	95 percentile mg/L	No of Samples			Mean	95 percentile	Mean	95 percentile
BOD	18.5	38.5	9				5.0	fish DO maintenance (Hichey 1989)	2.7	7		
TSS	11.6	50.8	9				10	fish impact (CWQG)	0.2	4		
Phosphorus	2.8	18.3	9				1.0	algal growth *	1.8	17		
Ammonia	3.3	66.4	9				1.4	fish toxicity ** (CWQG)	1.4	47		
Nitrate / Nitrite	4.7	52.8	9				10	drinking water (CWQG)	0.0	4		
							100	stock watering (CWQG)	0.0	0		
TDS	622.4	1450.2	9				500	drinking water (CWQG)	0.2	2		
							3000	stock watering (CWQG)	0.0	0.0		
							500-3500	irrigation **** (CWQG)	0.0	0.0		
Total Coliforms org./100 ml	1.0E+06	estimated					1000	irrigation (CWQG)	999.0			
Fecal Coliforms org./100 ml	1.0E+05	estimated					100	irrigation (CWQG)	999.0			
							200	bathing / recreation (CWQG)	499.0			

Table 4.4 : Dilution Required of Activated Sludge Plant Discharges to Achieve Desired Receiving Water Concentrations

Format of figure taken from Hickey, 1989

* effluent limit when P removal required

** pH=8.0, 10 deg C (79)

*** note : Coliform data is missleading, many samples exceeded the range of analysis of 8000 org/100 ml, see data table in Chp. 3

**** depends on crop and soil type, 3500 mg/l used for dilution calculation

note : Dilution Ratio = (Effluent quality / Criterion) - 1

Table 4.5 : Tolerance of Selected Crops to TDS

(adapted from CCREM, 1987)

Not Tolerant TDS < 500 mg/L	Slightly Tolerant TDS < 800 mg/L	Moderately Tolerant TDS <1500 mg/L	Tolerant TDS < 2500 mg/L	Very Tolerant TDS < 3500 mg/L
Fruits & berries	Fruits & berries	Fruits & berries	Fruits & berries	Fruits & berries
Strawberry	Boysenberry			
Raspberry	Currant	Vegetables	Vegetables	Vegetables
	Blackberry	Spinach	Beet	Asparagus
Vegetables	Gooseberry	Cucumber	Zucchini	
Bean	Plum	Tomato		Field crops
Carrot	Grape	Squash	Field crops	Soybean
	Apricot	Brussel sprout	Rape	Safflower
Field crops	Peach	Broccoli	Sorghum	Oats
Bean		Turnip		Rye
	Vegetables		Forages	Wheat
Forages	Onion	Field crops	Oat hay	Sugar beet
	Parsnip		Wheat hay	Barley
	Radish	Forages	Brome, mountian	
	Pea	Brome	Tall fescue	Forages
	Pumkin	Alfalfa	Sweet clover	Barley hay
	Lettuce	Big trefoil	Reed	Tall wheatgrass
	Sweet corn	Beardless	Canary grass	
	Potato	Wildrye	Birds foot	
	Celery	Vetch	Trefoil	
	Cabbage	Timothy	Perennial	
	Kohlrabi	Crested wheatgrass	Ryegrass	
	Caulifower			
	Field crops			
	Cowpea			
	Broadbean			
	Flax			
	Sunflower			
	Corn			
	Forages			
	Clover			
	Berseem clover			
	Forage corn			

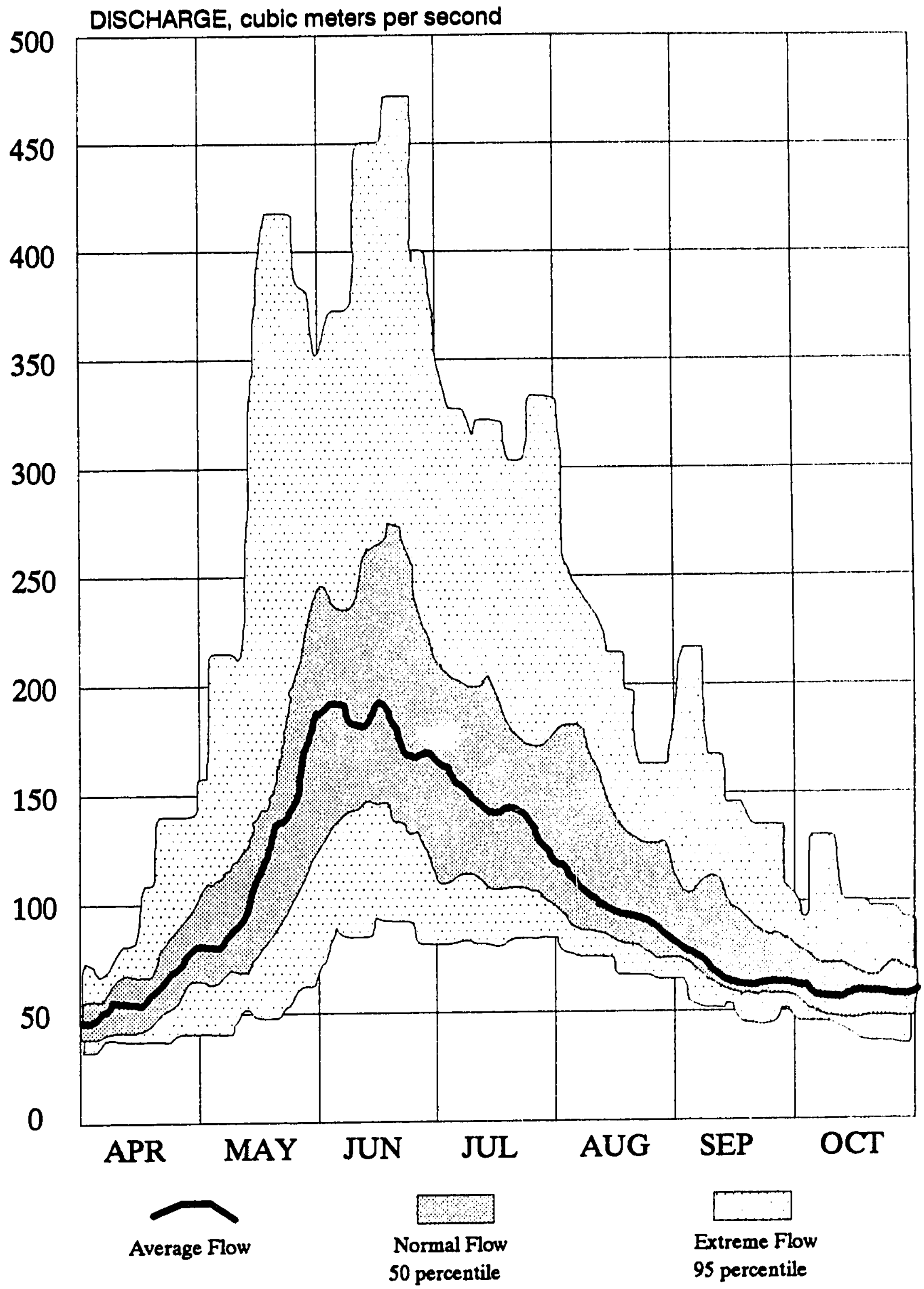


Figure 4.1 : Seasonal Flow Condition of the Bow River at Banff
(adapted from Alberta Environment, River Forecasting Centre 1992)

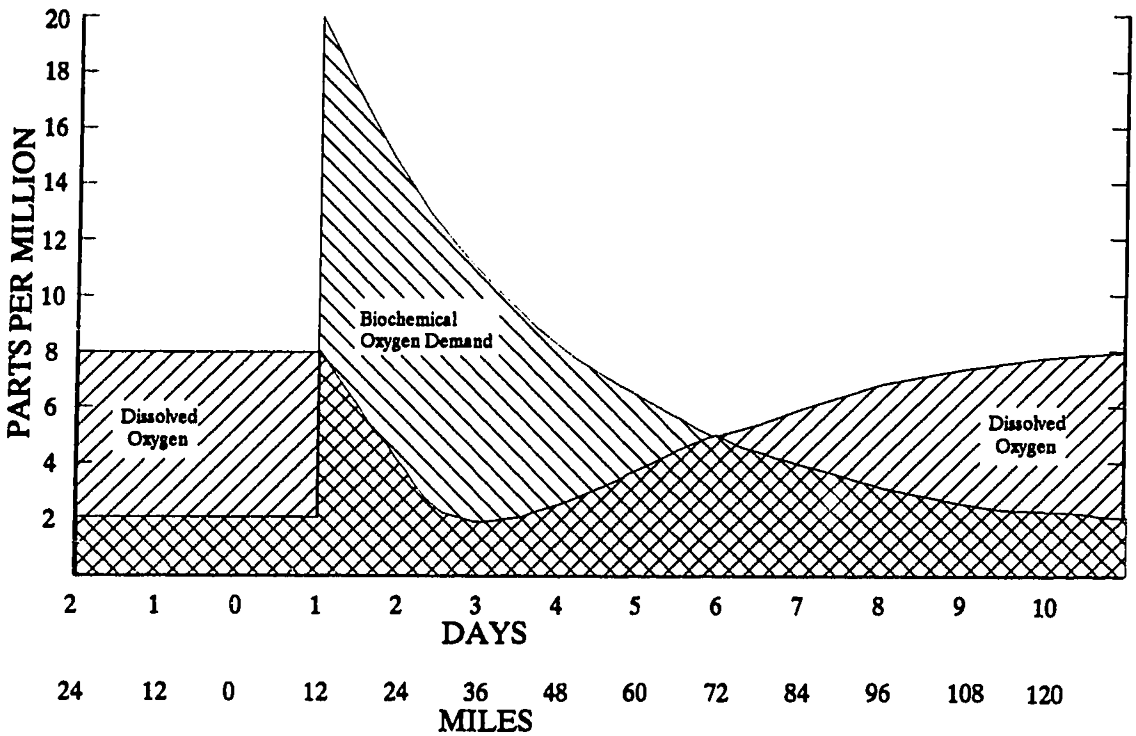


Figure 4.2 : Dissolved Oxygen Sag Curve
(adapted from Krenkel and Novotny, 1980)

5.0 CONCERNS

5.1 Introduction

Lagoon design and operations manuals are intended to minimize nuisances that cause public concern (Alberta Environment, 1988). The major public concerns arising from the operation of a lagoon are odours, appearance, seepage, insects, and the quality of the effluent.

Odour problems are often reported as the most challenging operational concern and are often linked to breakup in the spring. At the time of spring breakup the lagoon is anaerobic due to the winter ice cover and as temperatures rise the activity of anaerobic microbes producing sulfate also increase. A rapid temperature increase does not allow algal populations to become established and provide an aerobic - high pH surface to the lagoon to prevent these sulfate compounds forming hydrogen sulfide which cause the odour problem (McKinney, 1982). Fisher (1967), stated that odours in the north are associated with spring breakup and factors affecting odours in Saskatchewan, Alberta, and Manitoba are organic over loading and perhaps high sulfate concentrations. The relationship between sulfate and H_2S is pH dependent and can be expressed as follows:

$$SO_4^{=} + \text{organic mater} \rightarrow S^{=} + H_2O + \text{reduced organic matter}$$

$$S^{=} + 2H^{+} \rightarrow H_2S$$

At pH of 7, 80% is in the H_2S form, decreasing pH shifts the reaction toward H_2S.

Seepage from lagoons can cause problems for adjacent properties and ground water. Some earlier lagoon designs did not pay necessary attention to the hydraulic characteristics of the liner and seepage became a problem.

Operational problems and the level of public concern for these problems is investigated in this section of the report.

5.2 Analysis Approach

In an effort to assess public concern with respect to municipal wastewater treatment systems a survey was conducted. Surveys were sent to the operators of 354 treatment facilities on Alberta Environmental Protection's (AEP's) records. The operators were asked to report the number of complaints a year they receive in the categories of odour, insect and pests, appearance, flooding, leakage or seepage, and effluent quality. The operators were also asked to indicate their opinion of the severity of the problem on a scale from one to ten. There was space provided in the survey for any comments or clarification that operators could provide. The level of response to the survey was surprising with over 78% of surveys returned. Appendix A contains a copy of the survey sent to the operators and Appendix B contains a list of survey results.

The survey gauges two very different opinions. The number of complaints represents the public's perception of the treatment facility. These perceptions may be based on facts or feelings or headlines in news reports. A common aspect of public complaints is that one vocalized complaint may represent many non-vocalized complaints. The operator's perception of the problem is indicated by the grade given for severity. These perceptions are from someone with generally a more knowledgeable point of view but who may also have somewhat of a vested interest (i.e. the job). The survey results should be interpreted with a balance between the operator's and the public's point of view, an operator may be aware of a problem the public has not complained about or the public may complain about a problem the operator feels is unimportant.

Figures 5.1 and 5.2 presents distributions of the number of complaints received annually and the severity of the problem as perceived by the operator for lagoon systems. The figures show that in a vast majority of facilities there are no complaints received and operators do not feel that there was a problem with the different items of concern. The distributions show that most of the facilities that did receive complaints received only a very few (three or less) and there were only a very few operators that reported the severity of any problem over three on the scale. There are notes that give any clarification or comments that the operators included in the survey for the facilities that received many complaints (over five) or reported severe problems (over five on the severity scale). The figures show that there is only a small number of facilities that have high number of complaints or severe problems without a reasonable explanation.

5.3 Analysis of Non-Zero-Results

Table 5.1 contains a summary of the non-zero (non-zero meaning one or more complaints or more than one on the scale from one to ten for severity) survey results that have been broken down by treatment technology and lagoon configuration. Listed for each site and category are the number of non-zero responses, the percent of sites with non-zero responses, and the number of complaints per 10,000 people.

The last row of Table 5.1 that summarizes all lagoons indicates that in five of the six categories of concerns the operators reporting non-zero complaints and severity of problems is less than ten percent of the sites and many of these categories are even below five percent of the sites. The category of odour received more complaints with 17% of the sites reporting odour complaints.

5.3.1 Odour

Although the category of odour had the most complaints, Figure 5.1 shows that most lagoons received no complaints. A common clarification made by operators reporting odour complaints or problems was that they occurred in the spring or when the wind blew in an unusual direction. This is expected as odours can be generated immediately after the ice cover melts. Anaerobic cells can also cause some odours throughout the year.

The breakdown of non-zero complaints in Table 5.1 indicates that large lagoon systems have more odour problems than small systems. The 4S-2L systems and systems with more than 4S-2L had 27% and 46% of sites receiving complaints which is considerably more than 0S-1L, 0S-2L, and 2S-2L systems that received complaints at 5%,17%, and 3% of sites respectively. The opinions of operators compare in a similar manner. The number of complaints per 10,000 people also confirms these findings with 4S-2L and greater systems have 21 complaints per 10,000, while 0S-1L, 0S-2L, and 2S-2L systems have 3, 36, and 4 complaints per 10,000 respectively. This suggests that the larger systems (4S-2L and greater) can have several times more complaints per capita than smaller systems.

It was not clear why larger lagoon configurations receive more complaints than smaller ones. Figure 5.3 investigated the relationship between the facilities receiving complaints and size of population served. The figure shows that 30% of the complaints were from smaller communities (< 750) which account for 70% of the sites and 70% of the complaints were from larger communities (> 750) which account for only 30% of the sites. An investigation into the relationship between distance from facility to community and odour complaints yielded no correlation. Larger lagoon configurations may have received more complaints because they generate more odours due to larger surface area or alternatively because the larger communities they serve were more sensitive to odour problems than smaller communities. The reason for the complaints is secondary however to the revelation that larger lagoon configurations (which serve larger populations) received more odour complaints and operators felt odour problems were more severe.

In the comparisons of lagoon systems to mechanical plants only facilities of similar size were used in order to avoid any confusion in the results. A comparison of the largest lagoon systems (systems with more than 4S-2L, avg. pop. 1786) to aerated lagoons and RBCs (avg. pop. 2423 and 2989) showed that larger lagoons were more likely to receive complaints and operators felt odour problems are more severe The mechanical plants also received fewer complaints per 10,000 people than large lagoon systems.

5.3.2 Insects and Pests

The survey shows that insects were not a problem in lagoon treatment. Most of the 3% (7 of 222) of lagoon sites that received complaints about insects said the people did not attribute the problem to the lagoon system. Two of the lagoon sites (Swan Hills and Stirling) that had ranked the severity of the insect problem at six and eight out of ten attribute the problem to other factors in the surrounding area.

5.3.3 Appearance

The appearance of the lagoon systems was not a significant problem with only 4% of the sites receiving complaints. There were many operators that commented that most of the people in the community did not know where the lagoon was, these are examples of well sited facilities. The configuration of the lagoon systems did not have an effect on complaints received about the appearance of a facility.

5.3.4 Flooding

The survey indicates that most lagoon systems do not have a problem with flooding and in the cases where there was a problem, communication between the operator and the affected parties minimizes the impact. In most cases flooding resulting from lagoon discharges is due to poorly defined drainage courses. Table 5.1 shows that 10% of the lagoon sites had received complaints about flooding and that only 5% of the operators ranked the problem severity greater than one. Figure 5.2 showed that no operator had ranked the severity of flooding higher than three which indicates that operators felt that any flooding problems that may have existed were under control. A frequent comment made in the surveys when flooding was a problem was that the lagoon operators must communicate well with the people affected by the flooding in order to minimize the impact.

5.3.5 Leakage and Seepage

The majority of lagoons did not report a seepage problem and most that did, reported some remedial action had been taken. Table 5.1 shows that 8% of the lagoon sites have received complaints about seepage and that 7% of the operators rank the problem severity greater than one. A frequent comment made when complaints were received was that the situation was investigated to see if there was a problem and then remedial action was taken. If a seepage problem is confirmed it may require major remedial action. An example of this is the lagoon at Magrath where they reported a seepage problem and indicated that a new system was being designed. The different lagoon configurations maintain roughly a constant rate of complaints and operator problem severity estimates.

5.3.6 Effluent Quality

The survey reported that few sites received effluent quality complaints and larger lagoon systems (4S-2L or more) received a majority of the complaints. Table 5.1 shows that 6% of the lagoon sites had received complaints about effluent quality and that 5% of the operators ranked the problem severity greater than one. Table 5.1 also indicates larger lagoon configurations (systems with more than 4S-2L) received complaints at a higher rate than other configurations and accordingly Figure 5.4 confirms most of the complaints came from larger communities (>1700). The complaints from the larger lagoon systems may be due to a public perception problem because in earlier chapters of this report the effluent quality of these larger lagoon systems was found to be excellent and of better quality than smaller systems.

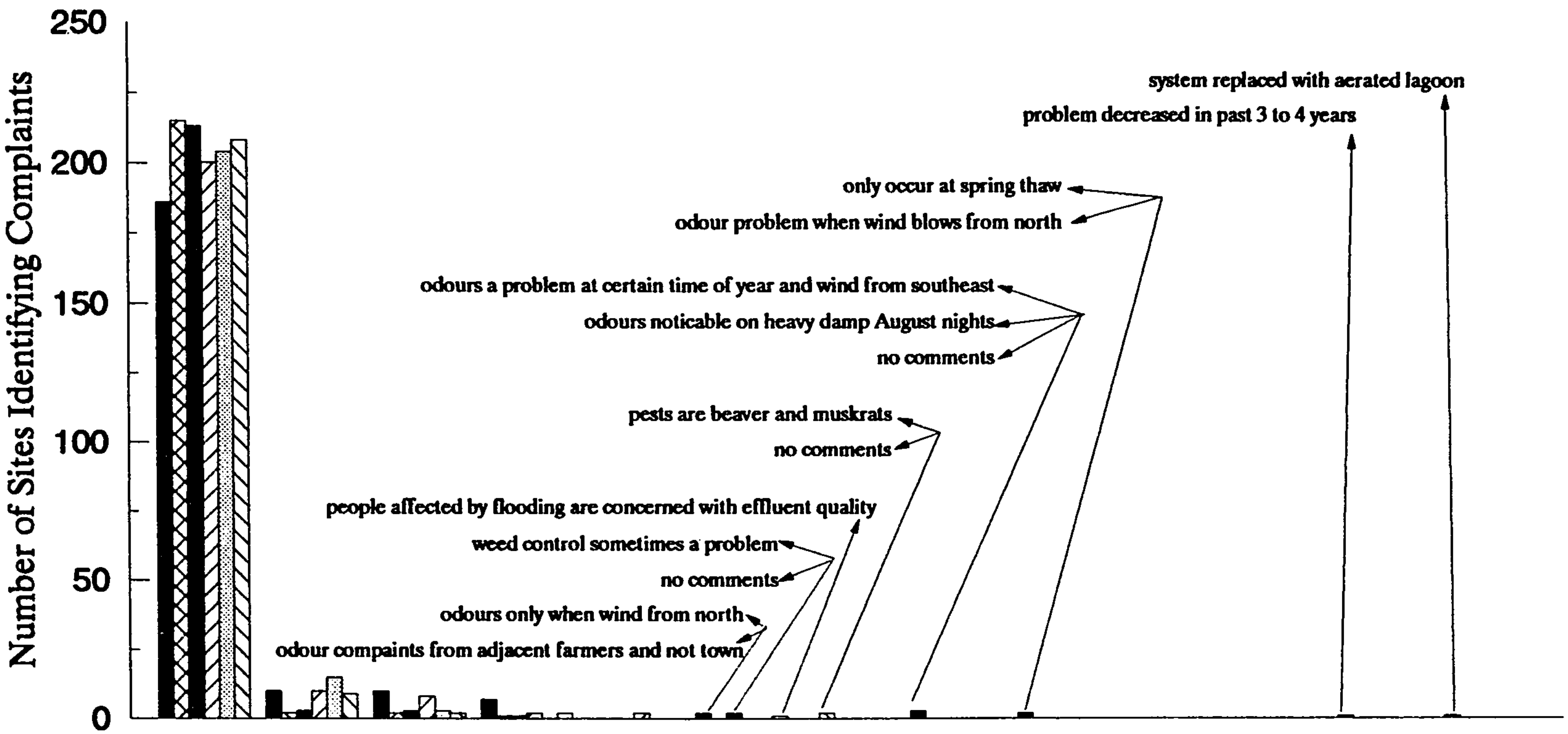
5.4 Conclusion

The analysis of public concern over lagoon treatment showed that insects, appearance, and effluent quality are not a significant problem and that a few lagoon facilities have problems with odours, flooding, and seepage. The survey data on odour trouble demonstrated that most lagoons, especially small systems, had no odour problems and those that did have some problems said the problems were minor and short lived, usually for a short time in the spring or when the wind deviated from its' traditional direction. The few facilities that have had flooding problems as the lagoon is discharged said the impacts of these problems was greatly reduced by communicating with the people affected. Most facilities that received complaints about seepage from the lagoon said they first verified the complaints and then took remedial action which may have meant extensive repairs.

The vast majority of lagoon systems did not report any problems or public complaints about the treatment facilities and operators of systems that did report problems did not feel the problems were severe.

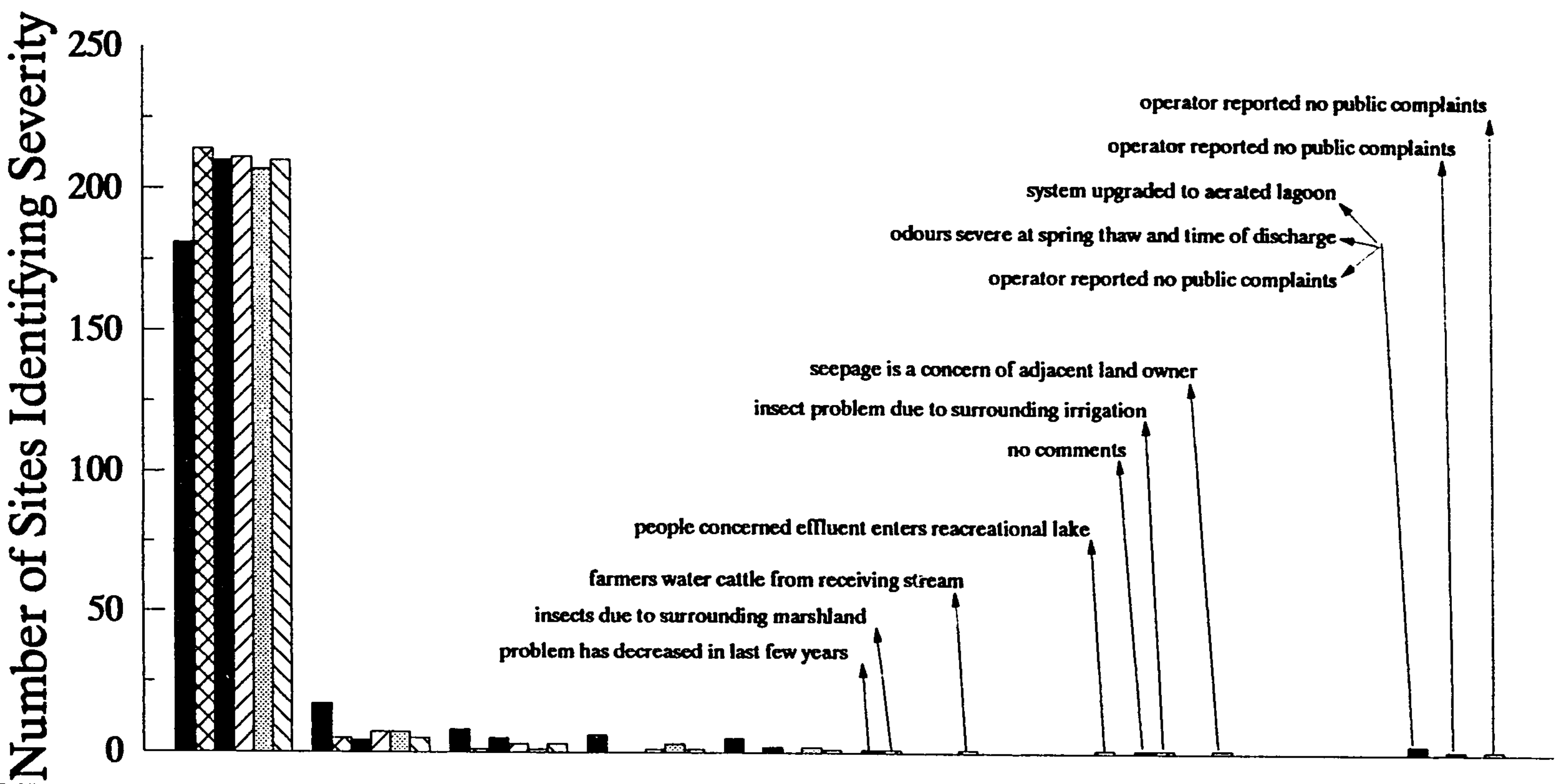
		ODOUR COMMENT	ODOUR SEVERITY	INSECT COMMENT	INSECT SEVERITY	APPEAR COMMENT	APPEAR SEVERITY	FLOOD COMMENT	FLOOD SEVERITY	LEAK COMMENT	LEAK SEVERITY	EFFLU COMMENT	EFFLU SEVERITY
AERATED LAGOON													
# OF SITES= 23	# NONZERO	2	5	0	3	0	3	0	0	1	0	2	1
AVE. POP.= 2,423	% NONZERO	9%	22%	0%	13%	0%	13%	0%	0%	4%	0%	9%	4%
TOTAL POP.= 71,197	PER 10,000	1.1								0.1		0.6	
RBC													
# OF SITES= 9	# NONZERO	2	2	1	0	2	3	1	1	0	0	1	1
AVE. POP.= 2,989	% NONZERO	22%	22%	11%	0%	22%	33%	11%	11%	0%	0%	11%	11%
TOTAL POP.= 34,851	PER 10,000	14.3		0.3		3.4		0.6				1.4	
LAGOON 0S,1L													
# OF SITES= 43	# NONZERO	2	1	1	0	0	0	4	1	4	2	1	4
AVE. POP.= 126	% NONZERO	5%	2%	2%	0%	0%	0%	9%	2%	9%	5%	2%	9%
TOTAL POP.= 6,181	PER 10,000	3.2		0.8				12.1		7.3		3.2	
LAGOON 0S,2L													
# OF SITES= 18	# NONZERO	3	2	0	0	1	0	3	2	1	0	2	0
AVE. POP.= 87	% NONZERO	17%	11%	0%	0%	6%	0%	17%	11%	6%	0%	11%	0%
TOTAL POP.= 1,664	PER 10,000	36.1				6.0		18.0		6.0		12.0	
LAGOON 2S,2L													
# OF SITES= 33	# NONZERO	1	3	4	2	1	2	3	2	3	4	1	0
AVE. POP.= 479	% NONZERO	3%	9%	12%	6%	3%	6%	9%	6%	9%	12%	3%	0%
TOTAL POP.= 18,700	PER 10,000	6.4		7.8		0.5		2.7		1.6		0.5	
LAGOON 4S,2L													
# OF SITES= 44	# NONZERO	12	15	1	1	2	2	6	4	3	2	3	4
AVE. POP.= 906	% NONZERO	27%	34%	2%	2%	5%	5%	14%	9%	7%	5%	7%	9%
TOTAL POP.= 52,316	PER 10,000	21.0		1.5		1.0		2.5		0.6		1.5	
MORE 4S,2L													
# OF SITES= 26	# NONZERO	12	9	0	3	1	4	2	1	3	4	4	1
AVE. POP.= 1,786	% NONZERO	46%	35%	0%	12%	4%	15%	8%	4%	12%	15%	15%	4%
TOTAL POP.= 78,101	PER 10,000	20.8				0.6		0.5		0.4		1.0	
ALL LAGOONS													
# OF SITES= 222	# NONZERO	37	38	7	8	9	12	22	11	18	15	14	11
AVE. POP.= 358	% NONZERO	17%	17%	3%	4%	4%	5%	10%	5%	8%	7%	6%	5%
TOTAL POP.= 182,795	PER 10,000	17.4		1.3		1.2		2.2		1.1		1.3	

Table 5.1: Summary of Non-zero Results



Number of Complaints per Community	0	1	2	3	4	5	7	9	15	25	50	75	100
Odour	186	10	10	7		2		3	2			1	1
Insects	215	2	2	1			2						
Appearance	213	3	3	1		2							
Flooding	200	10	8	2	2								
Leakage	204	15	3										
Eff. Quality	208	9	2	2		1							

Figure 5.1 : Distribution of Number of Complaints Related to Lagoons



Problem Severity	ONE	TWO	THREE	FOUR	FIVE	SIX	SEVEN	EIGHT	NINE	TEN
Odour	181	17	8	6	5	1		1		3
Insects	214	5	1			1		1		
Appearance	210	4	5		2					1
Flooding	211	7	3	1						
Leakage	207	7	1	3	2			1		1
Eff. Quality	210	5	3	1	1	1	1			

Figure 5.2 : Distribution of Severity of Problem Related to Lagoons

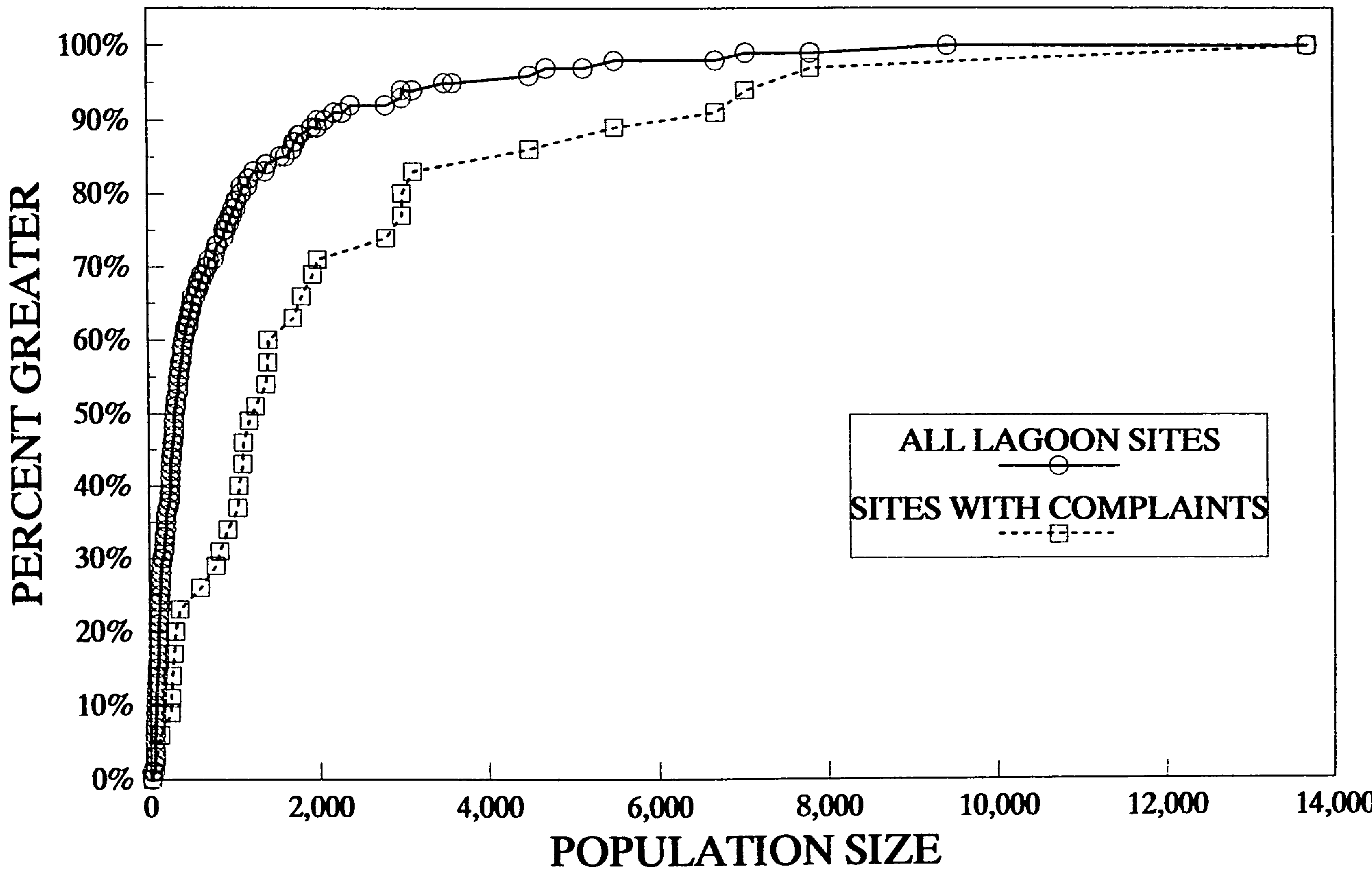


FIGURE 5.3 : Comparison of Odour Complaints to Population Size

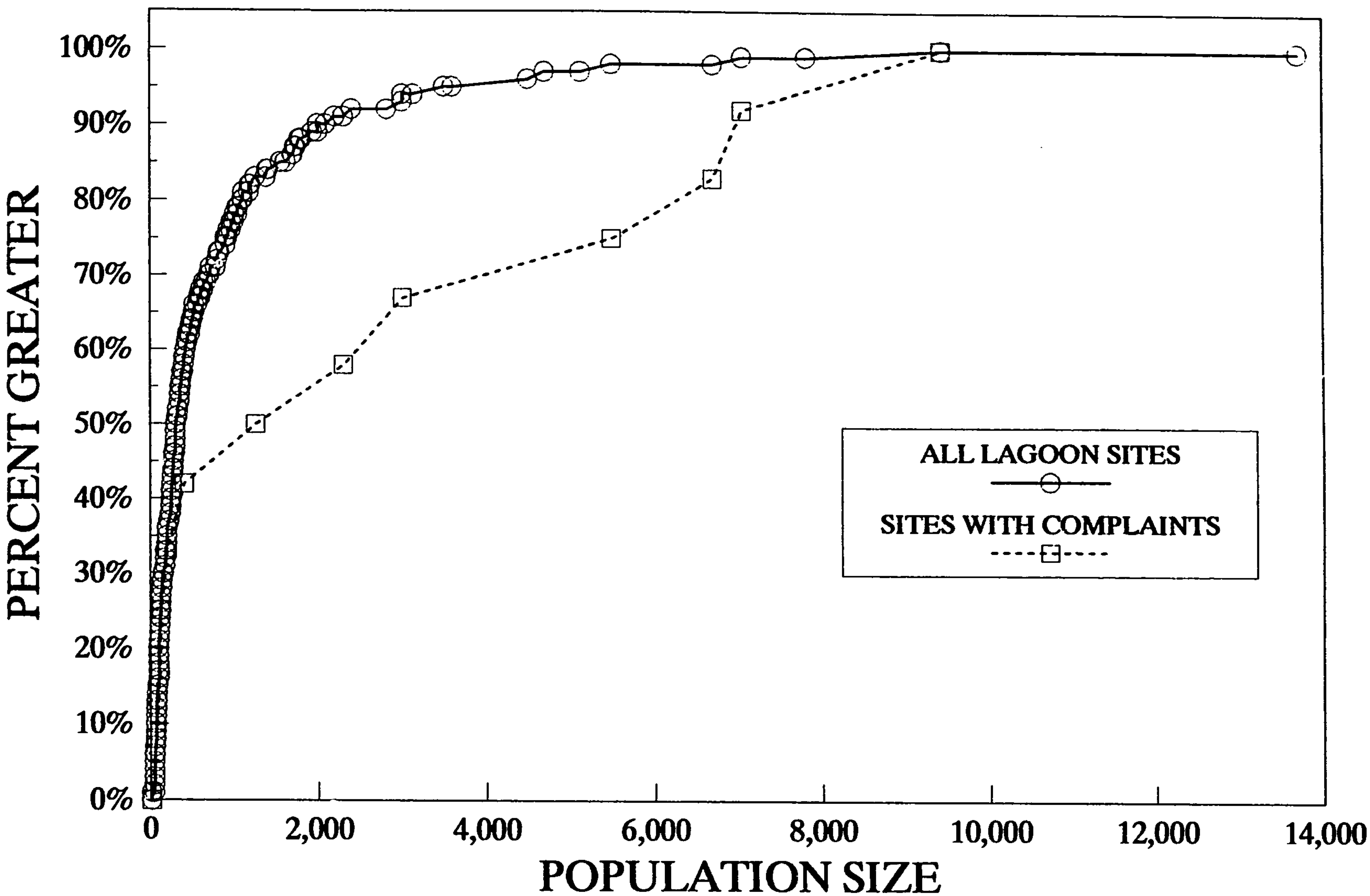


FIGURE 5.4 : Comparison of Effluent Quality Complaints to Population Size

6.0 ECONOMIC ANALYSIS

6.1 Introduction

An important consideration in the selection of the "best" treatment for municipal wastewater is the cost of building and maintaining the treatment facility. This economic analysis discusses lagoon treatment, aerated lagoons (AL), and rotating biological contactor plants (RBCs) which are viable alternatives presently being used in Alberta for wastewater treatment in smaller communities (i.e. less than 15,000). A rough indication of costs of the three treatment technologies has been obtained by means of a survey of treatment facility operators. Of the 354 surveys sent to treatment facility operators, 260 have been returned. This analysis groups facility costs into three categories; land costs, capital construction costs, and operating and maintenance costs. The analysis is based on cost versus population plots with regressions that indicate the trends in the data. There has not been an in-depth analysis of variance to establish confidence regions for the regression lines because there is not a reliable way to estimate the variability in the survey results. An indication of the level of confidence in the regression lines is the degree of scatter in the data points in the figures that accompany the subsequent sections. The limitations of the analysis are such that the results cannot predict treatment facility costs with a certain degree of error for a given population size, however the results do provide a guideline for relative costs of the treatment alternatives and estimates of costs which will be useful in the preliminary stages of facility planning.

6.2 Land Costs

The evaluation of the land costs based on the survey results did not yield conclusive results because information received was based on the parcel of land that the treatment facility was located and not the amount of land required by the treatment facility. Some of the facilities are situated on parcels of land that are much larger than what is actually required by the treatment facility and the cost of the extra land obscures the results. Another problem evaluating land costs was the many site specific factors affect the value of land making comparisons of one site to another difficult. To avoid these problems the comparison of treatment technology land requirements was based on the amount of land required to treat the wastewater of a given community size and where necessary a land value of $2471 per hectare or $1000 per acre was assumed (the sensitivity of assumed land cost was also investigated). The estimates of the land required were based on the Alberta Environmental Protection's guidelines of facility size and setback distances to property lines. Figure 6.1 shows the amount of land required for lagoon facilities is roughly 10 times greater than what is required for AL and RBC plants. Figure 6.2 shows the land costs per capita (based on design population) for the different treatment types and population sizes and it demonstrates that lagoon land costs are much greater than AL or RBCs.

The review of land requirements for the treatment technologies indicated that lagoons require much more land than AL and RBC plants.

6.3 Capital Construction Costs

Survey results for capital construction costs of treatment facilities were reasonable enough to use as the basis for the analysis. For comparison, facility construction costs have been converted to 1993 dollars using the consumer price index on total goods published by Statistic Canada (Stats. Can. - Cat. No. 11-010, May, 1993). Figure 6.3 presents the total capital construction costs versus population and Figure 6.4 indicates the costs per capita versus population (both figures based on design population). The regression lines and data points indicated that for most populations, lagoons were the least expensive of the treatment alternatives and RBCs were the most expensive. However, for populations of less than 2000 people the average RBC plant became cheaper than both lagoons and AL. Variability in the data was evident by the individual sites, there were examples of ALs built for less than a lagoon for the same population size even though the regression lines indicate the opposite. Given the variability in data, differences in the regression lines of lagoons and AL were not large enough to be considered significant.

6.4 Operating and Maintenance Costs

The survey has supplied a breakdown of operating and maintenance costs but for this analysis the combined operating and maintenance costs and manpower requirements will be used to compare the treatment alternatives. Figure 6.5 shows operating costs versus population and Figure 6.6 the costs per capita versus population (both figures based on actual population served). The regression lines indicate that for all populations, the operating and maintenance costs for lagoons were much less than RBCs which are the most expensive alternative. The difference in the relative costs was pronounced; in spite of the variability in the data. Generally AL were several times more expensive to operate and maintain than lagoons and RBCs were as much as 10 times more expensive than lagoons.

Figures 6.7 and 6.8 summarize survey results for the manpower requirements of treatment alternatives. The relative position of the treatment alternatives was unchanged with lagoons requiring the fewest person days per year to maintain and operate and RBCs needing the most. Manpower requirements for RBC plants increased at a higher rate with increased population than lagoon or AL facilities.

A maintenance problem with the lagoon technology is berm erosion, the frequency of berm erosion has been assessed. The survey showed that 62 of the 220 lagoon surveys returned (28%) had berm erosion trouble and the most common remedial action was lining the berms with waste rubble, rip rap, and a few sites used old tires. A novel technique used at two sites was to put log booms on the lagoons to reduce wave action.

6.5 Present Worth Analysis

The overall economic evaluation of treatment alternatives is based on the combined cost of each alternative. Combining the different costs can be done by first converting all cost into either an annual cost or a present worth cost by assuming an interest rate and a design life for the facilities. The present worth approach is pursued in this analysis with an assumed design life of 25 years and an interest rate of 6%. The capital construction costs were previously converted to present worth form and present worth land costs have been estimated by assuming a land value of $2471 per hectare. Operating and maintenance costs that will be paid out over the life of the facility were converted into present worth dollars. The design life of the facilities was assumed to be 25 years for all alternatives, however an argument could be made that with fewer mechanical parts a lagoon facility may have a longer design life than RBCs or AL therefore the assumption of similar design life was conservative toward lagoons which results in estimated lagoon costs being slightly higher than necessary. There is a point of inconsistency in combining the costs because a facility's operation and maintenance costs were based on actual population served while its' land and construction costs were based on design population. To avoid this inconsistency the regression curves of the three types of costs have been combined instead of combining costs of each site.

Figures 6.9 and 6.10 indicate total present worth costs and present worth costs per capita of treatment alternatives versus design population (note: these amounts relate to facilities operating at design capacity). The figures indicate that lagoon facilities had the lowest present worth costs of the treatment alternatives. AL facilities cost roughly twice as much as lagoon facilities and RBCs ranged from 3 to 7 times as costly as lagoons. An evaluation of confidence region intervals was not appropriate with the data but an indication of the confidence is given in Figures 6.11 and 6.12 where present worth costs of actual sites are plotted versus design population. In order to combine the costs in these figures, operation and maintenance costs were based on design population which under estimated the cost, especially for the mechanical plants. The figures indicate that there is a high degree of confidence in determining one treatment cost is more expensive than another but there is much less confidence in predicting the actual magnitude of cost differences.

Figures 6.13 to 6.15 give a graphical representation of changes in the component costs and of the overall treatment costs for the three treatment alternatives.

To check the sensitivity of the analysis with respect to land value the information in Figure 6.10 was recalculated in Figure 6.16 with an assumed land value of $24,710 per hectare or $10,000 per acre. Comparing the two figures it can be seen that cost differences between lagoons and AL shrank dramatically with increasing land values but the relationship to RBC costs was roughly the same.

6.6 Conclusions

When considering only the construction and maintaining of a wastewater treatment facility, economic analysis indicated lagoon treatment to be least expensive of the three alternatives considered for communities with less than 15,000 people (moderate land values assumed). Lagoons had much higher land requirements, slightly lower capital construction cost, and much lower operating costs than RBCs and AL. When costs were combined in present worth dollars lagoons were overall least expensive. The analysis was somewhat sensitive to land values which were site specific depending mostly on the economic activity in the community and land quality. While a detailed analysis of variance was not appropriate, the data points indicate with a degree of consistency that RBCs were the most costly alternative and lagoons were the least costly (see Figures 6.9 and 6.10). For populations of less than 1000 people the cost difference between RBCs and AL facilities was much smaller.

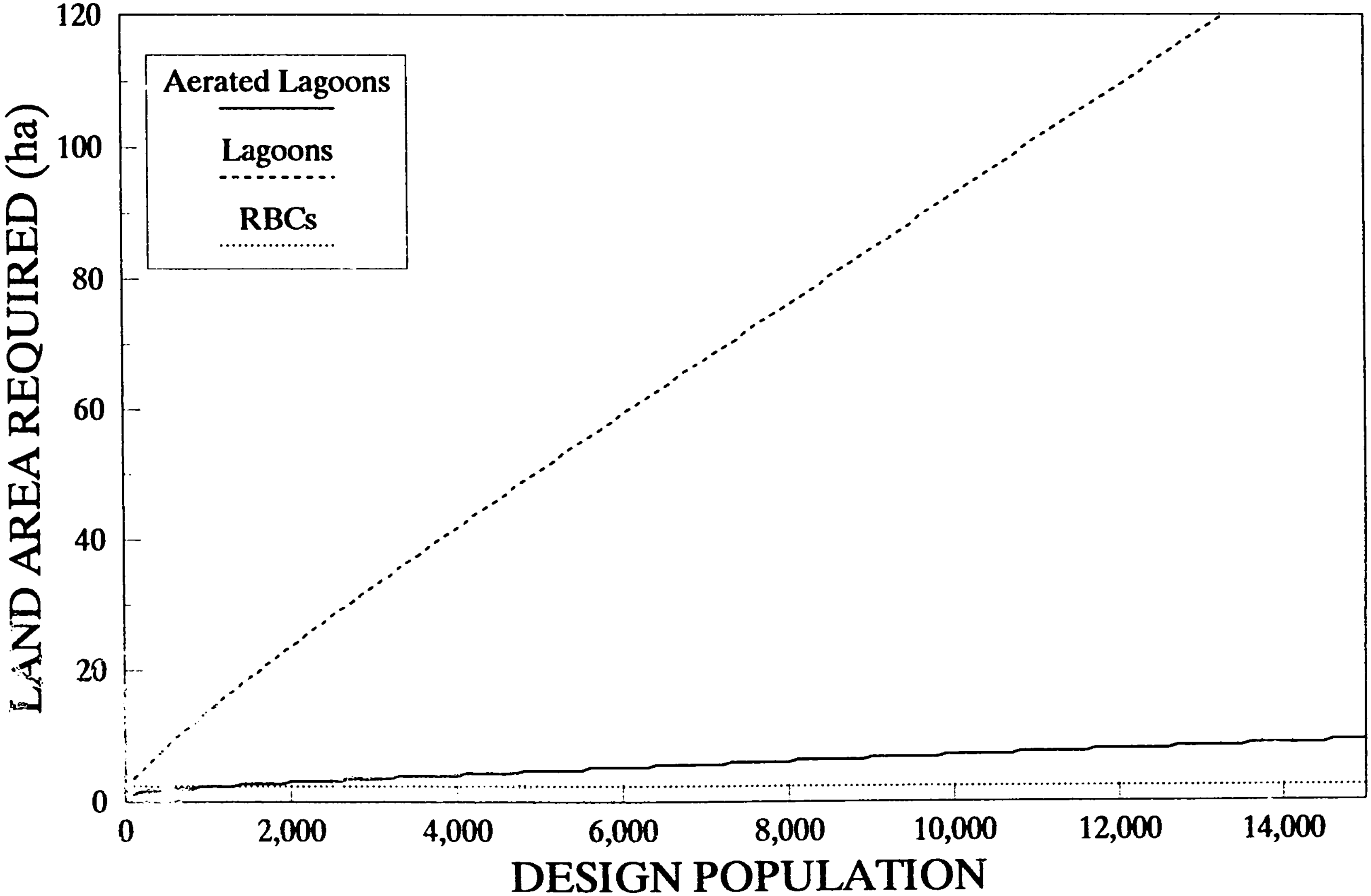


Figure 6.1: Land Area Required for Treatment Alternatives

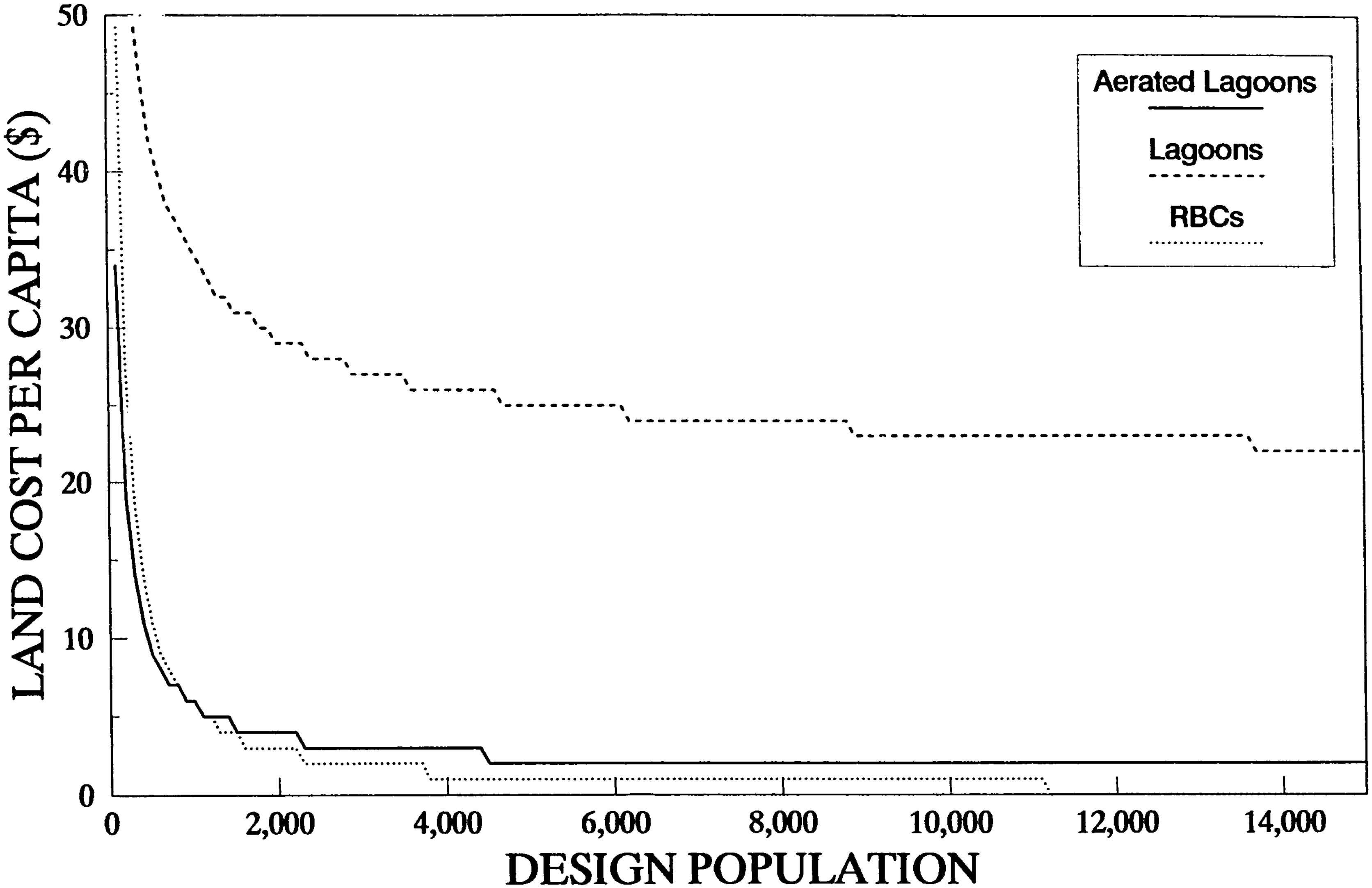


Figure 6.2: Lar ı Costs Per Capita for Treatment Alternatives

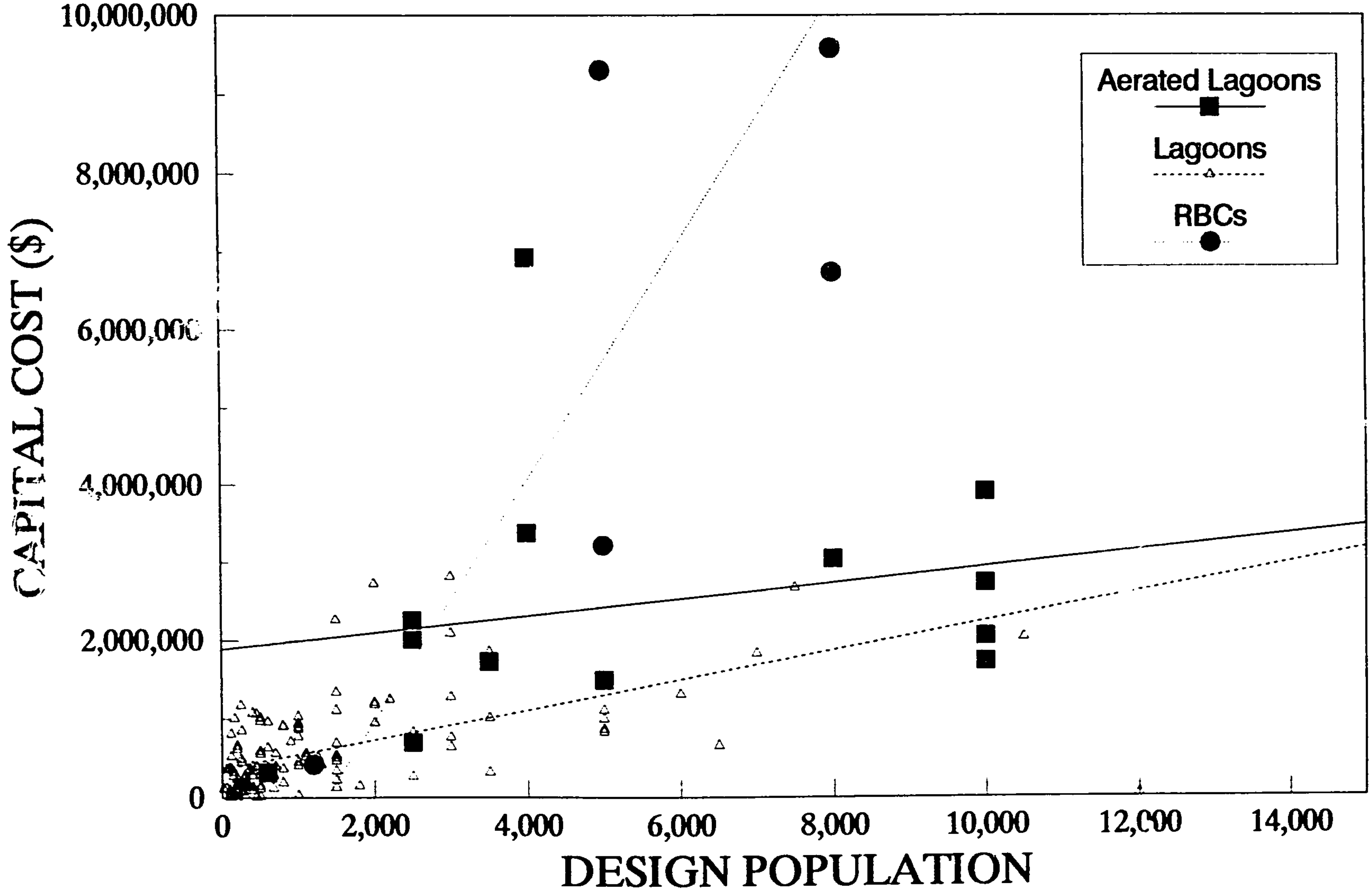


Figure 6.3: Capital Construction Costs for Treatment Alternatives

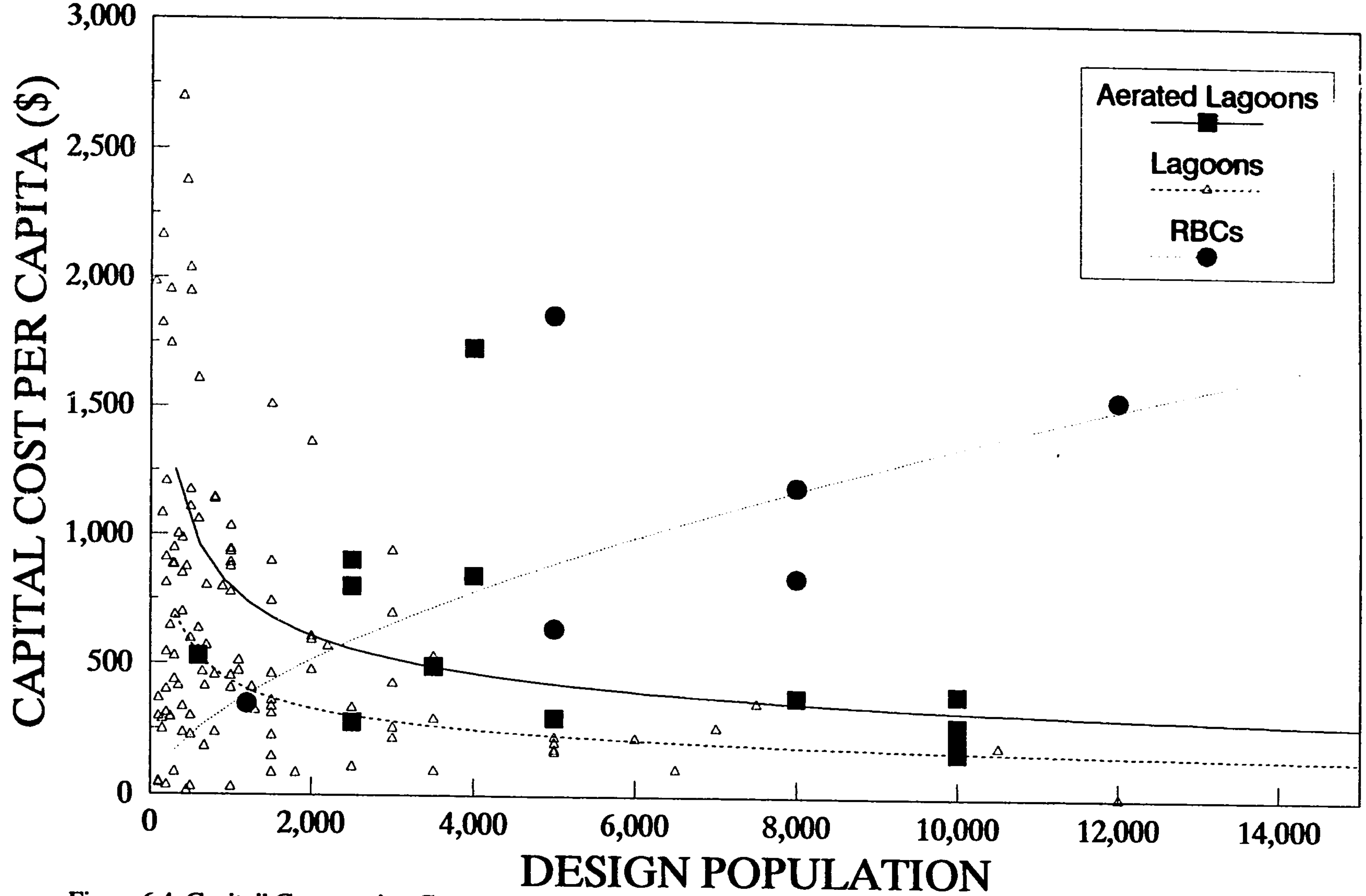


Figure 6.4: Capitail Construction Costs Per Capita for Treatment Alternatives

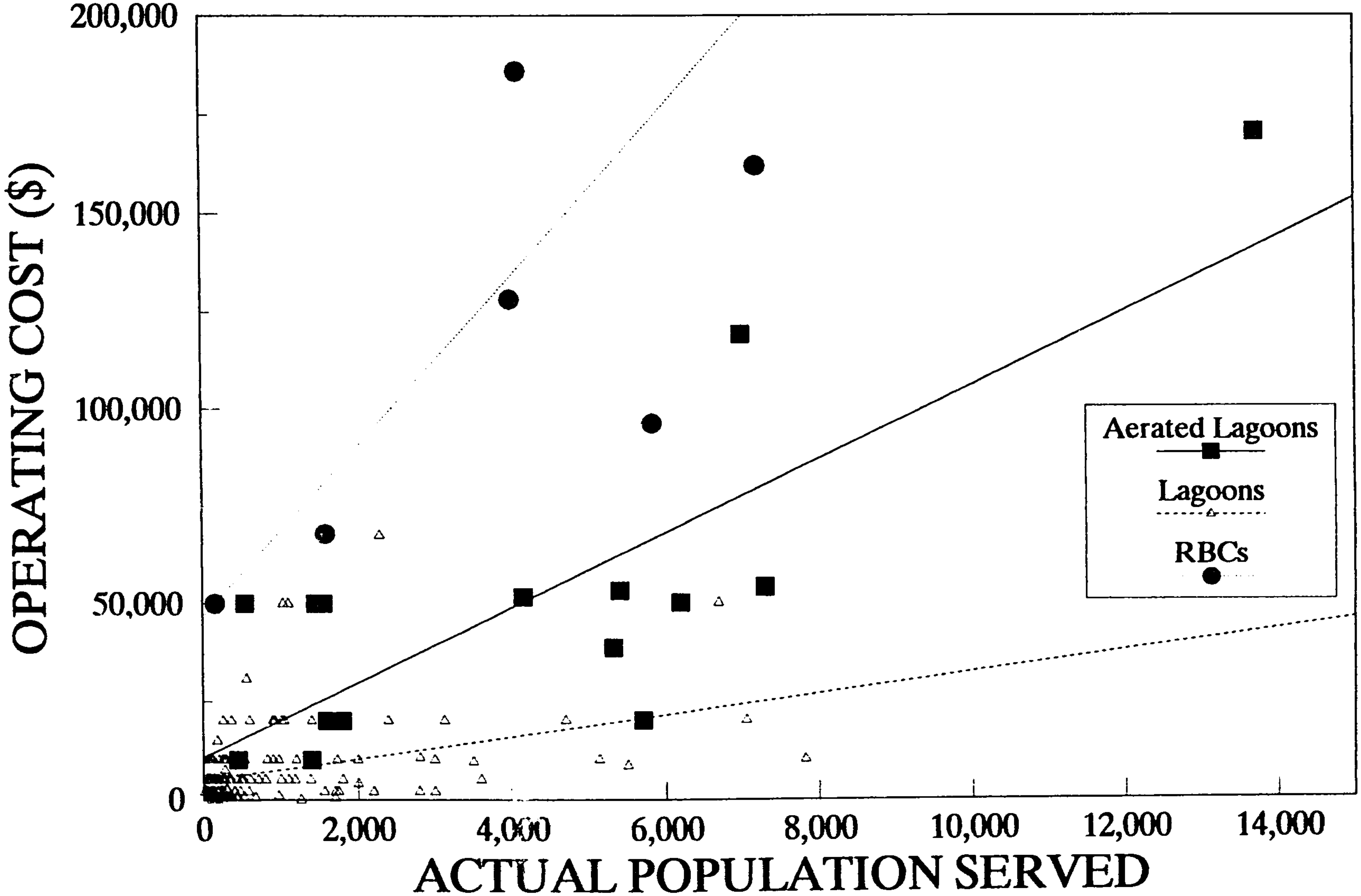


Figure 6.5:Operating and Maintenance Costs Per Capita for Treatment Alternatives

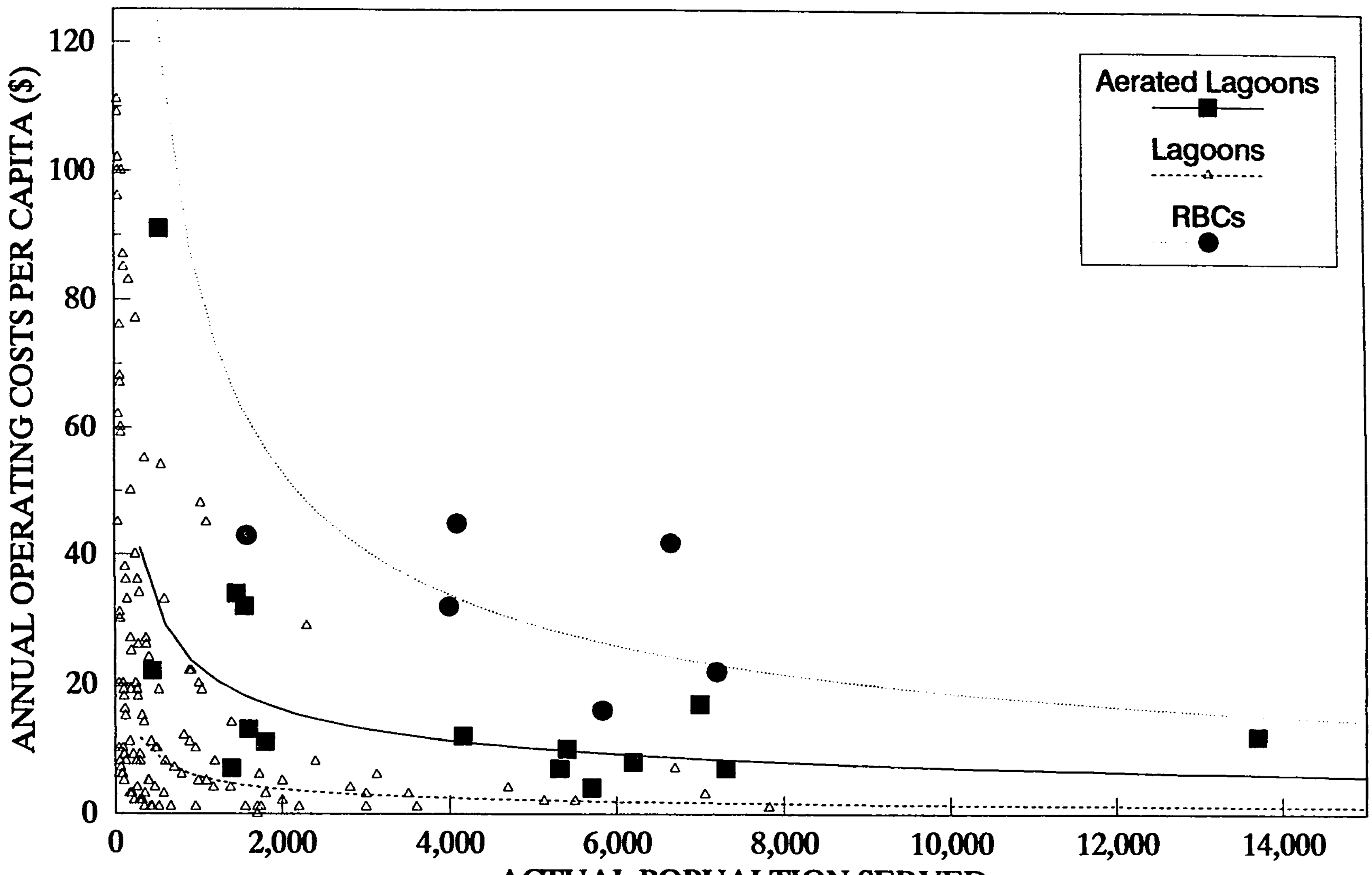


Figure 6.6:Operating and Maintenance Costs Per Capita for Treatment Alternatives

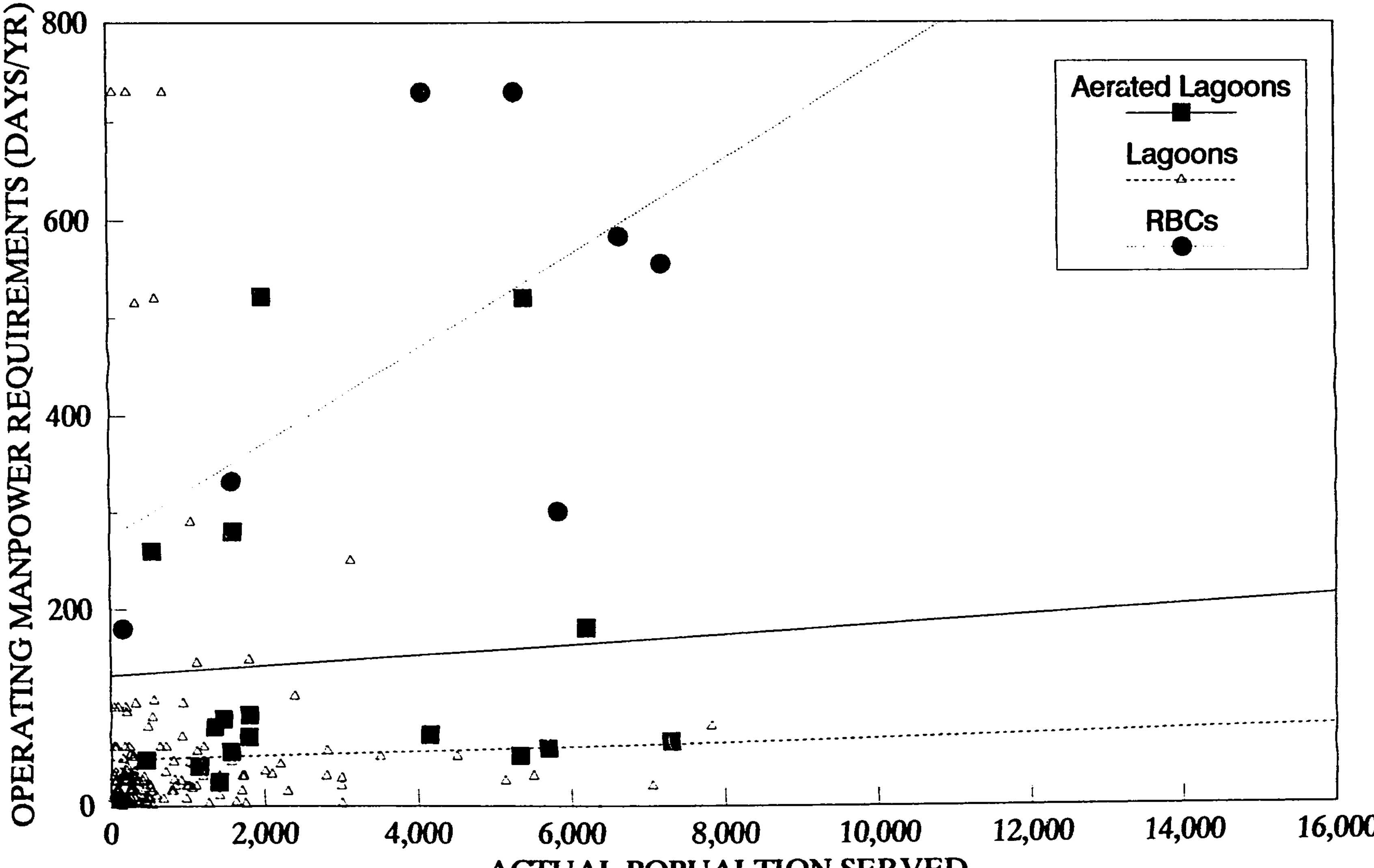
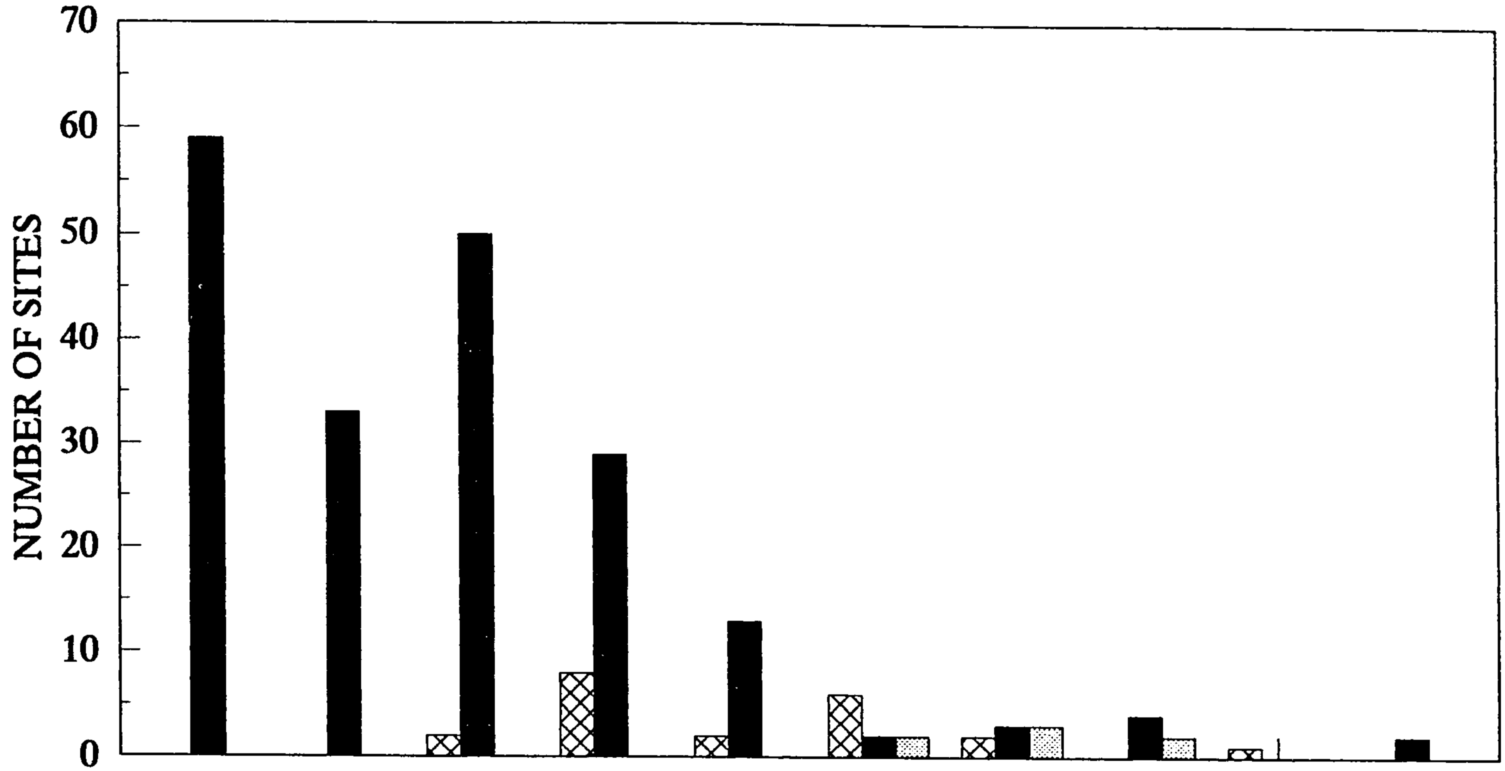


Figure 6.7 : Operating and Maintenance Manpower Needs for Treatment Alternatives



PERSON DAYS	10	20	40	80	160	320	640	1280	2560	5120	Total # of sites
Aerated Lagoons	0	0	2	8	2	6	2	0	1	0	21
Lagoons	59	33	50	29	13	2	3	4	0	2	195
RBCs	0	0	0	0	0	2	3	2	0	0	7

Figure 6.8 : Distribution of Operating Manpower Needs for Treatment Alternatives

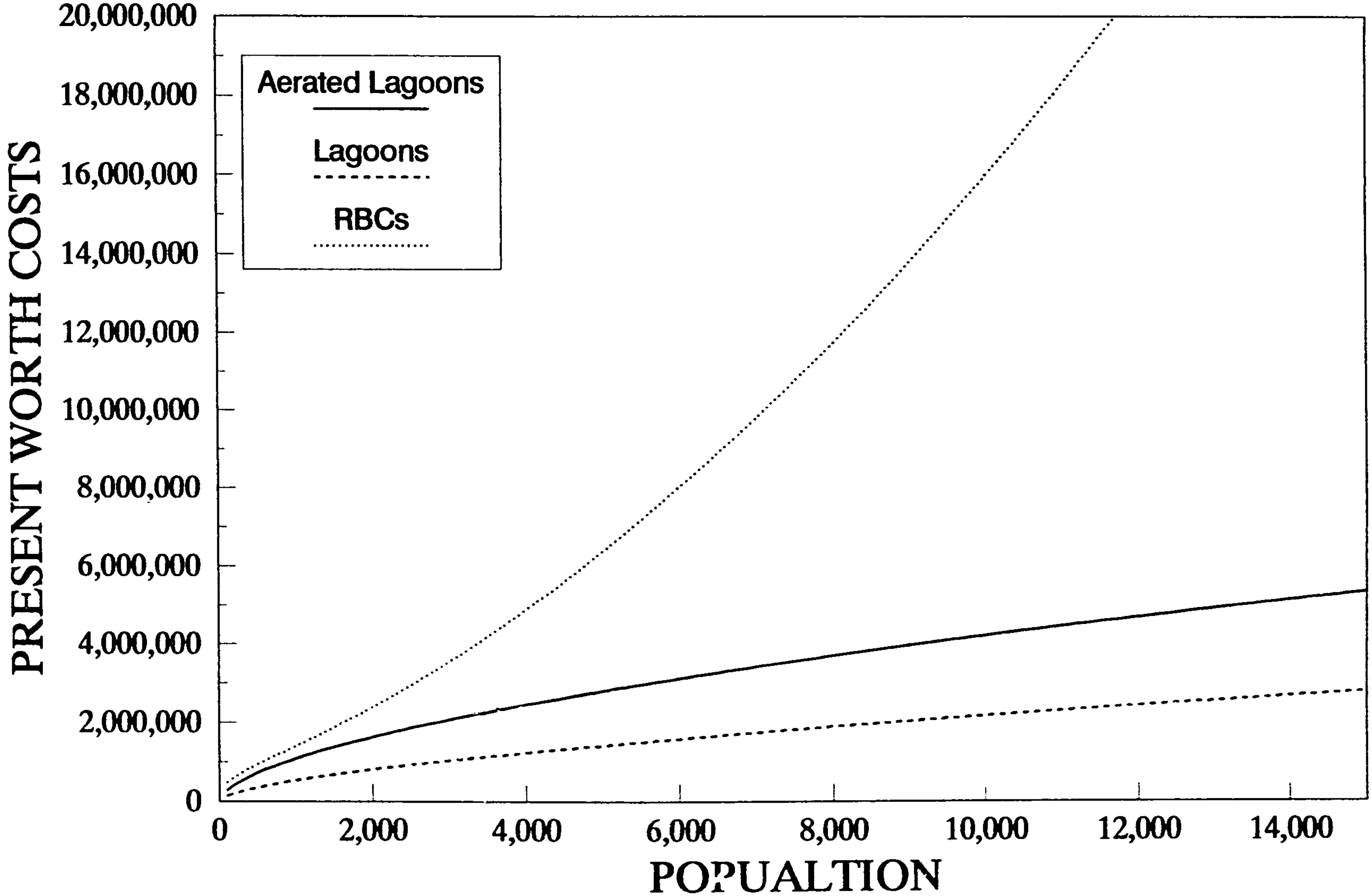


Figure 6.9: Present Worth Costs for Treatment Alternatives

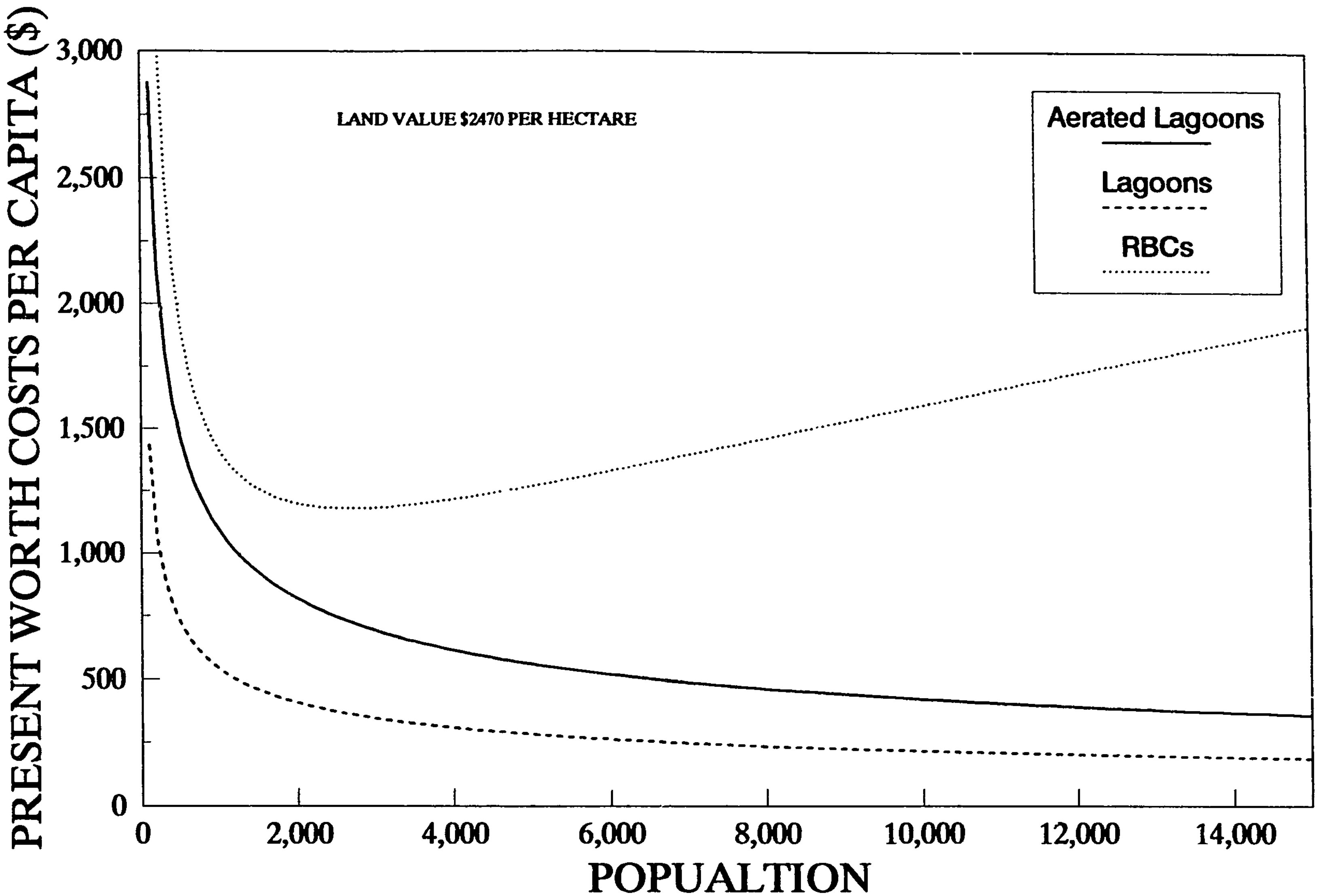


Figure 6.10: Present Worth Costs Per Capita for Treatment Alternatives

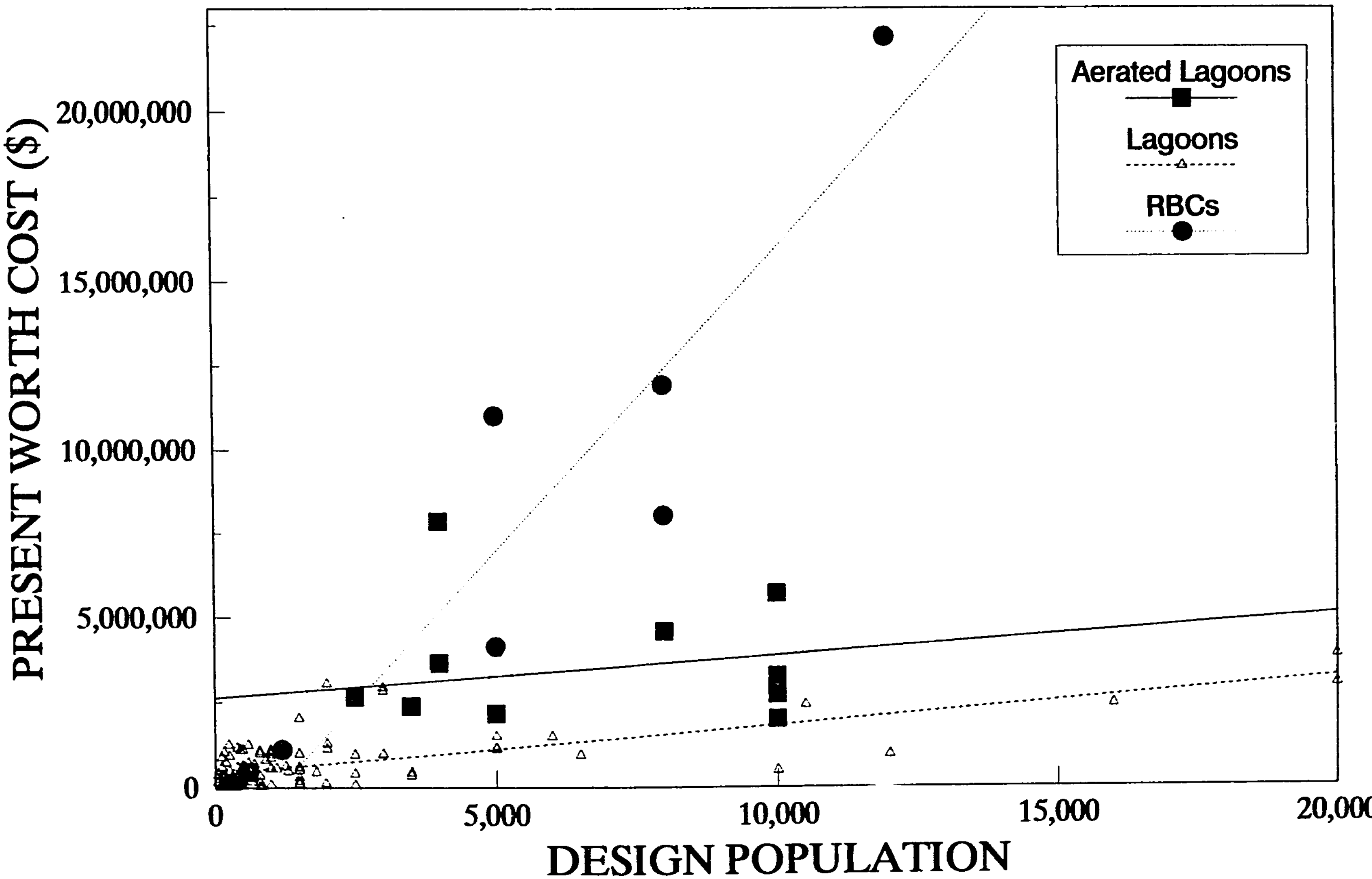


Figure 6.11 : Indication of Confidence for Present Worth Costs

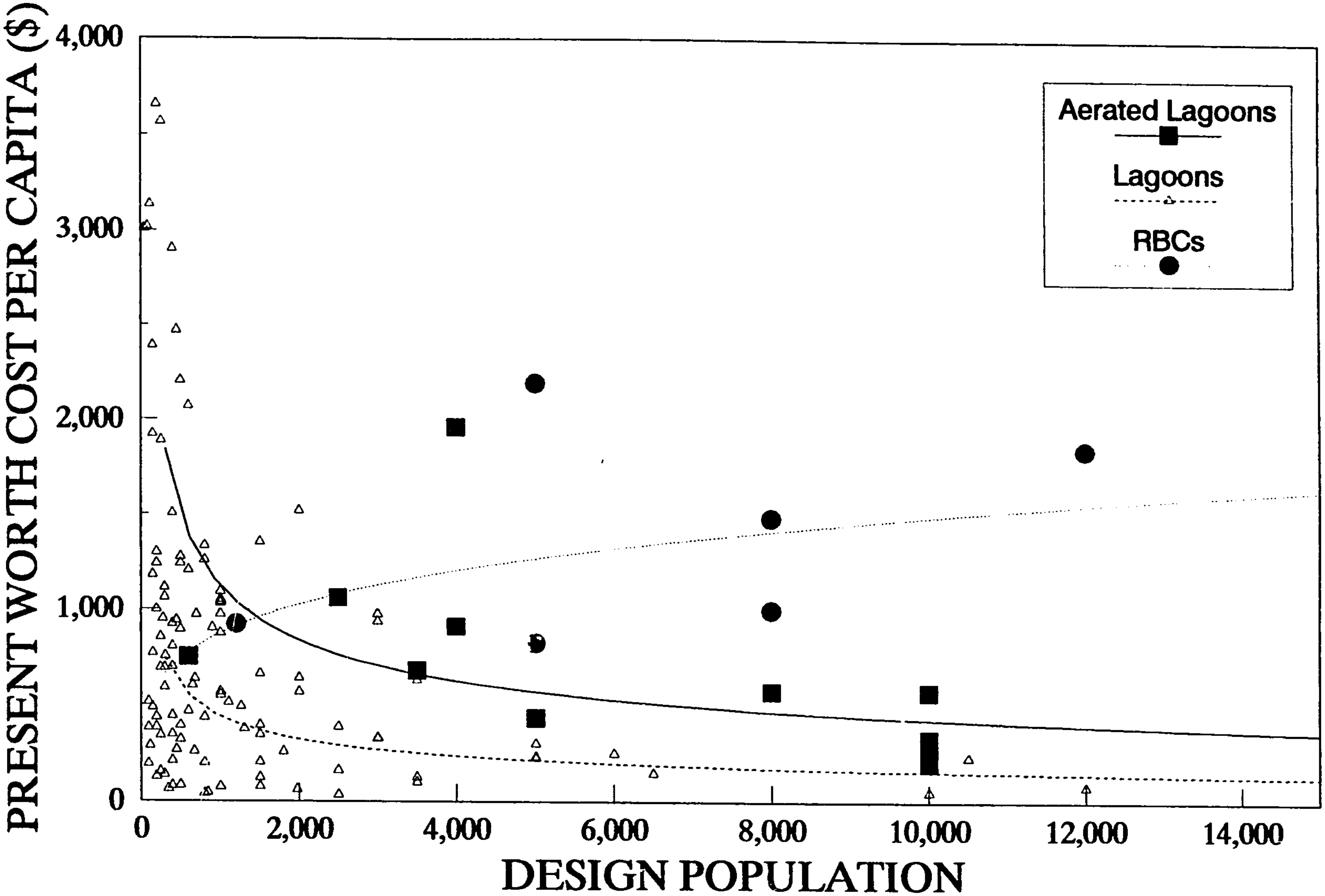
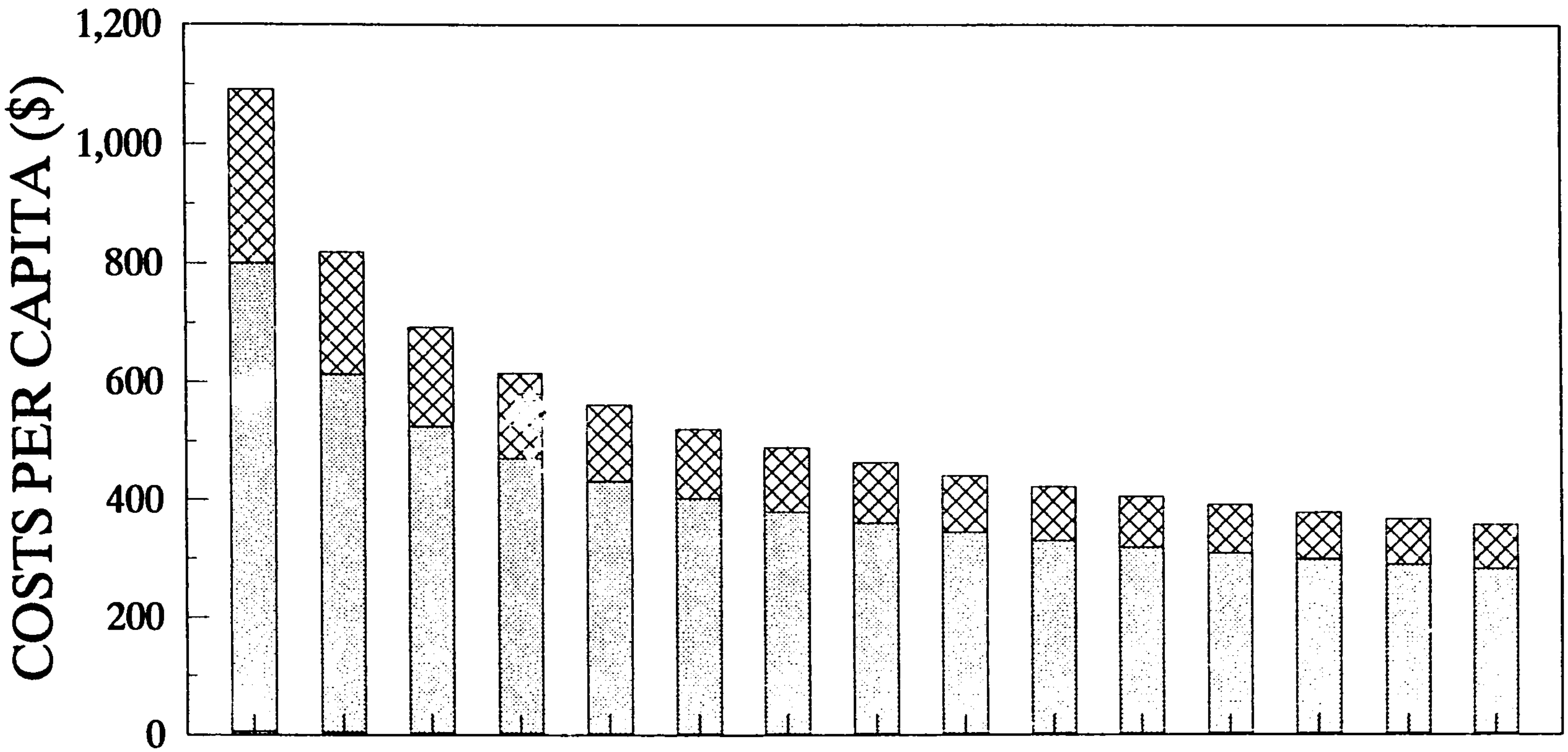
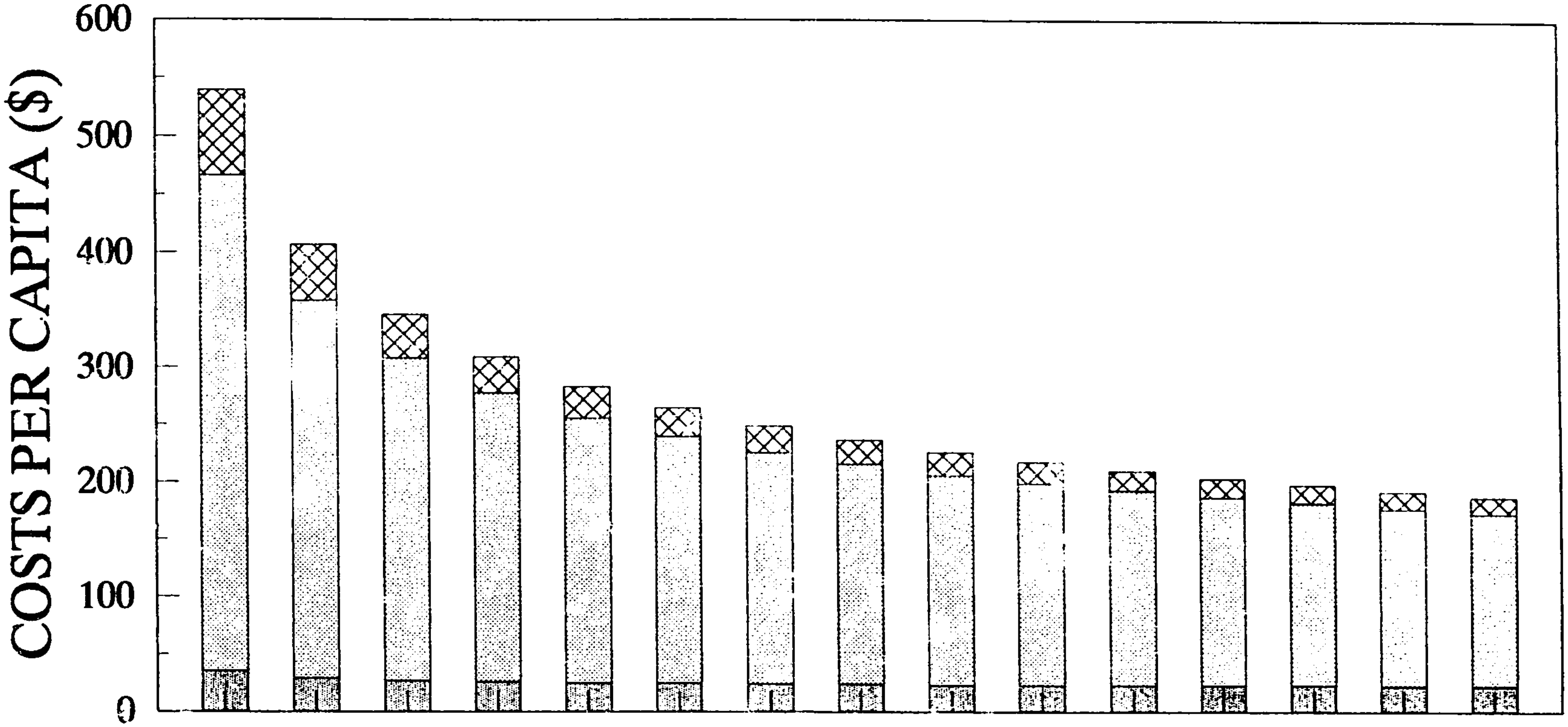


Figure 6.12 : Indication of Confidence for Present Worth Costs Per Capita



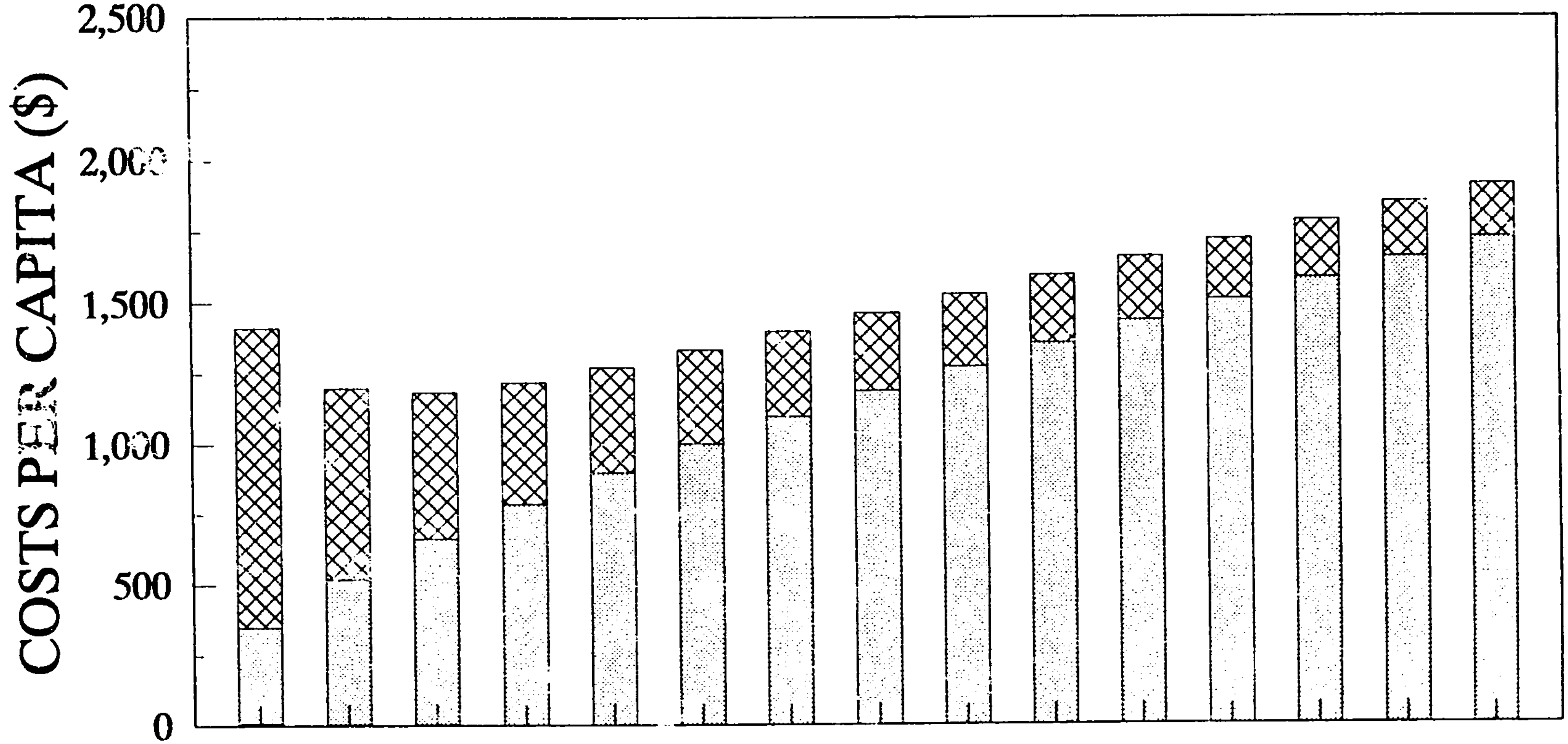
POPUALTION	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	11000	12000	13000	14000	15000
LAND COST	6	4	3	3	2	2	2	2	2	2	2	2	2	2	2
CAPITAL COST	795	609	521	467	429	400	377	358	342	329	317	306	297	289	281
OPERATING COST	290	205	167	145	130	118	110	102	97	92	87	84	80	77	75

Figure 6.13 : Component and Overall Costs Per Capita for Aerated Lagoons



POPUALTION	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	11000	12000	13000	14000	15000
LAND COST	35	29	27	26	25	25	24	24	23	23	23	23	23	22	22
CAPITAL COST	431	329	281	251	230	215	202	192	183	176	169	164	159	154	150
OPERATING COST	73	48	38	32	28	25	23	21	20	18	17	16	16	15	14

Figure 6.14 : Component and Overall Costs Per Capita for Lagoons



POPUALTION	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	11000	12000	13000	14000	15000
LAND COST	6	3	2	1	1	[illegible]	1	1	1	1	1	0	0	0	0
CAPITAL COST	343	518	660	[illegible]	896	999	1,095	1,186	1,273	1,356	1,435	1,512	1,586	1,657	1,727
OPERATING COST	1,063	678	522	433	375	333	301	276	256	239	225	212	202	192	184

Figure 6.15 : Component and Overall Costs Per Capita for RBCs

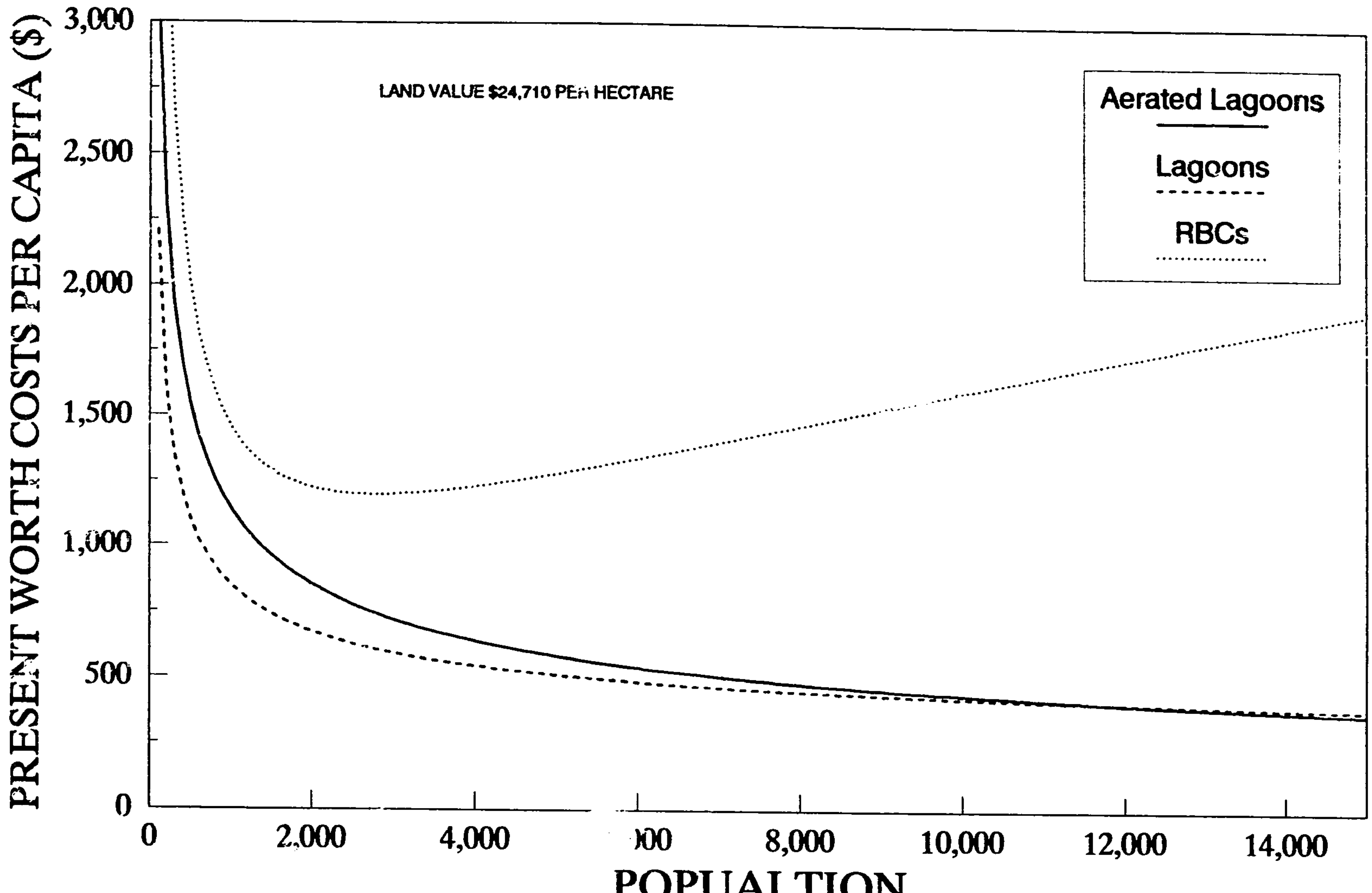


Figure 6.16 : Present Worth Costs Per Capita for Treatment Alternatives(land @ $24,710 per Hectare)

7.0 UPGRADE TECHNIQUES

7.1 Introduction

The previous evaluation of effluent quality demonstrated that lagoon systems meeting AEP's standards and guidelines produced exceptional effluent. Systems in compliance with the guidelines have no need of upgrade techniques to improve effluent quality except when extenuating circumstances exist. Examples of circumstances that may require upgrade techniques are:

- facilities forced to discharge in the spring due to hydraulic characteristics of receiving environment;
- facilities that are not required to upgrade to current AEP standards and guidelines;
- facilities operating at design capacity may increase capacity and avoid expansion or upgrading to a mechanical treatment system; and
- if improved effluent quality is required due to site specific situations (i.e. nutrient removal).

7.2 Available Upgrade Techniques

The topic of upgrade techniques for lagoon treatment is widely researched in the literature. TSS (algae) removal, nutrient removal, and disinfection are the common themes of the research. Most of the work has been with lagoons in temperate climates with continuous discharge and the information may be difficult to extrapolate to colder climates with intermittent discharge. Many of the techniques described in the literature do not meet the criteria that have made lagoons the best practicable technology for small communities. Generally they require high maintenance, operational costs, and skill levels which do not match the capabilities of small communities. Middlebrooks commented (Middlebrooks *et al.*, 1974) that it seems impractical to couple a unit process which has a disadvantage of high operating costs to a lagoon which has the advantage of low operating costs. Due to the intermittent discharge of Alberta lagoons, large capital expenditures on upgrade equipment that sit idle for 11 months of the year seem inappropriate as well. The upgrade techniques which have characteristic high capital and operating costs are not reasonable options in Alberta unless communities could share the cost of mobile equipment and operators.

The different techniques of upgrading lagoons vary in terms of effort required, capital cost, operation cost, operator skill, and effluent quality capabilities. The following table lists information on upgrade techniques, the list has been roughly ordered in terms of cost of implementation:

Table 7.1 : Upgrading Techniques for Lagoons

Technique	Effectiveness in Alberta	Benefits Gained	Capital Cost	Operating Cost	References of northern experience
Operational- Continuous summer discharge	Demonstrated to be effective, depends on receiving environment	- Lower discharge flow rate - increased capacity	none	very low	This report; Beier, 1979; Beier and Turnbull, 1980; Beier, 1983; Milos and Beier, 1978 .
Operational- Selected month of discharge for optimal effluent quality	Demonstrated to be effective	- improved effluent quality	none	very low	This report; Beier, 1979; Beier and Turnbull, 1980; Beier, 1983; Milos and Beier, 1978 .

Technique	Effectiveness in Alberta	Benefits Gained	Capital Cost	Operating Cost	References of northern experience
<u>Operational-</u> Discharge facultative cell in fall discharge	Only theoretical	- increased capacity	none	very low	This report; Beier, 1979; Beier and Turnbull, 1980; Beier, 1983; Milos and Beier, 1978 .
In pond chemical treatment	Demonstrated to be effective	- improve effluent quality - may accommodate twice a year discharge... increased capacity	low	low to medium	Finch, 1984
Adding a short detention cell where none exists	Demonstrated to be effective	- improved effluent quality	low to medium	very Low	This report; Beier, 1979; Beier and Turnbull, 1980; Beier, 1983; Milos and Beier, 1978 .
Baffling treatment cell	May be effective	Plug Flow operation in treatment cell, increased detention time and effluent quality	low to medium	very Low	
Effluent for irrigation	Demonstrated effective	- no discharge to water course - water for irrigation	low to medium	low to medium	Black *et al.*, 1984; Environment Canada. 1984
Aquaculture	Interesting possibilities but usefulness doubtful	- improve effluent quality - fish production	low to medium	low to medium	
Stationary microsceening	Interesting possibilities	- reduce TSS - algae	low to medium	low to medium	Fukunaga *et al.*, 1991
Wetlands treatment	some experience in the north... performance not proven	- improved effluent quality	medium (land costs)	low	Slupsky and Frith, 1971
Mechanical microsceening	some experience ... promising results	- improved effluent quality (TSS)	high	medium	

Technique	Effectiveness in Alberta	Benefits Gained	Capital Cost	Operating Cost	References of northern experience
Upgrade to aerated lagoon	Proven effective but major reconstruction needed	- improved effluent quality	very high	medium	Vallance , 1990
Dissolved air flotation	Effective with chemical treatment and filtration (bulky sludge problem)	- improved effluent quality	very high	very high	
Out of pond chemical treatment	proven effective but usually need filtration step	- improved effluent quality	very high	very high	
Mechanical addons	Proven effective	improved effluent quality	very high	very high	
UV disinfection	effective in cold climates, high TSS is a problem	- Improved bacteriological quality	high	medium to high	
Ozone disinfection	effective in cold climates, ozone must be produced on sight	- Improved bacteriological quality	high	very high	
Chlorine disinfection	effective in cold climates but toxic residuals are a concern	- Improved bacteriological quality	low to medium	low to medium	

7.3 Feasible Upgrade Techniques for Alberta

A brief overview of upgrade techniques that seems practical for the situation in Alberta follows.

7.3.1 Continuous Summer Discharge

The earlier sections of this report have demonstrated that except for TSS (due to algae) lagoon effluent quality in the spring improves greatly after approximately two months of ice free treatment. Beier (1980) showed that the TSS levels decreased in the summer. This indicates that a continuous discharge over the summer may be feasible and impacts on the receiving environment could be reduced because of lower effluent discharge rate. The benefits of this upgrade technique are increased capacity of the lagoon due to reducing storage time to 8 or 9 months and possibly reducing impact on receiving environment.

As Beier (1980) stipulated, effluent not disinfected should not be discharged to recreational waters during summer. Continuous discharges throughout the summer may require some algae removal and disinfection.

Continuous summer lagoon discharges are a cost effective operational upgrade but if additional TSS removal and disinfection are required the cost becomes prohibitive.

7.3.2 Selected Month of Discharge

The evaluation of effluent quality (section 3.5.1.6) has indicated the optimal months for effluent quality in the spring and fall seasons to be May and October. If receiving stream discharges are favorable lagoon discharges should occur in these months to minimize the impact on the receiving environment.

The cost for this operational upgrade is negligible and the benefits are a reduced impact on the environment.

7.3.3 Discharge Facultative Cell With Fall Discharges

The drawing down of the facultative cell in fall discharges will increase the lagoon capacity by roughly 15 percent. The excellent effluent quality of the fall discharges of the 4S-2L and 2S-2L lagoon systems indicates that the poorer quality facultative effluent may be assimilated and improved before it is discharged from the storage pond. Further work is needed to demonstrate the impact on discharged effluent quality.

This operational upgrade increases the capacity and may delay expansion of facilities operating near design capacity.

7.3.4 In-Pond Chemical Treatment

The study conducted by Finch (1984) at Gibbons, Alberta demonstrated in-pond alum treatment improved effluent quality of spring discharging lagoons significantly. The study proved in-pond alum treatment to be an effective upgrade option for lagoons forced to discharge in the spring.

Finch (1984) reported capital costs of $8400 (1984) and operating cost of 7¢ per m^3 of wastewater treated with an alum dose of 304 mg/L of $Al_2(SO_4)\bullet 18\ H_2O$. The low cost and effective treatment leave in-pond chemical addition an attractive upgrade option.

El-Gohary *et al.* (1991) investigated algae removal and found efficient separation of algae was achieved with alum dose of 5.14 mg Al^{3+}/l(almost one log unit of reduction of chlorophyll). Bond and Mowry (1989) found that chemical coagulants could be used effectively on pond effluents to remove algae. The doses required for optimal suspend solids removal was 60 to 100 mg/L alum, the discharge was also acceptable for BOD and phosphorus. They found lime could be used as well especially if ammonia is a problem. They tried polyelectrolytes with alum and found no significant improvement.

Airaksinen (1978) and Balmer and Bjarne (1978) describes the use of chemical precipitation used in the lagoon inlets to improve effluent quality in the winter in Finland and found that BOD and phosphorus removal were increased from 50% to 70 and 90% respectively but, he commented that the sludge accumulation was a problem. Folkman and Wachs (1972) found that lime was capable of removing algae and reducing nutrient levels in wastewater pond effluents and doses of roughly 600 mg/L of CaO were required for effective removal.

In-pond chemical treatment has proven effective both for costs and effluent quality improvement and is a useful upgrade technique. There may be slight difficulties with sludge accumulation but volumes will not be great.

7.3.5 Adding Short Detention Cell

Lagoon system designs that do not include short detention cells do not perform as well as systems with short detention cells. The addition of a short detention cell to an existing lagoon should be considered as a possible upgrade technique. The benefit of this upgrade technique is to improve effluent quality.

The retro-fitting of an operating lagoon with a short detention cell may require novel berm designs and construction techniques but costs should not be prohibitive.

7.3.6 Irrigation of Effluent

The use of irrigation as an upgrade technique was discussed in chapter 4 of this report. In summary, irrigation with lagoon effluent is a viable option but analysis must be done to ensure compatibility with soil and crop types. The benefits of irrigating with wastewater effluents include the elimination of discharges to natural drainage courses and crops under irrigation benefit from the nutrients present in the wastewater effluents.

The irrigation of wastewater effluents is an effective upgrade technique as long as precautions are use to avoid any microbial exposures to people or livestock.

7.3.7 Aquaculture

There is much written about successful aquaculture operations in lagoons but Middlebrooks *et al.* (1974) states that some of the high success rate is due to the inordinate amount of care given to study and test facilities and predicts that systems are not rugged enough to operate well with low levels of maintenance associated with lagoon facilities. The author concludes that aquaculture for protein production is practical but is unusable as a treatment step. Krishnamoorthi *et al.* (1973) related the vast experience gained in India over the years in the operation of fish ponds fertilized with sewage (raw) and said that the sewage needed to be diluted in order to avoid inhibiting the fish or causing algae blooms that made the ponds anoxic and caused fish mortality. Nyholm *et al.* (1978) used pilot scale tests to see if nutrients could be removed using algae and used fish to graze the zooplankton in order to maintain a stable ecosystem. Duffer (1974) related personal communication with A. Husley from Little rock Ark[illegible] [illegible]here Asian silver carp obtained on an experimental basis removed high concentratio[illegible] [illegible]gae in 24 hours.

The practice of aquaculture is untested in northern lagoons and may be hampered by operational difficulties. Aquaculture is of questionable value to lagoon treatment in Alberta.

7.3.8 Water Plants

Dinges (1978) demonstrated effective use of hyacinth culture in conjunction with a lagoon system to produce BOD5 and TSS removal of 97 and 95% and stated that hyacinths could be grown in cooler climates on a seasonal basis. Middlebrooks *et al.* (1974) stated that bio-production in wastewater lagoons is not a useful technique for improving effluent quality.

The use of water plants as an upgrade technique is of questionable value.

7.3.9 Stationary Microscreens

A researcher in Japan found good TSS removal by placing microscreens in front of the lagoon outlet (Fukunaga *et al.*, 1991). This use of microscreens would be well suited to the short discharge times associated with the intermittent discharge lagoons in Alberta.

7.3.10 Wetlands Treatment

Hartland-Rowe *et al.* (1974) wrote an extensive report on the use of swamplands for sewage effluents and commented it was a viable option. Mudroch and Capobianco (1979) studied the effect of treated effluent on marsh land and found that the vegetation had changed and there where higher concentrations of some heavy metals in the sediments. Slupsky and Frith (1971) evaluated wetlands treatment in Hay River N.W.T. and indicated that the system is effective but that travel to the receiving stream should be 10 km.

7.3.11 Mechanical Microscreening

The development of microscreen materials has evolved from the 23 micron stainless steel that had operating problems and did not produce consistent effluent quality to the 1 micron polyester materials that are viable alternatives for upgrading lagoon systems (Beier, 1979). Middlebrooks (1974) concluded that mechanical microscreening is effective and requires little maintenance and is a viable alternative for upgrading lagoon effluent quality.

7.3.12 Upgrading to Aerated Lagoon

Vallance (1990) explained that the upgrading of a lagoon to an aerated lagoon is a viable option. The existing facility can be used to some extent although the cells will need to be deeper (at least 2.5m and preferable 3.5m) and leaking berms will have to be fixed. The anaerobic cells can either be abandoned or converted to truck dumping basins. Disadvantages include: disposal of accumulated sludge, handling flows during conversion, and unacceptable location or odour problems.

Leininger (1977) stated that when costs are considered, the option of building a new wastewater treatment plant or upgrading a lagoon will usually result in staying with the lagoon.

While Vallance (1990) maintained the benefit of the original capital investment, the project was similar to the construction of a new facility except the land was already owned. The expansion of the lagoon will almost certainly have a lower capital and operating cost than converting to an aerated lagoon.

Upgrading to an aerated lagoon does not seem to be the least costly alternative but other factors may dictate [illegible] of aerated lagoons (i.e. odours).

7.3.13 Disinfection

Hom (1972) investigated chlorination of lagoon effluents while trying to avoid the destruction of the algae cells. With a chlorine dose of greater than 2.0 mg/L the effluent BOD increased drastically. Johnson *et al.* (1978) developed a mathematical model for the disinfection of lagoon effluents and in most cases found a combined chlorine residual of 0.5 to 1.0 mg/L sufficient to reduce fecal coliform concentrations below 200/100 mL. The author also discussed the negative effects of chlorinated by-products on the receiving environment.

Betzer (1980) demonstrated algae recovery by ozone floatation from wastewater effluent and said the dual benefit of obtaining two high quality products (algae and effluent) made the ozone floatation attractive.

Adams *et al.* (1987) demonstrated UV radiation and sedimentation of lagoon effluents and found 50% reduction of BOD_5 and 80% reduction in fecal coliforms.

The absents of harmful residuals make ozone and UV radiation attractive options for disinfection of lagoon effluents.

7.3.14 Miscellaneous Technique

Incorpera (1978) investigated the possibility of using waste heat from an industrial process to improve the efficiency of a wastewater treatment facility and found that it may be feasible in some circumstances. This technique does not have wide application possibilities.

7.4 Conclusions

The AEP standards and guidelines for lagoon design produce excellent effluent and only when extenuating circumstances exist is there a need for upgrade techniques to be considered. Lagoon facilities could use operational upgrades and maintain compliance with mechanical plant effluent standards and increase the capacity of the system by as much as 50%. There may be less impact on the receiving environment with continuous summer lagoon discharge than changing to a continuous flow mechanical plant because winter discharges are avoided. Other instances where upgrades may be useful are with spring discharges, facilities not required to meet current standards, and where the receiving water is sensitive or the use of the wastewater effluent is such that improved effluent quality is required.

If there is a need for upgrade techniques the inexpensive operational upgrades should be investigated first before more expensive techniques are considered. The upgrade techniques that appear to be most appropriate for the Alberta situation are operational upgrades, in-pond chemical treatment, additional short detention cells, and land application of effluents. Other options that are unproved but may be useful are stationary microscreens and wetlands treatment.

8.0 CONCLUSIONS AND RECOMENDATIONS

8.1 Conclusions

The following are conclusions drawn from the analysis of lagoon treatment:

- The Alberta Environmental Protection's guidelines for lagoon treatment are the most stringent in the country. Alberta is the only province that requires 365 days detention time and anaerobic cells which the study concluded are important in obtaining a good quality effluent.

-The lagoons meeting AEP's guidelines have produced good effluent that is superior to mechanical plants in all the parameters except TSS where it is still comparable.

-The important design factors to lagoon treatment are season of discharge, month of discharge, the presence of short detention cells, and storage time. The 4S-2L lagoons with fall discharge and 12 months of storage had an average BOD and TSS of 6 mg/L and 14 mg/L.

- The question of spring or fall discharge should be evaluated on a site specific basis to minimize the impact on the receiving water through the best combination of maximum dilution ratio, maximum effluent quality, and minimum impact on the recreational use of receiving stream.

- Generally, lagoon effluents are suitable for irrigation water.

- The evaluation of public concerns about lagoon treatment facilities showed that the vast majority of facilities received no complaints. Of the plants receiving complaints, odours were the category of highest concern with 17 % of the lagoon facilities reporting odour complaints. Except for a few sites, operators felt that odour occurred for short periods of time in the spring and that the problem was not severe.

-The results of the economic survey of treatment facilities indicated that generally lagoons are the most economical treatment option in terms of capital, land, and operation and maintenance costs.

- There are many upgrade techniques available for lagoons but facilities that meet the AEP's standards usually do not require improved effluent. Some of the operational techniques may increase lagoon capacity with only minimal increase in impact. Upgrades may be useful in improving spring effluent quality.

-The impact of the average lagoon treated effluents on public health and wildlife is minimal for lagoons with short detention cells. Fall discharges require roughly 1 to 1 dilution ratio and spring discharges require 1 to 10 to meet CCREM (1987) receiving water criterion. The spring discharges were variable and there were facilities with poor spring effluent, especially high coliform counts that required extremely high dilution ratios. The dilution required by mechanical plants is roughly 1 to 1000 and is governed by coliform counts.

8.2 Recommendations

The following are recommendations for lagoon treatment practices in Alberta:

- Due to the variability of spring discharges, poorly performing lagoons with spring discharge should be identified and efforts made to improve the effluent quality, perhaps using some of the upgrades discussed in chapter 7.

-Short detention cells provide significant improvement to effluent quality and should be included in all future facilities and may be retro fitted to existing facilities.

8.2 Proposals for Additional Studies

- Proper baffling of the treatment cell should improve performance, particularly for spring discharges.

- The comparison of indicator microorganism concentration in various lagoon discharges to their concentrations in mechanical plants should be evaluated. The quality of mechanical plant discharges may be improved by a storage lagoon.

- The treatment cell of a spring discharge lagoon does not affect the effluent quality which is governed by the quality of the wastewater stored over winter. Improved effluent quality in the spring may be possible if the treatment cell was on the other end of the storage cell. The storage cell could act as the treatment cell while filling in the summer and the treatment cell could be filled and isolated for the later part of the summer and through the winter. The treatment cell would have excellent effluent quality the following spring and could be used for final polishing and will have good microbial characteristics. Given two months of ice free treatment in the spring the storage cell will have low BOD and high TSS. Completely discharging the storage cell through the treatment cell over a 30 day period may gain considerable effluent quality improvement. Baffling the treatment cell would insure detention time. This theory can be tested on an existing facility with some temporary piping and pumping.

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APPENDIX A - OPERATOR'S SURVEY FORM

Municipal Sewage Treatment Facility Survey

Information is required to help complete a study on municipal sewage treatment technologies. You are requested to complete this questionnaire keeping in mind that the questions refer to the treatment system only and not the collection system. Any extra comments or information concerning the treatment facility would be appreciated.

Name of the person filling out this survey________________________Phone #____________
Name of municipality ______________________________________
Population served by facility ?___________

IDENTIFY TREATMENT SYSTEM
Lagoon ___ # short retention cells(<30 days)___
long retention cells(>30 days)___
Discharged every ____ months
Aerated Lagoon___
RBC Plant___
Activated Sludge___
Other___________________________________

LOCATION
Nearest resident of the municipality is located what distance to the treatment facility?_______(meters)
The treatment facility is located in what direction(North, Northeast. etc.) from the municipality?__________.

CONCERNS
Odours:
How many complaints a year from residents do you receive about the odours generated by the treatment facility?______
Comments____
____
On a scale of 1 to 10 (1=small, 10=very severe) how would you rank the severity of the odour problem to the residents?_____
Comments____
____

Insects and Pests:
How many complaints a year from residents do you receive about the insects and pests generated by the treatment facility?______
Comments____
____
On a scale of 1 to 10 (1=small, 10=very severe) how would you rank the severity of the insect and pest problem to the residents?_____
Comments____
____

Appearance:
How many complaints a year from residents do you receive about the appearance of the treatment facility?______
Comments____

On a scale of 1 to 10 (1=small, 10=very severe) how would you rank the severity of the appearance to the residents?_____
Comments____

Downstream Flooding:
How many complaints a year from residents do you receive about any downstream flooding due to the operation of the treatment facility?______
Comments____

On a scale of 1 to 10 (1=small, 10=very severe) how would you rank the severity of any flooding problems to the residents?_____
Comments____

Leakage or Seepage:
How many complaints a year from residents do you receive about any leakage or seepage from the treatment facility?______
Comments____

On a scale of 1 to 10 (1=small, 10=very severe) how would you rank the severity of any leakage or seepage problems to the residents?_____
Comments____

Effluent Quality:
How many complaints a year from residents do you receive about the quality of the effluent discharged from the treatment facility?______
Comments____

On a scale of 1 to 10 (1=small, 10=very severe) how would you rank the severity of the residents concerns over effluent quality?_____
Comments____

ECONOMICS

Operation and Maintenance:

No. of person days a year to operate facility?_____________

No. of person days a year to maintain facility?_____________

For the items in the following table please estimate the amount of money expanded annually in the O&M of the treatment facility. Indicate your estimate by checking the appropriate box.

ITEMS									
Labour	$0 ☐	$0 to $500 ☐	$500 to $1000 ☐	$1000 to $2000 ☐	$2000 to $5000 ☐	$5000 to $10,000 ☐	$10,000 to $20,000 ☐	$20,000 to $30,000 ☐	Specify if amount is off the scale $_______
Material	$0 ☐	$0 to $500 ☐	$500 to $1000 ☐	$1000 to $1500 ☐	$1500 to $2000 ☐	$2000 to $2500 ☐	$2500 to $3000 ☐	$3000 to $3500 ☐	Specify if amount is off the scale $_______
Equipment	$0 ☐	$0 to $500 ☐	$500 to $1000 ☐	$1000 to $1500 ☐	$1500 to $2000 ☐	$2000 to $2500 ☐	$2500 to $3000 ☐	$3000 to $3500 ☐	Specify if amount is off the scale $_______
Fuel	$0 ☐	$0 to $500 ☐	$500 to $1000 ☐	$1000 to $1500 ☐	$1500 to $2000 ☐	$2000 to $2500 ☐	$2500 to $3000 ☐	$3000 to $3500 ☐	Specify if amount is off the scale $_______
Power	$0 ☐	$0 to $500 ☐	$500 to $1000 ☐	$1000 to $1500 ☐	$1500 to $2000 ☐	$2000 to $2500 ☐	$2500 to $3000 ☐	$3000 to $3500 ☐	Specify if amount is off the scale $_______
Other	$0 ☐	$0 to $500 ☐	$500 to $1000 ☐	$1000 to $1500 ☐	$1500 to $2000 ☐	$2000 to $2500 ☐	$2500 to $3000 ☐	$3000 to $3500 ☐	Specify if amount is off the scale $_______
Total	$0 ☐	$0 to $500 ☐	$500 to $1000 ☐	$1000 to $2000 ☐	$2000 to $5000 ☐	$5000 to $10,000 ☐	$10,000 to $20,000 ☐	$20,000 to $50,000 ☐	Specify if amount is off the scale $_______

Have there been any berm erosion problems? YES or NO

If yes what corrective measures have been taken?____

____

Capital Costs: (give costs to the nearest $1000)

Land cost.

The cost (indicate the year of the dollar value) of the land that the facility is located on?____________year_________.

Construction cost.

Original construction costs_____________$ yr_________ Design Population _____________

Upgrade project______________$ yr_________ Design Population _____________

Upgrade project______________$ yr_________ Design Population _____________

Thank you for your cooperation in providing this information.

APPENDIX B - SURVEY RESULTS

COMMUNITY	TYPE	POP SERVED	TREATMENT	STORAGE	LOCATION DISTANCE	LOCATION DIRECTION	odour comp	odour sever	insect comp	insect sever	appear comp	appear sever	flood comp	flood sever	leak comp	leak sever	qualit comp	qualit sever
ACME	VILLAGE	527	LAGOON 4S,2L	7	?	N	0	3	0	1	0	1	1	2	0	1	0	1
ALDER FLATS	HAMLET	130	LAGOON 2S,1L	12	600	W	0	1	0	1	2	3	2	2	0	1	0	1
ALIX	VILLAGE	782	LAGOON 4S,4L	EVAP	1500	N	2	1	0	1	0	1	0	1	0	1	0	1
AMISK	VILLAGE	200	LAGOON 1S,1L	EXFILTRAT	300	NW	0	2	0	1	0	1	0	1	0	1	0	1
ARDMORE	HAMLET	?	LAGOON 2S,2L	12	800	S	0	1	0	1	0	1	0	1	0	1	1	1
ARDROSSAN	HAMLET	105+3SCHOOL	LAGOON 2S,2L	12	1500	NW	0	1	0	1	0	1	0	1	0	1	0	1
ARROWWOOD	VILLAGE	142	LAGOON 0S,2L	12	300	E	0	1	0	1	0	1	0	1	0	1	0	1
ATHABASCA	TOWN	?	AERATED LAGOO		?	N	0	1	0	1	0	1	0	1	0	1	0	1
BARONS	VILLAGE	260	LAGOON OS,3L	12	800	W	0	1	0	1	0	1	0	1	0	1	0	1
BARRHEAD	TOWN	4160	AERATED LAGOO		1000	SE	0	1	0	1	0	1	0	1	0	1	0	1
BASHAW	TOWN	829	LAGOON 4S,3L	12	4000	E	8	1	0	1	0	1	0	1	0	1	0	1
BASSANO	TOWN	1190	LAGOON 4S,1L	CONTIN	2500	E	0	1	0	1	0	1	0	1	0	1	0	1
BEAVERLODGE	TOWN	1779	LAGOON 4S,1L	7	400	S	0	1	0	1	0	1	0	1	0	1	0	1
BEISEKER	VILLAGE	639	LAGOON 2S,2L	6	400	E	0	1	0	1	0	1	0	1	1	8	0	1
BENTLEY	VILLAGE	900	LAGOON 2S,2L	6	150	SW	0	1	0	1	0	1	0	1	0	1	0	1
BERWYN	VILLAGE	606	LAGOON 4S,2L	12	2200	SE	0	1	0	1	2	1	0	1	1	1	0	1
BEZANSON	HAMLET	?	LAGOON 0S,1L	12	500	SW	0	1	0	1	0	1	0	1	0	1	0	1
BIG VALLEY	VILLAGE	350	LAGOON 4S,2L	6	?	SE	0	1	0	1	0	1	0	1	0	1	0	1
BITTERN LAKE	VILLAGE	169	?	12	1000	N	0	1	0	1	0	1	0	1	0	1	0	1
BLACK DIAMOND	TOWN	1727	LAGOON 0S,3L	2	?	?	0	1	0	1	0	1	0	1	0	1	0	1
BLACKFALDS	TOWN	1800	AERATED LAGOO		1500	?	0	3	0	1	0	1	0	1	0	1	0	1
BLACKFOOT	HAMLET	180	LAGOON 0S,3L	12	800	N	0	1	0	1	0	1	0	1	0	1	0	1
BLACKIE	VILLAGE	303	LAGOON 0S,2L	6		NE	3	2	0	1	0	1	1	3	1	1	0	1
BLUE RIDGE	HAMLET	180	LAGOON 0S,1L	12	2000	NW	0	1	0	1	0	1	0	1	0	1	0	1
BLUESKY	HAMLET	?	LAGOON 1S,1L	12	1000	E	0	1	0	1	0	1	0	1	0	1	0	1
BON ACCORD	TOWN	1460	AERATED LAGOON		?	S	5	4	0	1	0	1	0	1	0	1	0	1
BONNYVILLE	TOWN	5132	LAGOON 4S,2L	12	300	SE	0	4	0	1	0	1	0	1	0	1	0	1
BOTHA	VILLAGE	174	LAGOON 1S,1L	12			0	1	0	1	0	1	0	1	0	1	0	1
BOWDEN	TOWN	936	LAGOON 4S,2L	12	1000	SW	0	1	0	1	0	1	0	1	0	1	0	1
BOYLE	VILLAGE	710	LAGOON 2S,2L	6	1600	NW	0	1	0	1	0	1	2	1	0	1	0	1
BRETON	VILLAGE	511	LAGOON 4S,2L	12			0	1	0	1	0	1	0	1	0	1	0	1
BROOKS	TOWN	9433	LAGOON 7S,5L	6	2500	E	0	1	0	1	0	1	0	1	0	1	1	1
BRUCE	HAMLET	65	LAGOON 0S,2L	24	650	W	2	1	0	1	1	1	1	1	0	1	0	1
BUFORD	HAMLET	46	LAGOON 0S,1L	24	800	W	0	1	0	1	0	1	0	1	0	1	0	1
BUGSBY	HAMLET	300	LAGOON 0S,1L	12	1000	NNW	0	1	0	1	0	1	0	1	0	1	0	1
BURDETT	VILLAGE	2800?	LAGOON 0S,1L	6	500	NW	0	1	0.5	1	0	1	0	1	2	3	0	2
CALMAR	TOWN	1400	LAGOON 4S,2L	12	500	NW	2	2	0	1	0	3	0	1	0	1	0	1
CAMROSE NEW	CITY	13700	AERATED LAGOO		1000	SE	0	1	0	1	0	1	0	1	0	1	0	1
CAMROSE OLD	CITY	13700	LAGOON 4S,5L	7	1000	SE	100	10	0	1	0	1	0	1	1	1	0	1
CANMORE	TOWN	??0	RBC		75	S	40	8	1	1	10	7	0	1	0	1	5	8.5
CARBON	VILLAGE	437	LAGOON 2S,3L	12	1000	E	0	1	0	1	0	1	0	1	0	1	0	1
CARDSTON	TOWN	4000	RBC		150	NE	0	1	0	1	0	1	0	1	0	1	0	1
CARMANGAY	VILLAGE	259	LAGOON 2S,1L	IRRIGATION	500	N	6	1	0	1	0	1	0	1	0	1	0	1
CAROLINE	VILLAGE	452	AERATED LAGOO	CONTIN	800	S	0	1	0	1	0	1	0	1	0	1	3	3
CARSELAND	HAMLET	550	AERATED LAGOON		1000	SE	0	1	0	1	0	1	0	1	0	1	0	1
CASTOR	TOWN	1000	LAGOON 4S,2L	12	1000	NW	0	1	0	1	0	1	0	1	0	1	0	1
CAYLEY	VILLAGE	243	LAGOON 0S,1L	?	400	E	1	1	0	1	0	1	0	1	0	1	0	1
CHAMPION	VILLAGE	366	LAGOON 0S,1L	12	?	NE	0	1	0	1	0	1	0	1	0.5	1	0	1
CHAUVIN	VILLAGE	3600	LAGOON 2S,2L	24	1600	E	0	1	0	1	0	1	0	1	0	1	0	1
CHIPMAN	VILLAGE	239	LAGOON 4S,2L	NOT DISCH.	800	NE	0	1	0	1	0	1	0	1	0	1	0	1

COMMUNITY	TYPE	POP. SERVED	TREATMENT	STORAGE	LOCATION DISTANCE	LOCATION DIRECTION	odour comp.	odour sever	insect comp.	insect sever	appear comp.	appear sever	flood comp.	flood sever	leak comp.	leak sever	qualit comp	qualit sever
CLAIRMONT	HAMLET	900	LAGOON 4S,2L	EVAP	3000	W	0	1	0	1	0	1	0	1	0	1	0	1
CLANDONALD	HAMLET	189	LAGOON 0S,1L	12	3000	S	0	1	0	1	0	1	0	1	0	1	0	1
CLARESHOLM	TOWN	3500	LAGOON 4S,4L	IRRIGATION	1600	SW	0	1	0	1	0	1	0	1	0	1	0	1
CLUNY	VILLAGE	103	LAGOON 0S,1L	12	NONE	E	0	1	0	1	0	1	0	1	1	2	0	1
COALDALE	TOWN	5320	AERATED LAGOON		1000	N	0	2	0	2	0	2	0	1	0	1	0	1
COALHURST	VILLAGE	1350	AERATED LAGOO	3	800	SE	0	1	0	1	0	1	0	1	1	1	0	1
COCHRANE	TOWN	6200	AERATED LAGOO		1200	SE	0	1	0	1	0	1	0	1	0	1	0	1
COLD LAKE /GRA	TOWN	7818	LAGOON 4S,3L	6	6000	SE	2	3	0	1	0	1	0	1	0	4	0	1
COLINTON	HAMLET	260	LAGOON 1S,1L	?	600	SE	0	1	0	1	0	1	0	1	0	1	0	1
CONSORT	VILLAGE	114	LAGOON 2S,1L	6	300	SE	2	5	0	1	0	1	0	1	0	1	0	1
COUNTY OF FORT	??	80	LAGOON??	12	800	NW	0	1	0	1	0	1	0	1	0	1	0	1
COUTTS	VILLAGE	355	LAGOON 2S,1L	12	500	E	2	4	0	1	0	1	0	1	0	1	0	1
COWLEY	VILLAGE	290	LAGOON 2S,1L	12	475	W	0	1	0	1	0	1	0	1	0	1	0	1
CREMONA	VILLAGE	393	LAGOON 2S,3L	12	300	NW	0	1	0	1	0	1	0	1	0	1	0	1
CROSSFIELD	TOWN	1800	LAGOON 4S,2L	12	?	SW	3	1	0	1	0	1	0	1	0	1	0	1
CYNTHIA	HAMLET	100	LAGOON 0S,1L	8	300	E	0	1	0	1	0	1	0	1	0	1	0	1
DAPP	HAMLET	50	LAGOON 1S,1L	12	1000	WNW	0	1	0	1	0	1	0	1	0	1	0	1
DEBOLT	HAMLET	100	LAGOON 0S,1L	12	1500	SW	0	1	0	1	0	1	0	1	0	1	0	1
DELBURN	VILLAGE	564	LAGOON 4S,3L	12		E	0	1	0	1	0	1	0	1	0	1	0	1
DELIA	VILLAGE	198	LAGOON OS,1L	6	40000	SW	0	1	0	1	0	1	0	1	0	1	0	1
DEVON	TOWN	4100	RBC		50	N	0	1	0	1	0	1	0	1	0	1	0	1
DEWBERRY	VILLAGE	203	LAGOON 0S,2L	12	800	E	0	1	0	1	0	1	0	1	0	1	0	1
DONALDA	VILLAGE	225	LAGOON 1S,2L	12	1500	E	0	1	0	1	0	1	0	1	0	1	0	1
DONNELLY	VILLAGE	421	LAGOON 2S,SL	12	1600	NW	0	1	0	1	0	1	1	1	0	1	0	1
DRATON VALLEY	TOWN	7000	AERATED LAGOO		?	NE	0	1	0	1	0	1	0	1	0	1	0	1
ECKVILLE	TOWN	900	LAGOON 4S,2L	6	500	NE	0	1	0	1	0	1	0	1	0	1	0	1
EDBERG	VILLAGE	135	LAGOON 0S,1L	12	800	NE	0	1	0	1	0	1	0	1	0	1	0	1
EDSON	TOWN	7300	AERATED LAGOO	CONTIN	2000	E	0	1	0	1	0	1	0	1	0	1	1	1
EGALESHAM	VILLAGE	185	LAGOON 0S,1L	6	1000	N	0	1	0	1	0	1	0	1	0	1	0	1
EGREMONT	HAMLET	55	LAGOON 0S,1L	EVAP	500	SW	0	1	0	1	0	1	0	1	0	1	0	1
ELK POINT	TOWN	1400	AERATED LAGOON		1000	SE	0	1	0	1	0	1	0	1	0	1	0	1
ELNORA	VILLAGE	265	LAGOON 2S,3L	12	2400	SW	0	1	0	1	0	1	2	2	0	1	0	1
ENTWISTLE	VILLAGE	480	LAGOON 4S2L	6	500	NE	0	1	0	2	0	1	0	1	0	2	0	1
EVANSBURG	VILLAGE	725	LAGOON 4S,2L	11	160512?	NORTH	0	1	0	1	0	1	0	1	0	1	0	1
FABYAN	HAMLET	100	LAGOON	EVAP	800	SW	0	1	0	1	0	1	0	1	0	1	0	1
FALHER	TOWN	118[illegible]	LAGOON 4S,2L	12	750	SE	2	4	0	1	0	1	0	1	0	1	0	1
FAUST	?	379	LAGOON 4S,3L	12	1000	S	0	1	0	1	0	1	0	1	0	1	0	1
FAWCETT	HAMLET	300	LAGOON 0S,1L	12	600	W	0	1	0	1	0	1	0	1	0	1	0	1
FERINTOSH	VILLAGE	115	LAGOON0S,2L	NONE	?	S	0	2	0	1	0	1	0	1	0	1	0	1
FOOTNER LAKE	HAMLET	75	LAGOON 1S,2L	12	200	N	0	1	0	1	0	1	0	1	0	1	0	1
FOREMOST	VILLAGE	582	LAGOON 2S,2L	NONE	1500	NE	0	1	0	1	0	1	0	1	0	1	0	1
FORESTBURG	VILLAGE	967	LAGOON 0S,3L	12	1000	NE	0	1	0	1	0	1	0	1	0	1	0	1
FORT ASSINIBOIN	HAMLET	179	LAGOON 0S,1L	12	2000	E	0	1	0	1	0	1	0	1	0	1	0	1
FORT KENT	HAMLET	?	LAGOON 0S,2L	12	250	S	1	1	0	1	0	1	0	1	0	1	1	1
FORT VERMILION	HAMLET	800	LAGOON 4S,2L	6	450	E	0	2	0	1	0	1	0	1	0	1	0	1
FOX CREEK	TOWN	2300	LAGOON 4S,4L	6	600	N	0	1	0	1	0	5	0	1	0	1	3	7
GALAHAD	VILLAGE	158	LAGOON 0S,2L	12	?	SE	0	1	0	1	0	1	0	1	0	1	0	1
GIROUXVILLE	VILLAGE	349	LAGOON 2S,2L	12	50	SE	0	1	0	1	0	1	0	1	0	1	0	1
GLENWOOD	VILLAGE	306	LAGOON 2S,2L	6	400	SE	0	1	0	1	1	2	0	1	0	1	0	1
GRANUM	TOWN	371	LAGOON 2S,3L	12		E	0	1	75	1	0	1	0	1	0	1	0	1

COMMUNITY	TYPE	POP SERVED	TREATMENT	STORAGE	LOCATION DISTANCE	LOCATION DIRECTION	odour comp	odour sever	insect comp	insect sever	appear comp	appear sever	flood comp	flood sever	leak comp	leak sever	qualit comp	qualit sever
GRASSLAND	HAMLET	66	LAGOON 0S,2L	12	450	N	0	1	0	1	0	1	1	1	0	1	1	1
GREEN ACRES	TRAILER PAR	2000	LAGOON 0S,3L	EVAP	1000	W	12	1	0	1	0	1	0	1	0	1	0	1
GRENNSHIELDS	HAMLET	55	LAGOON	EVAP		N	0	1	0	1	0	1	0	1	0	1	0	1
GRIMSHAW	TOWN	2812	LAGOON 8S,5L	12	1000	SE	3	1	0	1	0	1	0	1	0	1	0	1
GROUARD	?	372	LAGOON 2S,2L	12	1000	E	0	1	0	1	0	1	0	1	0	1	0	1
GUNN	VILLAGE	105	LAGOON 0S,2L	12	600	N	0	1	0	1	0	1	0	1	0	1	0	1
GWYNNE	HAMLET	110	LAGOON 0S,1L	12	1000	SW	0	1	0	1	0	1	2.5	1	0	1	0	1
HAIRY HILL	VILLAGE	70	LAGOON 0S,1L??	12??	800	SE	0	1	0	1	0	1	0	1	0	1	0	1
HANNA	TOWN	3000	LAGOON 4S,2L	6	1000	S	0	1	0	1	0	1	0	1	0	1	0	1
HAY LAKES	VILLAGE	327	LAGOON 4S,2L	12	800	ESE	0	1	0	1	0	1	1	1	0	1	0	1
HAYS	HAMLET	104	LAGOON OS,2L	12	1500	NE	0	1	0	1	0	1	0	1	0	1	0	1
HAYTER	HAMLET	50	LAGOON 0S,1L	EVAP	477	SW	0	1	0	1	0	1	0	1	0	1	0	1
HIGH LEVEL	TOWN	3000	LAGOON 4S,2L	6	1000	SE	3	2	0	1	0	1	0	1	0	1	2	1
HIGH PRAIRIE	TOWN	3000	LAGOON 4S,3L	6	800	N	1	5	0	1	0	1	0	1	0	1	0	1
HIGH RIVER	TOWN	?	AERATED LAGOON		6400	NE	0	1	0	1	0	1	0	1	0	1	0	1
HILDA	HAMLET	44	LAGOON 1S,1L	EVAP	1000	NE	0	1	0	1	0	1	0	1	0	1	0	1
HINES CREEK	VILLAGE	423	LAGOON 4S,2L	12	750	NE	0	1	0	1	0	1	0	1	0	1	0	1
HOLDEN	VILLAGE	411	LAGOON 4S,2L	36	1610	N	0	1	0	1	0	1	0	1	0	1	0	1
ID # 22	??	130	LAGOON 0S,1L	12	1000	E	0	1	0	1	0	1	1	1	0	1	0	1
ID #17 EAST	?	275	LAGOON 2S,2L	?	350	NE	0	1	0	1	0	1	0	1	0	1	0	1
ID #17 EAST	?	100	LAGOON 0S,1L	?	1500	E	0	1	0	1	0	1	0	1	0	1	0	1
ID #21	??	52	LAGOON	12	1000	S	0	1	0	1	0	1	0	1	1	2	0	1
ID 18 NORTH	?	1300	AERATED LAGOO		600	N	0	1	0	1	0	1	0	1	0	1	0	1
ID 20	??	70	LAGOON??	12	402	NE	0	1	0	1	0	1	0	1	0	1	0	1
INNISFAIL	TOWN	5837	RBC	CONTIN.	300	SW	10	8	0	1	2	3	2	5	0	1	0	1
INNISFREE	VILLAGE	250	LAGOON 1S,3L	?	2000	NE	0	1	0	1	0	1	0	1	0	1	0	1
IRMA	VILLAGE	442	LAGOON 4S,2L	12	400	SE	0	1	0	1	0	1	0	1	0	1	0	1
IRRICANA	VILLAGE	817	LAGOON 2S,1L	?	1000	N	0	3	0	1	0	1	0	1	0	1	0	1
IRVINE	TOWN	326	LAGOON 2S,1L	12	1600	NE	0	1	0	1	0	1	0	1	0	1	0	1
ISLAY	HAMLET	280	LAGOON 2S,2L	12	400	SE	12	4	2	1	0	1	0	1	0	1	0	1
JARVIE	HAMLET	300	LAGOON 0S,1L	12	1500	WNW	0	1	0	1	0	1	0	1	0	1	0	1
JOSEPHBURG	HAMLET	100	LAGOON 2S,1L	7	750	NW	0	1	0	1	0	1	0	1	0	1	0	1
JOUSSARD	?	277	LAGOON 4S,1L	12	800	NE	0	1	0	1	0	1	0	1	0	1	0	1
KAVANAUGH	HAMLET	49	LAGOON 0S,1L	12	800	SW	0	1	0	1	0	1	0	1	0	1	0	1
KILLAM	TOWN	?	LAGOON 4S,2L	12	1610	SE	3	1	0	1	0	1	0	1	0	1	0	1
KING MAN	HAMLET	83	LAGOON 0S2L	12-24	1000	NE	0	1	0	1	0	1	0	1	0	1	0	1
KINUSO	VILLAGE	400	LAGOON 0S,1L	?	500	W	0	1	0	1	0	1	0	1	0	1	0	1
KITSCOTY	VILLAGE	??	LAGOON 4S,4L	12	900	NE	0	2	0	1	0	1	0	1	0	1	0	1
LA CRETE	HAMLET	1200	LAGOON 4S,2L	12	1000	NE	0	2	0	1	0	1	0	1	0	1	0	1
LACOMBE	TOWN	7050	LAGOON 4S,3L	6		NE	20	2	0	1	0	1	0	1	0	1	3	2
LAMONT	TOWN	1560	LAGOON 4S,2L	6	500	NW	0	2	0	2	0	1	0	1	1	1	0	3
LAVOY	VILLAGE	109	LAGOON 0S,1L	12	750	E	0	1	0	1	0	1	1	1	0	1	0	1
LEGAL	VILLAGE	973	LAGOON 4S,2L	12	800	NE	0	1	0	1	0	1	1	2	1	4	0	1
LETHBRIDGE	CITY	63000	A. SLUDGE			W	2	3	0	1	0	1	0	1	0	1	0	1
LINDEN	VILLAGE	475	LAGOON 2S2L	EVAP	1000	S	0	1	0	1	0	1	0	1	0	1	0	1
LITTLE SMOKY	HAMLET	50	LAGOON 0S,1L		1200	SE	0	1	0	1	0	1	0	1	0	1	0	1
MAGRATH	TOWN	1743	LAGOON 2S,2L	6	260	E	0	1	0	1	0	1	0	1	0	5	0	1
MALLAIG	HAMLET	220	LAGOON 0S,1L	6	800	SW	0	1	0	1	0	1	0	1	0	1	0	1
MANNING	TOWN	1139	AERATED LAGOON		800	NE	0	1	0	1	0	2	0	1	0	1	0	1
MANOLA	HAMLET	175	LAGOON	NOT DISCH	1000	SSW	0	1	0	1	0	1	0	1	0	1	0	1

COMMUNITY	TYPE	POP. SERVED	TREATMENT	STORAGE	LOCATION DISTANCE	LOCATION DIRECTION	odour comp.	odour sever	insect comp.	insect sever	appear comp.	appear sever	flood comp.	flood sever	leak comp.	leak sever	qualit comp	qualit sever
MARIE-REINE	WP	200	LAGOON	12	400	NE	0	3	0	2	0	3	0	1	0	1	0	1
MAYERTHORPE	TOWN	1700	LAGOON 4S,3L	6	400	E	0	1	0	1	0	1	0	1	0	1	0	1
MD BADLANDS #7	??	165	RBC	CONTIN	50	WITHIN	0	1	0	1	0	1	0	1	0	1	0	1
MD BADLANDS #7	??	240	EXT AREATION	CONTIN	100	WITHIN	0	1	0	1	0	1	0	1	0	1	0	1
MD NO 135	??	140	LAGOON 1S,1L EV	EVAP	1000	SE	0	1	0	1	0	1	0	1	0	1	0	1
MD PINCHER CRE	?	450	LAGOON?	12	500	E	0	2	0	1	0	1	0	1	0	1	0	1
MD ROCKY VEIW	?	350	LAGOON 4S,2L	EVAP	?	SE	0	1	0	1	0	1	0	1	0	1	0	1
MD SMOKY RIVE	?	85	LAGOON ??	12	300	S	0	1	0	1	0	1	2	1	0	1	0	1
MD SMOKY RIVE	?	65	LAGOON ??	12	300	S	0	1	0	1	0	1	0	1	0	1	0	1
MEADOWVIEW	SCHOOL	100	LAGOON	1 IN 10 YEARS	600	N	0	1	0	1	0	1	0	1	0	1	0	1
MEDICINE HAT???	??	200 UNITS	LAGOON	12	100	S	0	1	0	1	0	1	0	1	0	1	0	1
MELOD MEADOW	?	130	???		200	NW	0	1	0	1	0	1	0	1	0	1	0	1
METISKOW	HAMLET	100	LAGOON 0S,1L	12	914	NE	0	1	0	1	0	1	0	1	0	1	0	1
MILK RIVER	TOWN	926	LAGOON 3S,2L	NOT DISCH	800	SE	2	1	0	1	0	1	0	1	0	1	0	1
MILLET	TOWN	1703	LAGOON 4S,2L	12	500	S	2	1	0	1	0	1	0	1	0	1	0	1
MIRROR	VILLAGE	487	LAGOON 2S,2L	EVAP	800	N	0	1	0	1	0	1	0	1	1	1	0	1
MORRIN	VILLAGE	250	LAGOON 2S,2L	12	800	E	0	1	0	1	0	1	0	1	0	1	0	1
MULHURST / N E P	HAMLET	2000	LAGOON 3S,3L	12	1000	E	0	1	0	1	5	2	2.5	1	0	1	0	1
MUNDARE	TOWN	600	LAGOON 4S,3L	7	1000	SW	1	1	0	1	0	1	0	1	0	1	0	1
NAMPA	VILLAGE	496	LAGOON 4S,2L	NOT DISCH	1200	SE	0	1	0	1	0	1	0	1	0	1	0	1
NANTON	TOWN	1589	RBC	CONTIN	700	NE	0	1	0	1	0	2	0	1	0	1	0	1
NEERLANDIA	HAMLET	250	LAGOON 0S,1L	36	280	SW	0	1	0	1	0	1	0	1	1	1	0	6
NEW NORWAY	VILLAGE	275	LAGOON 1S,1L	12	1000	SE	0	1	0	1	0	1	0	1	0	1	0	1
NEW SAREPTA	VILLAGE	404	LAGOON 4S,2L	12	700	NW	0	1	0	1	0	1	2	2	0	1	1	2
NEWBROOK	HAMLET	115	LAGOON 0S,1L	12	350	NE	0	1	0	1	0	1	3	3.5	0	1	2	2.5
NORTHLAND SCH	SCHOOL		LAGOON 2S,1L	??			0	1	0	1	2	2	0	1	0	1	0	1
OHATON	HAMLET	118	LAGOON 2S,2L	12	800	NW	0	1	0	1	0	1	0	1	0	1	0	1
OKOTOKS	TOWN	7200	RBC	CONTIN	1000	SE	0	1	0	1	0	1	0	1	0	1	0	1
OLDS	TOWN	5300	RBC		800	W	0	1	0	1	0	1	0	1	0	1	0	1
ONOWAY	VILLAGE	670	LAGOON 4S,2L	48	1000	E	0	1	0	1	0	1	0	1	0	1	0	1
OYEN	TOWN	1041	LAGOON 2S,2L	6	3200	SW	0	10	0	1	0	10	0	1	0	10	0	1
PARKLAND VILLA	?	1600	AEARATED LAGO	12	300	NE	3	1	0	1	0	1	0	1	0	1	0	1
PATRICA	HAMLET	80	LAGOON 0S,1L	12	300	E	0	1	0	1	0	1	0	1	0	1	0	1
PEACE RIVER	TOWN	6696	LAGOON 4S,0L	CONTIN	600	NW	0.5	2	0	1	1	1	0	1	0.5	1	0.5	3
PEORIA	HAMLET	14	LAGOON 0S,2L GR	EVAP	?	SE	0	1	0	1	0	1	0	1	0	1	0	1
PIBROCH	HAMLET	300	LAGOON 0S,1L	12	700	SSW	0	1	0	1	0	1	0	1	0	1	0	1
PICADVILLE	HAMLET	300	LAGOON 0S,1L	12	1200	SW	0	1	0	1	0	1	0	1	0	1	0	1
PICTURE BUTTE	TOWN	1559	AERATED LAGOO	CONTIN	300	S	0	2	0	2	0	2	0	1	0	1	0	1
PLAMONDON	VILLAGE	253	LAGOON 4S,3L	60	575	NE	0	1	0	1	0	1	0	1	0	1	0	1
PONOKA	TOWN	5700	AERATED LAGOO	6	500	NE	0	1	0	1	0	1	0	1	0	1	0	1
RAINBOW LAKE	TOWN	1100	LAGOON 4S,2L	12	1000	SE	0	1	0	1	0	1	0	1	0	1	0	1
RAYMOND	TOWN	3130	LAGOON 4S,2L	12	500	E	3	2	0	1	0	1	4	3	0	2	0	2
RED DEER	CITY	58656	A S		800	NE	0	4	0	1	0	1	0	1	0	1	0	1
RED DEER	COUNTY	125	LAGOON	NOT DISCH	800	S	0	1	0	1	0	1	0	1	0	1	0	1
RED DEER	COUNTY		LAGOON 0S,2L	NOT DISCH	440	SW	0	1	0	1	0	1	0	1	0	1	0	1
RED DEER	COUNTY	200	LAGOON	12	810	SE	0	1	0	1	0	1	2	1	0	1	1	1
REDCLIFF	SEE MEDICINE HAT						0	1	0	1	0	1	0	1	0	1	0	1
REDWATER	TOWN	2090	LAGOON 4S,3L	6	1500	N	0	1	0	1	0	1	0	1	0	1	0	1
RIDGEVALLEY	HAMLET	100	LAGOON 1S,2L	12	1000	SE	0	1	0	1	0	1	0	1	0	1	0	1
RIMBEY	TOWN	1937	LAGOON 6S, 2L	6	?	S	3	1	0	1	0	1	3	2	0	1	0	1

COMMUNITY	TYPE	POP. SERVED	TREATMENT	STORAGE	LOCATION DISTANCE	LOCATION DIRECTION	odour comp	odour sever	insect comp	insect sever	appear comp	appear sever	flood comp	flood sever	leak comp	leak sever	qualit comp	qualit sever
ROCHESTER	HAMLET	100	LAGOON 1S,2L	12	400	SE	0	1	0	1	0	1	0	1	0	1	0	1
ROCKY MOUNTAI	TOWN	5407	AERATED LAGOO	CONTIN	2000	N	0	1	0	1	0	1	0	1	0	1	0	1
ROCKY RAPIDS	??0	130	LAGOON??	8	300	SE	0	1	0	1	0	1	0	1	0	1	1	4
ROCKYFORD	VILLAGE	318	LAGOON 4S,2L	12-24	600	S	0	1	0	1	0	1	0	1	0	1	0	1
ROLLEYVEIW	HAMLET	66	LAGOON 0S,1L	12	200	NW	0	1	0	1	0	1	0	1	0	1	0	1
ROUND HILL	??	138	LAGOON	24	900	NE	0	1	0	1	0	1	0	1	0	1	0	1
RUMSEY	VILLAGE	70	LAGOON EVAP	EVAP	400	SW	0	1	0	1	0	1	0	1	0	1	0	1
RYCROFT	VILLAGE	634	LAGOON 2S,2L	12	1000	N	0	1	0	1	0	1	0	1	0	1	0	1
SANGUDO	VILLAGE	401	LAGOON 4S,3L	6	200	S	0	3	0	1	0	3	0	1	0	1	0	1
SCHULER	HAMLET	?	LAGOON 0S,2L	EVAPORATIO	1000	NE	0	1	0	1	0	1	0	1	0	1	0	1
SEXSMITH	TOWN	1256	LAGOON 4S,2L	7	3000	E	1	10	8	1	3	5	4	1	0	1	5	5
SHAUGHNESSY	HAMLET	296	LAGOON 2S,2L	12	240	NE	0	1	0	1	0	1	0	1	0	1	0	1
SMOKY LAKE	TOWN	1054	LAGOON 4S,3L	12	200	NE	20	3.5	0	1	0	2.5	0	1	0.5	5	0	1
SPIRIT RIVER	TOWN	1044	LAGOON 3S,3L	12	500	N	1	2	0	1	0	1	0	1	0	1	0	1
ST. ISIDORE	HAMLET	200	LAGOON 2S,2L	12	400	NW	0	2	3	2	0	1	0	1	0	1	0	1
ST. PAUL	TOWN	5100	CONTACT STABILI	CONTIN.	500	S	0	1	0	1	0	1	0	1	0	1	0	1
STANDARD	VILLAGE	329	LAGOON 4S,2L	12	675	SE	0	1	0	1	0	1	0	1	0	1	0	1
STAVELY	TOWN	528	LAGOON 2S,3L	12	300	E	0	1	0	1	0	1	0	1	0	1	0	1
STIRLING	VILLAGE	799	LAGOON 2S,2L	EVAP	2600	NW	0	1	2	8	0	1	0	1	0	1	0	1
STRATHCONA	COUNTY	SCHOOL	LAGOON 0S,2L	36	N/A	N/A	0	1	0	1	0	1	0	3	0	1	0	1
STRATHMORE	TOWN	4500	LAGOON 7S,6L	12	4000	S	0	1	0	1	0	1	0	1	0	1	0	1
SUFFIELD	HAMLET	?	LAGOON 2S,2L	EVAP	500	NE	0	1	0	1	0	1	0	1	0	1	0	1
SUNDRE	TOWN	1800	AERATED LAGOO	CONTIN.	765	N	0	1	0	1	0	1	0	1	0	1	0	1
SUNNYBROOK	HAMLET	74	LAGOON 0S,1L	12	1600	W	0	1	0	1	0	1	0	1	0	1	0	1
SWALWELL	HAMLET	59	LAGOON 0S,1L EV	EVAP	900	SW	0	1	0	1	0	1	0	1	0	1	0	1
SWAN HILLS	TOWN	2400	LAGOON 5S,2L	12	650	SW	0	1	0	6	0	1	0	1	0	1	0	1
SYLVAN LAKE	TOWN	4500	LAGOON 5S,4L	12	1000	E	2	4	0	1	0	2	0	1	0	1	0	1
TABER	TOWN	6660	RBC/AERATED LA		2000	NW	0	1	0	1	0	1	0	1	0	1	0	1
TANGENT	HAMLET	65	LAGOON 0S,1L EV		500	E	0	1	0	1	0	1	0	1	0	1	0	1
THERIEN	HAMLET	?	LAGOON 0S,1L	12	800	E	0	1	0	1	0	1	0	1	0	1	0	1
THORHILD	VILLAGE	500?	LAGOON 2S,1L	12	?	S	0	1	0	1	0	1	0	1	2	4	0	1
THORSBY	VILLAGE	700	LAGOON 4S,2L	12	800	NE	0	1	0	1	0	1	0	1	0	1	0	1
TOFIELD	TOWN	1620	LAGOON 2S,3L	12	420	N	0	1	0	1	0	1	0	2	0	2	0	1
TOMAHAWK LAG	COUNTY OF P	120	LAGOON 0S,1L	6	300	E	0	1	0	1	0	1	0	1	0	1	0	2
TROCHU	TOWN	1010	LAGOON 4S,2L	12	7920	ENE	0	1	0	1	0	1	0	1	0	1	0	1
TWILIGHT	??	90	LAGOON 0S,1L	12	?	SW	0	1	0	1	0	1	0	1	0	1	0	1
TWO HILLS	TOWN	1107	LAGOON 4S,2L	12	350	S	75	6	0	1	0	1	0	1	0	1	0	1
VALHALLA	HAMLET	45	LAGOON 1S,1L	EVAP	350	SE	0	1	0	1	0	1	0	1	0	1	0	1
VALLEYVIEW	TOWN	2200	LAGOON 4S,2L	12	350	NW	0	1	0	1	0	1	0	1	0	1	0	1
VEGREVILLE	TOWN	5500	LAGOON 4S,6L	12	750	NE	0.5	2	0	2	5	1	0	1	2	2	0.5	1
VERMILION	TOWN	4500	EXT. AERATION		1000	NE	0	1	0	1	0	1	0	1	0	1	0	1
VIKING	TOWN	1109	LAGOON 4S,2L	6	1500	E	5	3	0	1	0	1	0	1	0	1	0	1
VILINA	VOLLAGE		LAGOON 2S,2L	6		S	0	1	0	1	0	1	0	1	0	1	0	1
VIOLET GROVE	HAMLET	50	LAGOON 0S,2L	36	400	S	0	1	0	1	0	1	0	1	0	1	0	1
VULCAN	TOWN	1407	LAGOON 4S,2L	12	400	SE	10	8	0	1	0	1	0	1	0	1	0	1
WABAMUN	VILLAGE	603	LAGOON 4S,2L	6	1000	N	0	1	0	1	0	1	0	1	0	1	0	1
WABASCA	HAMLET	2000	AERATED LAGOO	CONTIN.	300	N	0	2	0	2	0	1	0	1	0	1	0	1
WAINWRIGHT	TOWN	?	AERATED LAGOO		850	W	0	1	0	1	0	1	0	1	0	1	0	1
WANDERING RIV	??	150	LAGOON 1S,1L	12	600	NE	0	1	0	1	0	1	0	1	1	2	0	1
WARBURG	VILLAGE	519	LAGOON 4S,3L	12	305		0	1	0	1	0	1	1	1	0	1	0	1

COMMUNITY	TYPE	POP. SERVED	TREATMENT	STORAGE	LOCATION DISTANCE	LOCATION DIRECTION	odour comp.	odour sever	insect comp.	insect sever	appear comp.	appear sever	flood comp.	flood sever	leak comp.	leak sever	qualit comp.	qualit sever
WARNER	VILLAGE	?	LAGOON 2S,1L	6	1000	NE	0	1	1	3	0	1	0	1	0	1	0	1
WARSPITE	VILLAGE	75	LAGOON 0S,2L	12	1000	SE	0	1	0	1	0	1	0	1	0	1	0	1
WASKATENAU	VILLAGE	256	LAGOON 2S,2L	12	800	S	0	1	0	1	0	1	0	1	1	1	0	1
WATINO	HAMLET	14	LAGOON 0S,2L GR	EVAP	1500	E	0	1	0	1	0	1	0	1	0	1	0	1
WEMBLEY	TOWN	1382	LAGOON 4S,2L	12	100	NE	1	2	0	1	0	1	0	1	0	1	0	1
WESTLOCK	TOWN	4700	LAGOON 4S,2L	7	900	W	0	3	0	1	0	1	0	1	0	1	0	1
WESTWIND	PARK	130	LAGOON	12	400	S	0	1	0	1	0	1	0	1	0	1	0	1
WHITECOURT	TOWN	7000	A.S.		500	NE	0	1	0	1	0	1	0	1	0	1	0	1
WHITELAW	HAMLET	?	LAGOON 1S,1L	12	?	NE	0	1	0	1	0	1	0	1	0	1	0	1
WILLINGDON	VILLAGE	353	LAGOON 2S,2L	6	800	NE	0	1	0	1	0	1	0	1	0	1	0	1
WIMBORNE	HAMLET	50	LAGOON 0S,1L EV	EVAP	2500	W	0	1	0	1	0	1	0	1	0	1	0	1
WINFIELD	HAMLET	250	LAGOON 0S,2L	12	500	SW	0	1	0	1	0	1	0	1	0	1	0	1
YOUNGSTOWN	VILLAGE	245	LAGOON 0S,1L	?	?	W	1	3	0	1	0	1	0	1	0	1	0	1

COMMUNITY	TYPE	POP. SERVED	TREATMENT	STORAGE	OPER DAYS	MAINT DAYS	LABOUR COSTS	MATERIAL COSTS	EQUIPMENT COSTS	FUEL COSTS	POWER COSTS	OTHER COSTS	TOTAL COSTS	BERM ERROSION
ACME	VILLAGE	527	LAGOON 4S,2L	7	0	14	500	500	500	500	0	0	500	YES
ALDER FLATS	HAMLET	130	LAGOON 2S,1L	12	5	10	2000	500	500	1000	0	500	5000	NO
ALIX	VILLAGE	782	LAGOON 4S,4L	EVAP	10	5	1000	500	500	500	0			YES
AMISK	VILLAGE	200	LAGOON 1S,1L	EXFILTRAT		5	500							NO
ARDMORE	HAMLET	?	LAGOON 2S,2L	12	?	?	2000	1500	500		500	500	2000	NO
ARDROSSAN	HAMLET	105+3SCHOOL	LAGOON 2S,2L	12	2	10	2000	500					5000	NO
ARROWWOOD	VILLAGE	142	LAGOON 0S,2L	12	0	0	0	0	0	0	0	0	0	NO
ATHABASCA	TOWN	?	AERATED LAGOO		110	160	30000	3000	3000	500	40000	5000	71500	NO
BARONS	VILLAGE	260	LAGOON OS,3L	12	365	365	10000	2500	3500	0	3737		20000	YES
BARRHEAD	TOWN	4160	AERATED LAGOO		65	7	20000	500	500	500	30000		51500	NO
BASHAW	TOWN	829	LAGOON 4S,3L	12	7	13	2000	1000	500	500	2000		10000	YES
BASSANO	TOWN	1190	LAGOON 4S,1L	CONTIN.	15	15	5000				500			NO
BEAVERLODGE	TOWN	1779	LAGOON 4S,1L	7										NO
BEISEKER	VILLAGE	639	LAGOON 2S,2L	6										NO
BENTLEY	VILLAGE	900	LAGOON 2S,2L	6	450	450	10000	2000	3000	1000	0	500	20000	YES
BERWYN	VILLAGE	606	LAGOON 4S,2L	12	?	?	2000	15000	15000	0	0	0	5000	YES
BEZANSON	HAMLET	?	LAGOON 0S,1L	12	25	5	5000	1000	1000	500	1500		5000	NO
BIG VALLEY	VILLAGE	350	LAGOON 4S,2L	6	40	COMB.	500	500					500	NO
BITTERN LAKE	VILLAGE	169	?	12	2	10	1000	500	1000	500				YES
BLACK DIAMOND	TOWN	1727	LAGOON 0S,3L	2	0	30	10000	2000	500	0	0	500	10000	YES
BLACKFALDS	TOWN	1800	AERATED LAGOO		45	25	5000	1000	1000	0	29500	5200		NO
BLACKFOOT	HAMLET	180	LAGOON 0S,3L	12	30		24000		11000		1500		14900	NO
BLACKIE	VILLAGE	303	LAGOON 0S,2L	6			12072		7600		1462	4214		
BLUE RIDGE	HAMLET	180	LAGOON 0S,1L	12	3	5	2000	500	500	0	0	0	2000	NO
BLUESKY	HAMLET	?	LAGOON 1S,1L	12	10	10	1000	2000	500	500				NO
BON ACCORD	TOWN	1460	AERATED LAGOON		23	65	20000	1500	500	500	6600		50000	YES
BONNYVILLE	TOWN	5132	LAGOON 4S,2L	12	5	20	5000	1000	1500	500	0	0	10000	NO
BOTHA	VILLAGE	174	LAGOON 1S,1L	12	12	12	500	500	500	500	0	0	500	NO
BOWDEN	TOWN	936	LAGOON 4S,2L	12	52	52		2500		0	0			YES
BOYLE	VILLAGE	710	LAGOON 2S,2L	6	30	30	5000	1000	5000	1000	0		5000	YES
BRETON	VILLAGE	511	LAGOON 4S,2L	12	14	4	500	2500	500	500	0	0	5000	NO
BROOKS	TOWN	9433	LAGOON 7S,5L	6	?	?	1000	500	500	0	0	0		YES
BRUCE	HAMLET	65	LAGOON 0S,2L	24										NO
BUFORD	HAMLET	46	LAGOON 0S,1L	24	30	30	2000			500		500	5000	NO
BUGSBY	HAMLET	300	LAGOON 0S,1L	12	15	15	2000	500	500	500	0	0	2400	NO
BURDETT	VILLAGE	2800?	LAGOON 0S,1L	6	20	10	5000	500	0	0	0	0	2000	NO
CALMAR	TOWN	1400	LAGOON 4S,2L	12		30	5000	3000	1000	500	2000		20000	YES
CAMROSE NEW	CITY	13700	AERATED LAGOO		?	?	60000	10000	10000	500	90000		170500	NO
CAMROSE OLD	CITY	13700	LAGOON 4S,5L	7										
CANMORE	TOWN	??0	RBC				70000	15000	20000	3000	45000		177300	NO
CARBON	VILLAGE	437	LAGOON 2S,3L	12	2	5	500	2500	0	0	0	0	5000	NO
CARDSTON	TOWN	4000	RBC				50000		40000		38000			NO
CARMANGAY	VILLAGE	259	LAGOON 2S,1L	IRRIGATION	5	2	1000	500	500	0	0	0	1000	NO
CAROLINE	VILLAGE	452	AERATED LAGOO	CONTIN	23	23	5000	1000	1000	0	5500	0	10000	NO
CARSELAND	HAMLET	550	AERATED LAGOON		260	COMB.	30000	>	>	>	>	30000	50000	NO
CASTOR	TOWN	1000	LAGOON 4S,2L	12	15	5	2000	2000	2000	0	1500	0	5000	YES
CAYLEY	VILLAGE	243	LAGOON 0S,1L	?	0	52	?	?	?	?	?	?	?	YES
CHAMPION	VILLAGE	366	LAGOON 0S,1L	12	24	COMB.	10000	8633	0	0	0	2456	20000	YES
CHAUVIN	VILLAGE	3600	LAGOON 2S,2L	24			1000	500	0	500	0	1500	5000	NO
CHIPMAN	VILLAGE	239	LAGOON 4S,2L	NOT DISCH.	60	COMB.	5000	3000	3000	500	2000	12326	23530	NO

COMMUNITY	TYPE	POP. SERVED	TREATMENT	STORAGE	OPER. DAYS	MAINT. DAYS	LABOUR COSTS	MATERIAL COSTS	EQUIPMENT COSTS	FUEL COSTS	POWER COSTS	OTHER COSTS	TOTAL COSTS	BERM ERROSION
CLAIRMONT	HAMLET	900	LAGOON 4S,2L	EVAP	15	10	5000	1000	1000	500	2500	500	10000	YES
CLANDONALD	HAMLET	189	LAGOON 0S,1L	12	30		2400		1200				3600	YES
CLARESHOLM	TOWN	3500	LAGOON 4S,4L	IRRIGATION	40	10	1000	1000	500	500	6500		9500	NO
CLUNY	VILLAGE	103	LAGOON 0S,1L	12	4	4	500	0	0	0	0			YES
COALDALE	TOWN	5320	AERATED LAGOON		1	50	5000	1000	6000		26000	500	38500	NO
COALHURST	VILLAGE	1350	AERATED LAGOO	3	50	30	10000	1000	1500	1000	7900			NO
COCHRANE	TOWN	6200	AERATED LAGOO		120	60	30000	35000	35000	1000	21000		50000	NO
COLD LAKE /GRA	TOWN	7818	LAGOON 4S,3L	6	50	30	5000	1500	1000	500	0	3000	10000	YES
COLINTON	HAMLET	260	LAGOON 1S,1L	?	12	12	1000		500				2000	NO
CONSORT	VILLAGE	114	LAGOON 2S,1L	6	0.5	0.5	500	500	0	0	0	0	1000	
COUNTY OF FORT	??	80	LAGOON??	12	3	1	500	0	0	0	0	0	500	NO
COUTTS	VILLAGE	355	LAGOON 2S,1L	12	4		500	500				500	1000	YES
COWLEY	VILLAGE	290	LAGOON 2S,1L	12	25	25	500	500	500	500	500	0	500	NO
CREMONA	VILLAGE	393	LAGOON 2S,3L	12	?	16	500	500	500	500				NO
CROSSFIELD	TOWN	1800	LAGOON 4S,2L	12	100	48	100	500	1500	500			5000	YES
CYNTHIA	HAMLET	100	LAGOON 0S,1L	8	5	5	500	500	500	500	0	0	2000	YES
DAPP	HAMLET	50	LAGOON 1S,1L	12	12	12	2000	500	0	500	1500	0	3100	NO
DEBOLT	HAMLET	100	LAGOON 0S,1L	12	50	50	1000	0	0	0	0	0	1000	NO
DELBURN	VILLAGE	564	LAGOON 4S,3L	12	107	COMB	12000	5000			8700	5000	30700	NO
DELIA	VILLAGE	198	LAGOON OS,1L	6	2	5	500	500	500	500	500		500	NO
DEVON	TOWN	4100	RBC		730	COMB							185800	NO
DEWBERRY	VILLAGE	203	LAGOON 0S,2L	12	20	20	500							NO
DONALDA	VILLAGE	225	LAGOON 1S,2L	12	2	2	500	500	500	500	0	0	500	NO
DONNELLY	VILLAGE	421	LAGOON 2S,SL	12	20	20	1000	1000	1000	0	0			NO
DRATON VALLEY	TOWN	7000	AERATED LAGOO		1200	300	20000	2500	7000	0	75000	15000	119000	NO
ECKVILLE	TOWN	900	LAGOON 4S,2L	6	15	10	5000	1500	1000	500	0	500	10000	YES
EDBERG	VILLAGE	135	LAGOON 0S,1L	12	0	10								NO
EDSON	TOWN	7300	AERATED LAGOO	CONTIN	52	13	11000	7700	6300		25000	4000	54000	YES
EGALESHAM	VILLAGE	185	LAGOON 0S,1L	6	30	30	2000	1000	1000	500	500	1000	5000	NO
EGREMONT	HAMLET	55	LAGOON 0S,1L	EVAP	17	17	5000	500	500	0	500	500	10000	NO
ELK POINT	TOWN	1400	AERATED LAGOON		12	12	1000	0	0	0	4930	500	10000	NO
ELNORA	VILLAGE	265	LAGOON 2S,3L	12	10	10	1000	500	1000	500	0	0	5000	NO
ENTWISTLE	VILLAGE	480	LAGOON 4S2L	6	40	40	500	0	200	100	100			YES
EVANSBURG	VILLAGE	725	LAGOON 4S,2L	11	365	365	5000	3500	3500		5600		20000	NO
FABYAN	HAMLET	100	LAGOON	EVAP	0	4	2000	1000			1000			NO
FALHER	TOWN	1180	LAGOON 4S,2L	12	20	20	1000	500	500	500	0	1000	5000	YES
FAUST	?	379	LAGOON 4S,3L	12	25	25	500	1000	1000	1500	3000		10000	NO
FAWCETT	HAMLET	300	LAGOON 0S,1L	12	15	15	2000	500	500	500	0	0	2500	NO
FERINTOSH	VILLAGE	115	LAGOON0S,2L	NONE	1	5	500	500	500	500	0	0	1000	YES
FOOTNER LAKE	HAMLET	75	LAGOON 1S,2L	12	12	13	1000	500	1000	500	0	0	5000	YES
FOREMOST	VILLAGE	582	LAGOON 2S,2L	NONE	4	6	1000	1000	500	500	0	500	2000	YES
FORESTBURG	VILLAGE	967	LAGOON 0S,3L	12	1	6		0	500	500	0	0	1000	YES
FORT ASSINIBOIN	HAMLET	179	LAGOON 0S,1L	12	3	5	2000	500	500	0	0	0	2000	NO
FORT KENT	HAMLET	?	LAGOON 0S,2L	12	?	?	1000	1000	1000		500	1000	5000	NO
FORT VERMILION	HAMLET	800	LAGOON 4S,2L	6	10	35	10000	1000	1000	500	0			NO
FOX CREEK	TOWN	2300	LAGOON 4S,4L	6		14	5000	1000	1000	500	4908		67324	NO
GALAHAD	VILLAGE	158	LAGOON 0S,2L	12	32.5	COMB	500	500	500	500	500	500		NO
GIROUXVILLE	VILLAGE	349	LAGOON 2S,2L	12	365	150	5000	1000	1000	500	2000		5000	YES
GLENWOOD	VILLAGE	306	LAGOON 2S,2L	6	7	1	500	500	500	500	0	0	500	NO
GRANUM	TOWN	371	LAGOON 2S,3L	12			5000							YES

COMMUNITY	TYPE	POP SERVED	TREATMENT	STORAGE	OPER. DAYS	MAINT DAYS	LABOUR COSTS	MATERIAL COSTS	EQUIPMENT COSTS	FUEL COSTS	POWER COSTS	OTHER COSTS	TOTAL COSTS	BERM ERROSION
GRASSLAND	HAMLET	66	LAGOON 0S,2L	12	12	12	1000		500				2000	NO
GREEN ACRES	TRAILER PAR	2000	LAGOON 0S,3L	EVAP			3500	500					4000	YES
GRENNSHIELDS	HAMLET	55	LAGOON	EVAP	0	4	5000	1000			1000			NO
GRIMSHAW	TOWN	2812	LAGOON 8S,5L	12	33	23	3200	4000				3400	10600	YES
GROUARD	?	372	LAGOON 2S,2L	12	25	25	500	0	5000	500	3500		10000	NO
GUNN	VILLAGE	105	LAGOON 0S,2L	12	1	8	1000	0	500	500	0	0	2000	YES
GWYNNE	HAMLET	110	LAGOON 0S,1L	12	2	5	1000	500	500	500	0	500	2000	NO
HAIRY HILL	VILLAGE	70	LAGOON 0S,1L??	12??	?	?	100	0	0	0	300	100	500	NO
HANNA	TOWN	3000	LAGOON 4S,2L	6	1	1	1000	500	500	500	0	0	2000	YES
HAY LAKES	VILLAGE	327	LAGOON 4S,2L	12	10	15	5000	0	500	500	0	0	5000	NO
HAYS	HAMLET	104	LAGOON OS,2L	12	?	?	500	0	0	0	0	0	500	YES
HAYTER	HAMLET	50	LAGOON 0S,1L	EVAP	?	?								NO
HIGH LEVEL	TOWN	3000	LAGOON 4S,2L	6	15	5	500	500	500	0	0	0	2000	NO
HIGH PRAIRIE	TOWN	3000	LAGOON 4S,3L	6	8	20	1000	3000	3500	500		2000	10000	NO
HIGH RIVER	TOWN	?	AERATED LAGOON		183	2	37600	5000	0	0	95000	0	137600	NO
HILDA	HAMLET	44	LAGOON 1S,1L	EVAP	?	?	500	500	1000	1000	0	0	2000	NO
HINES CREEK	VILLAGE	423	LAGOON 4S,2L	12	4	25	500	500	500	500	500	500	500	YES
HOLDEN	VILLAGE	411	LAGOON 4S,2L	36	25	COMB	5000	0	2500		1500		10000	YES
ID # 22	??	130	LAGOON 0S,1L	12	10	15	2000	0	2500	500	0			YES
ID #17 EAST	?	275	LAGOON 2S,2L	?	10	15	5000	1500	1000	500	500		10000	NO
ID #17 EAST	?	100	LAGOON 0S,1L	?	10	5	2000	1500	1000	500	500		10000	NO
ID #21	??	52	LAGOON	12	12	12	5000	1000	1000	500	2000	1000	5000	YES
ID 18 NORTH	?	1300	AERATED LAGOO		?	?	?	?	?	?	?	?	?	?
ID 20	??	70	LAGOON??	12	7	7	500	500	2000	1000	1000		10000	NO
INNISFAIL	TOWN	5837	RBC	CONTIN.	300	COMB.	37000	55000				4000	96000	NO
INNISFREE	VILLAGE	250	LAGOON 1S,3L	?	52	0	5000	500	500	500	0			NO
IRMA	VILLAGE	442	LAGOON 4S,2L	12	6	12	500	500	500	0	0	0	500	NO
IRRICANA	VILLAGE	817	LAGOON 2S,1L	?	12	14	2000		500	500	0	1000		NO
IRVINE	TOWN	326	LAGOON 2S,1L	12	52	52	500	500	0	500	0	0	500	YES
ISLAY	HAMLET	280	LAGOON 2S,2L	12		30	2400		3000		2000		7400	NO
JARVIE	HAMLET	300	LAGOON 0S,1L	12	15	15	2000	500	500	500	0	0	2400	NO
JOSEPHBURG	HAMLET	100	LAGOON 2S,1L	7	1	4	1000	500					2000	NO
JOUSSARD	?	277	LAGOON 4S,1L	12	25	25	500	500	2500	500	3000		10000	NO
KAVANAUGH	HAMLET	49	LAGOON 0S,1L	12	30	30	2000			500		500	5000	
KILLAM	TOWN	?	LAGOON 4S,2L	12	0.5	3	1000	500	1000	500	0		1000	YES
KING MAN	HAMLET	83	LAGOON 0S2L	12-24	?	?	5000	1000	0	0	1500		5000	NO
KINUSO	VILLAGE	400	LAGOON 0S,1L	?	0	2	500	500	500				2000	NO
KITSCOTY	VILLAGE	??	LAGOON 4S,4L	12	365	20	10000	500	500	0	3000	1500	20000	YES
LA CRETE	HAMLET	1200	LAGOON 4S,2L	12	20	40	10000	1000	1000	1000	0	0	10000	NO
LACOMBE	TOWN	7050	LAGOON 4S,3L	6	10	10	10000	1000	3500	0	0	3500	20000	YES
LAMONT	TOWN	1560	LAGOON 4S,2L	6	?	45	2000	1000	1000	500			2000	YES
LAVOY	VILLAGE	109	LAGOON 0S,1L	12	2	2	500	500	500	500	0	500	1000	NO
LEGAL	VILLAGE	973	LAGOON 4S,2L	12	10	10	2000	1500	1500	1000	0		10000	YES
LETHBRIDGE	CITY	63000	A. SLUDGE		2080	3120	1000000	175000	50000	90000	705000	240000	2260000	NO
LINDEN	VILLAGE	475	LAGOON 2S2L	EVAP	>	8	500	0	0		0	500	2000	NO
LITTLE SMOKY	HAMLET	50	LAGOON 0S,1L		50	50	1000	0	0	0	0	0	1000	NO
MAGRATH	TOWN	1743	LAGOON 2S,2L	6	1	1	500	500	1000	500	0		2000	NO
MALLAIG	HAMLET	220	LAGOON 0S,1L	6	1	1	1000	500	500	500	0	0	2000	NO
MANNING	TOWN	1139	AERATED LAGOON		16	24	5000	500	1500	0		500		NO
MANOLA	HAMLET	175	LAGOON	NOT DISCH	1	2	500	0	500	0	0	0	0	NO

COMMUNITY	TYPE	POP SERVED	TREATMENT	STORAGE	OPER. DAYS	MAINT. DAYS	LABOUR COSTS	MATERIAL COSTS	EQUIPMENT COSTS	FUEL COSTS	POWER COSTS	OTHER COSTS	TOTAL COSTS	BERM ERROSION
MARIE-REINE	WP	200	LAGOON	12	12	14	2000	1000	1000	500	0		5000	NO
MAYERTHORPE	TOWN	1700	LAGOON 4S,3L	6	5	10	500		500	500			500	NO
MD BADLANDS #7	??	165	RBC	CONTIN	180		30000	3000	1500	1000	3000	2000	50000	N/A
MD BADLANDS #7	??	240	EXT AREATION	CONTIN	365		30000	3000	2000	1000	3500	4000	50000	N/A
MD NO 135	??	140	LAGOON 1S,1L EV	EVAP		LITTLE								YES
MD PINCHER CRE	?	450	LAGOON??	12	2	2	500		500	500				NO
MD ROCKY VEIW	?	350	LAGOON 4S,2L	EVAP	1	1	500	500	500	500			500	NO
MD SMOKY RIVE	?	85	LAGOON ??	12	5	10	2000	500	1000	500	500	500	5000	NO
MD SMOKY RIVE	?	65	LAGOON ??	12	5	10	2000	500	1000	500	500	500		NO
MEADOWVIEW	SCHOOL	100	LAGOON	1 IN 10 YEARS	1	2	500	0	500	0	0	0	0	NO
MEDICINE HAT???	??	200 UNITS	LAGOON	12	100		10000				1500			NO
MELOD MEADOW	?	130	???		>	35	100	100	100	50	0	0	350	NO
METISKOW	HAMLET	100	LAGOON 0S,1L	12	?	?								NO
MILK RIVER	TOWN	926	LAGOON 3S,2L	NOT DISCH	30	40	10000	2000	0	0	0	2000	20000	NO
MILLET	TOWN	1703	LAGOON 4S,2L	12	20	10	2000	500	500	500	0	0	2000	NO
MIRROR	VILLAGE	487	LAGOON 2S,2L	EVAP		50	2000	6	0	0	3000		5000	NO
MORRIN	VILLAGE	250	LAGOON 2S,2L	12	15	15	1000	1000	2500	1000	0	0	10000	?
MULHURST / N.E.P	HAMLET	2000	LAGOON 3S,3L	12	15	20	5000	1000	500	1500	0	500	10000	NO
MUNDARE	TOWN	600	LAGOON 4S,3L	7	260	260		7500					20000	NO
NAMPA	VILLAGE	496	LAGOON 4S,2L	NOT DISCH	2	5	10000							YES
NANTON	TOWN	1589	RBC	CONTIN	280	52	30000	5000	9000		22300	1500		NO
NEERLANDIA	HAMLET	250	LAGOON 0S,1L	36	1	2	500		500	0	0	0	0	NO
NEW NORWAY	VILLAGE	275	LAGOON 1S,1L	12	4	12	2000	500	1000	500	0	0	5000	YES
NEW SAREPTA	VILLAGE	404	LAGOON 4S,2L	12	2	6	500	0	500	500	0	0	2000	YES
NEWBROOK	HAMLET	115	LAGOON 0S,1L	12	17	17	5000	500	500	500			10000	NO
NORTHLAND SCH	SCHOOL		LAGOON 2S,1L	??	4	10	5000	500	1000	1000			1000	YES
OHATON	HAMLET	118	LAGOON 2S,2L	12	?	?	5000	3500	0	0	1500		10000	NO
OKOTOKS	TOWN	7200	RBC	CONTIN	375	180	63000	14200	8700	27000	49000		161900	
OLDS	TOWN	5300	RBC		365	365								
ONOWAY	VILLAGE	670	LAGOON 4S,2L	48	5	2	500	500	500	500	0		500	NO
OYEN	TOWN	1041	LAGOON 2S,2L	6	260	30	30000	2500		500	3500		50000	NO
PARKLAND VILLA	?	1600	AEARATED LAGO	12	100	180	10000	500	2000	[illegible]	2000	1500	20000	NO
PATRICA	HAMLET	80	LAGOON 0S,1L	12	3	1	500	0	0	0	0	0	500	NO
PEACE RIVER	TOWN	6696	LAGOON 4S,0L	CONTIN	600	2000	20000	2500	3000	1000	3500	3500	50000	NO
PEORIA	HAMLET	14	LAGOON 0S,2L GR	EVAP	1	7	1000	500	500				2000	NO
PIBROCH	HAMLET	300	LAGOON 0S,1L	12	15	15	2000	500	500	500	0	0	2650	NO
PICADVILLE	HAMLET	300	LAGOON 0S,1L	12	15	15	2000	500	500	500	0	0	2700	NO
PICTURE BUTTE	TOWN	1559	AERATED LAGOO	CONTIN	50	5	20000	3500	5000	14700	INCL <	3500	50000	NO
PLAMONDON	VILLAGE	253	LAGOON 4S,3L	60	2	15	2000	500	1500	500	0	500	5000	YES
PONOKA	TOWN	5700	AERATED LAGOO	6	28	30	10000	1500	3000	0	4950	0	20000	YES
RAINBOW LAKE	TOWN	1100	LAGOON 4S,2L	12	10	10	1000	2000	1500				5000	YES
RAYMOND	TOWN	3130	LAGOON 4S,2L	12	100	150	10000	1500	2000	1500	2500	3000	20000	NO
RED DEER	CITY	58656	A S		3250	780	790000	108000	150000	68000	434000		1559000	YES
RED DEER	COUNTY	125	LAGOON	NOT DISCH	6	2	1000	0	0	0	0	500	2000	NO
RED DEER	COUNTY		LAGOON 0S,2L	NOT DISCH	6	2	500	500	0	0	0	0	500	YES
RED DEER	COUNTY	200	LAGOON	12	45	50	2000	1000	500	0	1500	500	10000	NO
REDCLIFF	SEE MEDICINE HAT													
REDWATER	TOWN	2090	LAGOON 4S,3L	6	12	20	2000	1500						NO
RIDGEVALLEY	HAMLET	100	LAGOON 1S,2L	12	50	50	1000	0	0	0	0	0	1000	NO
RIMBEY	TOWN	1937	LAGOON 6S,2L	6			1000	2000	2000					YES

COMMUNITY	TYPE	POP SERVED	TREATMENT	STORAGE	OPER DAYS	MAINT DAYS	LABOUR COSTS	MATERIAL COSTS	EQUIPMENT COSTS	FUEL COSTS	POWER COSTS	OTHER COSTS	TOT. L COSTS	BERM ERROSION
ROCHESTER	HAMLET	100	LAGOON 1S,2L	12	12	12	500		500				1000	NO
ROCKY MOUNTAI	TOWN	5407	AERATED LAGOO	CONTIN	260	260	5000	3500	2000	500	40000	1500	53000	
ROCKY RAPIDS	??0	130	LAGOON??	8	5	10	500	500	1000	500	0	0	2000	YES
ROCKYFORD	VILLAGE	318	LAGOON 4S,2L	12-24	1	13	1000	500	500	500	1500	1000		NO
ROLLEYVEIW	HAMLET	66	LAGOON 0S,1L	12	30	30	2000			500		500	5000	NO
ROUND HILL	??	138	LAGOON	24		2	0	1500	0	0	0	0	5000	NO
RUMSEY	VILLAGE	70	LAGOON EVAP	EVAP	0	10	500	500	500	0	0	0	500	NO
RYCROFT	VILLAGE	634	LAGOON 2S,2L	12	30	30	20000	1000	2500	500	1500	3500		YES
SANGUDO	VILLAGE	401	LAGOON 4S,3L	6	1	1	5000	2500	1500	500	3500			YES
SCHULER	HAMLET	?	LAGOON 0S,2L	EVAPORATION			2000	500	1000	500	1000	1000	5000	NO
SEXSMITH	TOWN	1256	LAGOON 4S,2L	7	1	1	0	0	0	0	0	0	0	YES
SHAUGHNESSY	HAMLET	296	LAGOON 2S,2L	12	17	18	5000	500	1000	0	0	0	10000	NO
SMOKY LAKE	TOWN	1054	LAGOON 4S,3L	12	21	21	5000	2000	500	500	0	0		NO
SPIRIT RIVER	TOWN	1044	LAGOON 3S,3L	12	3	15	2000	3000	3000	500	500	0	20000	YES
ST ISIDORE	HAMLET	200	LAGOON 2S,2L	12	16	20	1000	500	1500	500	0		5000	NO
ST. PAUL	TOWN	5100	CONTACT STABILI	CONTIN	150	150	20000	3000	7000	500	42000	1000		NO
STANDARD	VILLAGE	329	LAGOON 4S,2L	12	2.5	2.5	500	1000	0	0	500		5000	NO
STAVELY	TOWN	528	LAGOON 2S,3L	12	90	COMB	10000					1000	10000	NO
STIRLING	VILLAGE	799	LAGOON 2S,2L	EVAP	7	8	1000	1000	500	500	1500		5000	NO
STRATHCONA	COUNTY	SCHOOL	LAGOON 0S,2L	36	2	10	2000	500	0	0	0	0	2000	YES
STRATHMORE	TOWN	4500	LAGOON 7S,6L	12	25	25	1000	3500	1000	0	1500	3500		YES
SUFFIELD	HAMLET	?	LAGOON 2S,2L	EVAP			1000	500	1000	500	0	1000	2000	NO
SUNDRE	TOWN	1800	AERATED LAGOO	CONTIN	60	32	10000	1000	2500	1000	3500	2500	20000	NO
SUNNYBROOK	HAMLET	74	LAGOON 0S,1L	12	30	30	2000			500		500	5000	NO
SWALWELL	HAMLET	59	LAGOON 0S,1L EV	EVAP	0.5	0.5	500	0	500	0	0	0	500	NO
SWAN HILLS	TOWN	2400	LAGOON 5S,2L	12	46	65	5000	2500	1000	500	4600		20000	YES
SYLVAN LAKE	TOWN	4500	LAGOON 5S,4L	12	1460	1460	20000	3000	3000	3000	10500	3000		YES
TABER	TOWN	6660	RBC/AERATED LA		283	300	70000	31000	10000	6500	155000	9000	281500	YES
TANGENT	HAMLET	65	LAGOON 0S,1L EV		1	7	1000	500	500				2000	NO
THERIEN	HAMLET	?	LAGOON 0S,1L	12	?	?								NO
THORHILD	VILLAGE	500?	LAGOON 2S,1L	12	7	14	2000	500	500	500	0	500	5000	NO
THORSBY	VILLAGE	700	LAGOON 4S,2L	12	4	30	2000	500	1000	500	0			YES
TOFIELD	TOWN	1620	LAGOON 2S,3L	12	2	2	?	?	?	?	?	?	?	YES
TOMAHAWK LAG	COUNTY OF P	120	LAGOON 0S,1L	6	4	7	1000	500	500	0	0			YES
TROCHU	TOWN	1010	LAGOON 4S,2L	12	4	40	10000	2500	1000	500	0	0	20000	YES
TWILIGHT	??	90	LAGOON 0S,1L	12		2	500	500	500	500			500	NO
TWO HILLS	TOWN	1107	LAGOON 4S,2L	12	35	20	30000	5500	1500	1000	2500		50000	YES
VALHALLA	HAMLET	45	LAGOON 1S,1L	EVAP	25	5	5000	1000	1000	500	1500		5000	NO
VALLEYVIEW	TOWN	2200	LAGOON 4S,2L	12	2	40	500	0	500	500	0	0	2000	NO
VEGREVILLE	TOWN	5500	LAGOON 4S,6L	12	10	20	5000	2500	3000	1000			8500	YES
VERMILION	TOWN	4500	EXT. AERATION		375	395								
VIKING	TOWN	1109	LAGOON 4S,2L	6	95	50	20000	3000	2000	1500	3000	1000	50000	YES
VILINA	VOLLAGE		LAGOON 2S,2L	6	2	2	5000		1000	1500	1500		10000	NO
VIOLET GROVE	HAMLET	50	LAGOON 0S,2L	36	5	5	500	500	200	500	500	0	5000	YES
VULCAN	TOWN	1407	LAGOON 4S,2L	12		10	2000	5000	1000	500	500			NO
WABAMUN	VILLAGE	603	LAGOON 4S,2L	6			5000	1000	2000	500				YES
WABASCA	HAMLET	2000	AERATED LAGOO	CONTIN.	261	261	5000	1500	2000	3000	7500			NO
WAINWRIGHT	TOWN	?	AERATED LAGOO		170	25	30000	500	2000	500	27142	0	51038	YES
WANDERING RIV	??	150	LAGOON 1S,1L	12	22 875	25	5000	500	500	500	1000	500	5000	NO
WARBURG	VILLAGE	519	LAGOON 4S,3L	12	1	0								NO

COMMUNITY	TYPE	POP. SERVED	TREATMENT	STORAGE	OPER. DAYS	MAINT. DAYS	LABOUR COSTS	MATERIAL COSTS	EQUIPMENT COSTS	FUEL COSTS	POWER COSTS	OTHER COSTS	TOTAL COSTS	BERM ERROSION
WARNER	VILLAGE	?	LAGOON 2S,1L	6	50	50	10000	3000	1500	1500	0		20000	NO
WARSPITE	VILLAGE	75	LAGOON 0S,2L	12	365	365	5000							NO
WASKATENAU	VILLAGE	256	LAGOON 2S,2L	12	3	5	1000	500	500	500	1000	0	2000	YES
WATINO	HAMLET	14	LAGOON 0S,2L GR	EVAP	1	7	1000	500	500				2000	NO
WEMBLEY	TOWN	1382	LAGOON 4S,2L	12	20	5	5000	3500	500	500	1000		5000	YES
WESTLOCK	TOWN	4700	LAGOON 4S,2L	7	365?	365?	10000	3500	1500	500	3500	500	20000	NO
WESTWIND	PARK	130	LAGOON	12	6	6	500	500	500		500		1000	NO
WHITECOURT	TOWN	7000	A.S.		140	140	54695	11315	9000	2500	31741		109102	NO
WHITELAW	HAMLET	?	LAGOON 1S,1L	12	10	10	1000	1500	500	500				NO
WILLINGDON	VILLAGE	353	LAGOON 2S,2L	6	1	2	500	500	500	500			1000	NO
WIMBORNE	HAMLET	50	LAGOON 0S,1L EV	EVAP	0.5	0.5	500	0	0	0	0	0	500	NO
WINFIELD	HAMLET	250	LAGOON 0S,2L	12	2	12	2000	500	500	1000	0	500	5000	NO
YOUNGSTOWN	VILLAGE	245	LAGOON 0S,1L	?	?	?	10000	1000	500		1000	1000		NO

COMMUNITY	TYPE	POP. SERVED	TREATMENT	STORAGE	LAND COST	YEAR	LAND #2 COST	YEAR	CONST COST	YEAR	DESIGN POP	UPGRADE #1 COST	YEAR	DESIGN POP	UPGRADE #2 COST	YEAR	DESIGN POP
ACME	VILLAGE	527	LAGOON 4S,2L	7	23,750	1977			210,000	1977	1100						
ALDER FLATS	HAMLET	130	LAGOON 2S,1L	12	26,000	1983			374,000	1983	120						
ALIX	VILLAGE	782	LAGOON 4S,4L	EVAP	68,000	1993			850,000	1993	1500	300,000	1993	1500			
AMISK	VILLAGE	200	LAGOON 1S,1L	EXFILTRAT	?	?			?	1967	?						
ARDMORE	HAMLET	?	LAGOON 2S,2L	12	8,164	1977			509,428	1979	1000						
ARDROSSAN	HAMLET	05+3SCHOOL	LAGOON 2S,2L	12	?	?			634,000	1985	118						
ARROWWOOD	VILLAGE	142	LAGOON 0S,2L	12	1,000	1961			5,000	1961	300						
ATHABASCA	TOWN	?	AERATED LAGOO		?	?			4,718,848	1982	4000						
BARONS	VILLAGE	260	LAGOON OS,3L	12								600,000	1981	600			
BARRHEAD	TOWN	4160	AERATED LAGOO		25,000	1973			1,200,000	1986	5000						
BASHAW	TOWN	829	LAGOON 4S,3L	12	?	?			422,478	1980	3000						
BASSANO	TOWN	1190	LAGOON 4S,1L	CONTIN	?	1910	24,000	1985	?	1912	?	30,000	1972	2000	420,000	1985	2500
BEAVERLODGE	TOWN	1779	LAGOON 4S,1L	7	5,700	1973	171,000	1993	90,000	1973	1500	1,000,000	1993	3000			
BEISEKER	VILLAGE	639	LAGOON 2S,2L	6	3,000	1976			124,000	1976	600						
BENTLEY	VILLAGE	900	LAGOON 2S,2L	6	12,000	1990			25,000	1954	1800	10,000	1992	1800			
BERWYN	VILLAGE	606	LAGOON 4S,2L	12	45,000	1980			426,000	1980	1000						
BEZANSON	HAMLET	?	LAGOON 0S,1L	12	10,000	1985			155,000	1986	150						
BIG VALLEY	VILLAGE	350	LAGOON 4S,2L	6	?	?			?	?	?						
BITTERN LAKE	VILLAGE	169	?	12	10,000	1979			221,000	1979	300	25,000	1988	300			
BLACK DIAMOND	TOWN	1727	LAGOON 0S,3L	2	?	1957	19,516	1973	?	1957	?	62,000	1973	1300			
BLACKFALDS	TOWN	1800	AERATED LAGOO		?	?			?	?	?						
BLACKFOOT	HAMLET	180	LAGOON 0S,3L	12	1,000	1967			30,000	1967	145	27,000	1989	400	230,000	1991	400
BLACKIE	VILLAGE	303	LAGOON 0S,2L	6													
BLUE RIDGE	HAMLET	180	LAGOON 0S,1L	12	25??	1992			100,000	1975	400						
BLUESKY	HAMLET	?	LAGOON 1S,1L	12	5,000	1993			?	1975	600?						
BON ACCORD	TOWN	1460	AERATED LAGOON		1000/ACRE	1976			700,000	1977	3500						
BONNYVILLE	TOWN	5132	LAGOON 4S,2L	12					1,200,000	1981	16000						
BOTHA	VILLAGE	174	LAGOON 1S,1L	12	1,000	1963	28,000	1963	100	5500	1989	150					
BOWDEN	TOWN	936	LAGOON 4S,2L	12					??	1980	3000						
BOYLE	VILLAGE	710	LAGOON 2S,2L	6	5,000	1982			?	?	1500						
BRETON	VILLAGE	511	LAGOON 4S,2L	12	52,000	1979			518,000	1980	1000						
BROOKS	TOWN	9433	LAGOON 7S,5L	6	48,000	1976			2,000,000	1980	13000	4,500,000	1984	16000			
BRUCE	HAMLET	65	LAGOON 0S,2L	24						1978							
BUFORD	HAMLET	46	LAGOON 0S,1L	24	25,403	1985			127,903	1985							
BUGSBY	HAMLET	300	LAGOON 0S,1L	12	3,000	1978			61,590	1978							
BURDETT	VILLAGE	2800?	LAGOON 0S,1L	6	8,000	1965			20,000	1965	400						
CALMAR	TOWN	1400	LAGOON 4S,2L	12	120,000	1986			2,200,000	1986	2000						
CAMROSE NEW	CITY	13700	AERATED LAGOO		?	1959			?	1960	?	?	1973	15000	6,000,000	1992	20000
CAMROSE OLD	CITY	13700	LAGOON 4S,5L	7													
CANMORE	TOWN	770	RBC		1,500,000	1993			3,000,000	1976	8000	400,000	1982	8000	850,000	1986	8000
CARBON	VILLAGE	437	LAGOON 2S,3L	12	52,500	1976			170,000	1976	1000						
CARDSTON	TOWN	4000	RBC		94,000	1984			7,000,000	1984	5000						
CARMANGAY	VILLAGE	259	LAGOON 2S,1L	IRRIGATION	3,000	1992			175,000	1978	450						
CAROLINE	VILLAGE	452	AERATED LAGOO	CONTIN	9,221	1980			195,500	1982	600	19,286	1991	600	10,147	1992	600
CARSELAND	HAMLET	550	AERATED LAGOON		?	?			?	?	?	50,000	1993	665			
CASTOR	TOWN	1000	LAGOON 4S,2L	12	10,000	1976			100,000	1976	2500						
CAYLEY	VILLAGE	243	LAGOON 0S,1L	?	?	?			?	?	?						
CHAMPION	VILLAGE	366	LAGOON 0S,1L	12	?	1955			?	1955	600						
CHAUVIN	VILLAGE	3600	LAGOON 2S,2L	24	19,000	1980			560,000	1980	500						
CHIPMAN	VILLAGE	239	LAGOON 4S,2L	NOT DISCH.	95,000	1980			275,700	1980	1500						

COMMUNITY	TYPE	POP. SERVED	TREATMENT	STORAGE	LAND COST	YEAR	LAND #2 COST	YEAR	CONST. COST	YEAR	DESIGN POP.	UPGRADE #1 COST	YEAR	DESIGN POP.	UPGRADE #2 COST	YEAR	DESIGN POP.
CLAIRMONT	HAMLET	900	LAGOON 4S,2L	EVAP	130,000	1982			896,671	1983	2200						
CLANDONALD	HAMLET	189	LAGOON 0S,1L	12	1,200	1967											
CLARESHOLM	TOWN	3500	LAGOON 4S,4L	IRRIGATION	?	1978			1,800,000	1980	20000						
CLUNY	VILLAGE	103	LAGOON 0S,1L	12	?	?			?	1980	250						
COALDALE	TOWN	5320	AERATED LAGOON		20,000	1970			2,133,000	1985	10000						
COALHURST	VILLAGE	1350	AERATED LAGOO	3	10,000	1975			812,277	1975	2500						
COCHRANE	TOWN	6200	AERATED LAGOO		?	?			?	?	?						
COLD LAKE /GRA	TOWN	7818	LAGOON 4S,3L	6	335,000	1981			1,380,000	1982	10500						
COLINTON	HAMLET	260	LAGOON 1S,1L	?	18,000	1992			?	?	?						
CONSORT	VILLAGE	114	LAGOON 2S,1L	6	700	1974			40,000	1974	1500						
COUNTY OF FORT	??	80	LAGOON??	12	150	1980			3,500	1980	200						
COUTTS	VILLAGE	355	LAGOON 2S,1L	12	20,000	1985			?	1960	500	20,000	1985	1000			
COWLEY	VILLAGE	290	LAGOON 2S,1L	12	?	?			165,000	?	840						
CREMONA	VILLAGE	393	LAGOON 2S,3L	12	?	1982			?	1962	300	250000?	1982	680			
CROSSFIELD	TOWN	1800	LAGOON 4S,2L	12	?	?			?	?	?						
CYNTHIA	HAMLET	100	LAGOON 0S,1L	8	?	?			?	1956	250						
DAPP	HAMLET	50	LAGOON 1S,1L	12	9,000	1990			249,000	1990	300						
DEBOLT	HAMLET	100	LAGOON 0S,1L	12	9,000	1976			47,943	1976	?						
DELBURN	VILLAGE	564	LAGOON 4S,3L	12	?	?			?	?	?						
DELIA	VILLAGE	198	LAGOON OS,1L	6	531	1958			47,790	1958	280						
DEVON	TOWN	4100	RBC		150,000	1992			?	1963				REPLACEM	4,100,000	1992	7000
DEWBERRY	VILLAGE	203	LAGOON 0S,2L	12	?	1964			24,000	1964	20/ACER						
DONALDA	VILLAGE	225	LAGOON 1S,2L	12	?	?			?	1965	250	199,850	1990	310			
DONNELLY	VILLAGE	421	LAGOON 2S,5L	12	42,000	1980			308,000	1980	1100						
DRATON VALLEY	TOWN	7000	AERATED LAGOO		130,000	1988			300,000	1974	4000	150,000	1981	5000	1,700,000	1989	8000
ECKVILLE	TOWN	900	LAGOON 4S,2L	6	23,000	1975			320,000	1975	1000						
EDBERG	VILLAGE	135	LAGOON 0S,1L	12	?	?			?	?	?						
EDSON	TOWN	7300	AERATED LAGOO	CONTIN													
EGALESHAM	VILLAGE	185	LAGOON 0S,1L	6	?	?			?	1968	200						
EGREMONT	HAMLET	55	LAGOON 0S,1L	EVAP	5,400	1980			308,000	1981	87						
ELK POINT	TOWN	1400	AERATED LAGOON		?	?			?	?	?						
ELNORA	VILLAGE	265	LAGOON 2S,3L	12	3,500	1976			145,000		400						
ENTWISTLE	VILLAGE	480	LAGOON 4S2L	6					350,000	1975	500						
EVANSBURG	VILLAGE	725	LAGOON 4S,2L	11	5,000	1980			120,000	1980	1500						
FABYAN	HAMLET	100	LAGOON	EVAP	7,000	1982			250,141	1982	92						
FALHER	TOWN	1180	LAGOON 4S,2L	12	?	1977			336,000	1977	2500						
FAUST	?	379	LAGOON 4S,3L	12	?	?			?	1975	800						
FAWCETT	HAMLET	300	LAGOON 0S,1L	12	4,202	1979			141,828	1979							
FERINTOSH	VILLAGE	115	LAGOON0S,2L	NONE	36,000	1980			148,000	1980	400	60,000	1988	400			
FOOTNER LAKE	HAMLET	75	LAGOON 1S,2L	12	?	?			?	?	?						
FOREMOST	VILLAGE	582	LAGOON 2S,2L	NONE	?	?			?	?	?						
FORESTBURG	VILLAGE	967	LAGOON 0S,3L	12	28,740	1979	168,000	1979	1,200								
FORT ASSINIBOIN	HAMLET	179	LAGOON 0S,1L	12	25	1992			50,000	1978	500						
FORT KENT	HAMLET	?	LAGOON 0S,2L	12	3,010	1977	2,750	1979	272,590	1979	500						
FORT VERMILION	HAMLET	800	LAGOON 4S,2L	6	321,071	1992			?	1978	?						
FOX CREEK	TOWN	2300	LAGOON 4S,4L	6													
GALAHAD	VILLAGE	158	LAGOON 0S,2L	12	$1/YR	?			238,105	1982	350						
GIROUXVILLE	VILLAGE	349	LAGOON 2S,2L	12													
GLENWOOD	VILLAGE	306	LAGOON 2S,2L	6	10,000	1993			6,000	1978	500						
GRANUM	TOWN	371	LAGOON 2S,3L	12													

COMMUNITY	TYPE	POP. SERVED	TREATMENT	STORAGE	LAND COST	YEAR	LAND #2 COST	YEAR	CONST COST	YEAR	DESIGN POP	UPGRADE #1 COST	YEAR	DESIGN POP	UPGRADE #2 COST	YEAR	DESIGN POP
GRASSLAND	HAMLET	66	LAGOON 0S,2L	12	40,000	1992			?	?	?	373,000	1992	?			
GREEN ACRES	TRAILER PA	2000	LAGOON 0S,3L	EVAP	?	1949			?	1975		50,000	1985				
GRENNSHIELDS	HAMLET	55	LAGOON	EVAP	?	?			278,691	1985	41	842	1990	56			
GRIMSHAW	TOWN	2812	LAGOON 8S,5L	12	113,000	1987			550,000	1987	6500						
GROUARD	?	372	LAGOON 2S,2L	12	?	?			190,000	1982	680						
GUNN	VILLAGE	105	LAGOON 0S,2L	12	4000?	1992			256,000	1991	?						
GWYNNE	HAMLET	110	LAGOON 0S,1L	12	65,000	1982			142,800	1983	?						
HAIRY HILL	VILLAGE	70	LAGOON 0S,1L??	12??	5,000	1984			?	?	?						
HANNA	TOWN	3000	LAGOON 4S,2L	6	?	?			?	?	?						
HAY LAKES	VILLAGE	327	LAGOON 4S,2L	12	37,727	1978			283,700	1978	600						
HAYS	HAMLET	104	LAGOON OS,2L	12	?	?			150,000	1981	200						
HAYTER	HAMLET	50	LAGOON 0S,1L	EVAP	5,000	1981			52,819	1981	100?						
HIGH LEVEL	TOWN	3000	LAGOON 4S,2L	6	32,000	1979			550,000	1980	5000						
HIGH PRAIRIE	TOWN	3000	LAGOON 4S,3L	6	40,000	1976			328,000	1976	5000						
HIGH RIVER	TOWN	?	AERATED LAGOON		320,000	1988			3,400,000	1988	10000						
HILDA	HAMLET	44	LAGOON 1S,1L	EVAP	20,000	1981			628,575	1981	163						
HINES CREEK	VILLAGE	423	LAGOON 4S,2L	12	?	?			?	?	?						
HOLDEN	VILLAGE	411	LAGOON 4S,2L	36	81,000	1981			652,000	1983	800						
ID # 22	??	130	LAGOON 0S,1L	12	1,200	1980			100,000	1980	200						
ID #17 EAST	?	275	LAGOON 2S,2L	?	0	?			184,697	1981	500						
ID #17 EAST	?	100	LAGOON 0S,1L	?	0	?			73,465	1982	200						
ID #21	??	52	LAGOON	12	10,000	1982			??	1982	50						
ID 18 NORTH	?	1300	AERATED LAGOO		?	?	?	?	?	?	?	?					
ID 20	??	70	LAGOON??	12	10,500	1981			45,463	1981	250						
INNISFAIL	TOWN	5837	RBC	CONTIN.	135,000	1977			2,264,000	1977	8000	400,000	1987	8000	674,000	1991	8000
INNISFREE	VILLAGE	250	LAGOON 1S,3L	?	42,876	1981			385,200	?	500						
IRMA	VILLAGE	442	LAGOON 4S,2L	12	?	1974			150,000	1974	1500						
IRRICANA	VILLAGE	817	LAGOON 2S,1L	?	10,572	1974			?	1974	500						
IRVINE	TOWN	326	LAGOON 2S,1L	12	1,000	1978			?	?	350						
ISLAY	HAMLET	280	LAGOON 2S,2L	12	1,500	1967			40,000		120	5,000	1989	450			
JARVIE	HAMLET	300	LAGOON 0S,1L	12	2,000	1977			52,908	1977	300						
JOSEPHBURG	HAMLET	100	LAGOON 2S,1L	7	?	?			?	?	?						
JOUSSARD	?	277	LAGOON 4S,1L	12	?	?			117,250	1981	800						
KAVANAUGH	HAMLET	49	LAGOON 0S,1L	12	17,478	1985			163,669	1985							
KILLAM	TOWN	?	LAGOON 4S,2L	12	195,473	1982			823,583	1982	2000						
KING MAN	HAMLET	83	LAGOON 0S2L	12-24	18,336	1981			407,885	1981	200						
KINUSO	VILLAGE	400	LAGOON 0S,1L	?	SED NO COST				??	1969							
KITSCOTY	VILLAGE	??	LAGOON 4S,4L	12	4,000	1975			191,667	1975	800	97,850	1981	1500			
LA CRETE	HAMLET	1200	LAGOON 4S,2L	12	26,875	1992			?	?	?						
LACOMBE	TOWN	7050	LAGOON 4S,3L	6	44,000	1973			450,000	1977	5000						
LAMONT	TOWN	1560	LAGOON 4S,2L	6	59,057	1970			79,000	1970	3500						
LAVOY	VILLAGE	109	LAGOON 0S,1L	12	?	1976			?	?	200						
LEGAL	VILLAGE	973	LAGOON 4S,2L	12	20,000	?			150,000	1972	800	171,000	1978	2000			
LETHBRIDGE	CITY	63000	A. SLUDGE		220,000	1993			38,000,000	1989	80000						
LINDEN	VILLAGE	475	LAGOON 2S2L	EVAP	?	?			73,000	1979	500						
LITTLE SMOKY	HAMLET	50	LAGOON 0S,1L		CROWN	1982			159,436	1982	?						
MAGRATH	TOWN	1743	LAGOON 2S,2L	6	13,500	1972			110,262	1972	1300						
MALLAIG	HAMLET	220	LAGOON 0S,1L	6		1976			50,000	1976	400						
MANNING	TOWN	1139	AERATED LAGOON		1,800	1975			250,000	1975	2500						
MANOLA	HAMLET	175	LAGOON	NOT DISCH	5,000	1979			40,000	1970	250						

COMMUNITY	TYPE	POP. SERVED	TREATMENT	STORAGE	LAND COST	YEAR	LAND #2 COST	YEAR	CONST COST	YEAR	DESIGN POP.	UPGRADE #1 COST	YEAR	DESIGN POP.	UPGRADE #2 COST	YEAR	DESIGN POP.
MARIE-REINE	WP	200	LAGOON	12	1,846	1990			65,000	?	1975						
MAYERTHORPE	TOWN	1700	LAGOON 4S,3L	6							0						
MD BADLANDS #7	??	165	RBC	CONTIN	MD OWNE	1987			350,000	1987	1200						
MD BADLANDS #7	??	240	EXT AREATION	CONTIN	5,000	1976			275,000	1976	350						
MD NO 135	??	140	LAGOON 1S,1L EV	EVAP	19,000	1979			79,000	1980	350						
MD PINCHER CRE	?	450	LAGOON?	12	20,000	1988			315,000	1988	800						
MD ROCKY VEIW	?	350	LAGOON 4S,2L	EVAP	158,000	1983			384,000	1983	1500						
MD SMOKY RIVE	?	85	LAGOON ??	12	1,800	1986			34,387	1986	150						
MD SMOKY RIVE	?	65	LAGOON ??	12	1,800	1986			29,763	1986	150						
MEADOWVIEW	SCHOOL	100	LAGOON	IN 10 YEAR	0	1982			20,000	1982	100						
MEDICINE HAT???	??	200 UNITS	LAGOON	12					100,000	1975		25,000	1992	00 HOMES			
MELOD MEADOW	?	130	???		?	?			?	?	200						
METISKOW	HAMLET	100	LAGOON 0S,1L	12	1,500	1985			61,877	1985	200						
MILK RIVER	TOWN	926	LAGOON 3S,2L	NOT DISCH	1,749	1964			232,000	1975	3000						
MILLET	TOWN	1703	LAGOON 4S,2L	12	325,000	1983			2,200,000	1985	3000						
MIRROR	VILLAGE	487	LAGOON 2S,2L	EVAP	12,500	1975			345,000	1976	800						
MORRIN	VILLAGE	250	LAGOON 2S,2L	12	?	?			?	?	?						
MULHURST / N.E.P	HAMLET	2000	LAGOON 3S,3L	12	70,000	1986			360,000	1986	?	500,000	1989	?			
MUNDARE	TOWN	600	LAGOON 4S,3L	7	?	?			?	?	?						
NAMPA	VILLAGE	496	LAGOON 4S,2L	NOT DISCH	36,000	1982			559,547		1500						
NANTON	TOWN	1589	RBC	CONTIN					84,000	1972		1,800,000	1981	5000			
NEERLANDIA	HAMLET	250	LAGOON 0S,1L	36	6,586	1980			40,000	1980	250						
NEW NORWAY	VILLAGE	275	LAGOON 1S,1L	12	50,000	1975			200,000	1975	500	300,000	1990	1000			
NEW SAREPTA	VILLAGE	404	LAGOON 4S,2L	12	45,000	1978			??								
NEWBROOK	HAMLET	115	LAGOON 0S,1L	12	?	1981			203,000	1981	?	45,000	1992	115			
NORTHLAND SCH	SCHOOL		LAGOON 2S,1L	??							400						
OHATON	HAMLET	118	LAGOON 2S,2L	12	10,000	1977			250,000	1977	200?						
OKOTOKS	TOWN	7200	RBC	CONTIN													
OLDS	TOWN	5300	RBC		?	?			?	?	?						
ONOWAY	VILLAGE	670	LAGOON 4S,2L	48	?	?			?	?	2500						
OYEN	TOWN	1041	LAGOON 2S,2L	6	62,800	1988			980,000	1988	?						
PARKLAND VILLA	?	1600	AEARATED LAGO	12	?	?			?	?	?						
PATRICA	HAMLET	80	LAGOON 0S,1L	12	5,000	1975			130,000	1975	120						
PEACE RIVER	TOWN	6696	LAGOON 4S,0L	CONTIN	?	1964			30,000	1992	12000						
PEORIA	HAMLET	14	LAGOON 0S,2L GR	EVAP	3,000	1982			81,000	1982	60						
PIBROCH	HAMLET	300	LAGOON 0S,1L	12	10,000	1979			77,798	1979	300						
PICADVILLE	HAMLET	300	LAGOON 0S,1L	12	3,500	1977			115,000	1977	300						
PICTURE BUTTE	TOWN	1559	AERATED LAGOO	CONTIN	30,000	1974			721,800	1975	2500						
PLAMONDON	VILLAGE	253	LAGOON 4S,3L	60	36,000	1981			581,000	1981	1000						
PONOKA	TOWN	5700	AERATED LAGOO	6	100,000	1979			850,000	1979	10000						
RAINBOW LAKE	TOWN	1100	LAGOON 4S,2L	12	?	?			?	1967	?	?	1987	1500			
RAYMOND	TOWN	3130	LAGOON 4S,2L	12	?	?			?	1964	3500						
RED DEER	CITY	58656	A.S.		3,200,000	1992			18,000,000	1983	78000						
RED DEER	COUNTY	125	LAGOON	NOT DISCH.	21,000	1979			67,000	1980	672						
RED DEER	COUNTY		LAGOON 0S,2L	NOT DISCH	62,000	?			186,000	1982	150						
RED DEER	COUNTY	200	LAGOON	12	40,825	1981			95,000	1983	400						
REDCLIFF	SEE MEDICINE HAT																
REDWATER	TOWN	2090	LAGOON 4S,3L	6	?	?			240,000	1968	3500						
RIDGEVALLEY	HAMLET	100	LAGOON 1S,2L	12	?	?			?	?	?	74,785	1980	?			
RIMBEY	TOWN	1937	LAGOON 6S, 2L	6	?	?			?	?	?	2,800,000	1997	3000			

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ROCHESTER	HAMLET	100	LAGOON 1S,2L	12	10,000	1992			?	?	?						
ROCKY MOUNTAI	TOWN	5407	AERATED LAGOO	CONTIN													
ROCKY RAPIDS	??0	130	LAGOON??	8	70,000	1992			?	1977	120						
ROCKYFORD	VILLAGE	318	LAGOON 4S,2L	12-24	35,000	1977			154,000	1977	600						
ROLLEYVEIW	HAMLET	66	LAGOON 0S,1L	12	24,830	1986			263,821	1986							
ROUND HILL	??	138	LAGOON	24	21,700	1979			420,000	1979	260						
RUMSEY	VILLAGE	70	LAGOON EVAP	EVAP	0	1992			200	1992	?						
RYCROFT	VILLAGE	634	LAGOON 2S,2L	12	23,000	1978			150,400	1978	1500						
SANGUDO	VILLAGE	401	LAGOON 4S,3L	6	10,000	1978			250,000	1978	700						
SCHULER	HAMLET	?	LAGOON 0S,2L	VAPORATIO	20,000	1980			645,688	1980	250						
SEXSMITH	TOWN	1256	LAGOON 4S,2L	7	21,000	1974			??	1974	800						
SHAUGHNESSY	HAMLET	296	LAGOON 2S,2L	12	?	?			?	?	?						
SMOKY LAKE	TOWN	1054	LAGOON 4S,3L	12	5,000	1985			20,000	1968	1500	1,700,000	1985	1500			
SPIRIT RIVER	TOWN	1044	LAGOON 3S,3L	12	?	?			?	?	?						
ST. ISIDORE	HAMLET	200	LAGOON 2S,2L	12	4,344	1981			?	1982	150						
ST. PAUL	TOWN	5100	CONTACT STABILI	CONTIN.	35,000	1992			500,000	1974	7000	500,000	1988	10000			
STANDARD	VILLAGE	329	LAGOON 4S,2L	12	26,148	1979			353,090	1979	900						
STAVELY	TOWN	528	LAGOON 2S,3L	12	?	?			?	1955	350	325,000	1986	1000			
STIRLING	VILLAGE	799	LAGOON 2S,2L	EVAP	20,000	?			405,400	1989	?						
STRATHCONA	COUNTY	SCHOOL	LAGOON 0S,2L	36	?	?			?	?	?						
STRATHMORE	TOWN	4500	LAGOON 7S,6L	12	160,000	1993			1,807,000	1991	7000						
SUFFIELD	HAMLET	?	LAGOON 2S,2L	EVAP	20,000	1980			588,000	1980	450						
SUNDRE	TOWN	1800	AERATED LAGOO	CONTIN.	140,000	1982			2,300,000	1982	4000						
SUNNYBROOK	HAMLET	74	LAGOON 0S,1L	12	35,480	1984			258,756	1984		3,800	1989				
SWALWELL	HAMLET	59	LAGOON 0S,1L EV	EVAP	2,000	1980			20,000	1980	100						
SWAN HILLS	TOWN	2400	LAGOON 5S,2L	12	?	?			700,000	1976	2500	1,000	1992	3500			
SYLVAN LAKE	TOWN	4500	LAGOON 5S,4L	12	160 ACRES	1954			250,000	54	4000	250,000	1975	5000	450,000	1984	7500
TABER	TOWN	6660	RBC/AERATED LA		350,000	1984			11,000,000	1983	10000	2,500,000	1985	12000			
TANGENT	HAMLET	65	LAGOON 0S,1L EV		6,000	1982			110,000	1982	200						
THERIEN	HAMLET	?	LAGOON 0S,1L	12	19,350	1981			303,950	1981	250						
THORHILD	VILLAGE	500?	LAGOON 2S,1L	12	4,000	1972			80,000	1972	650						
THORSBY	VILLAGE	700	LAGOON 4S,2L	12	120,000	1983			850,000	1983	2000						
TOFIELD	TOWN	1620	LAGOON 2S,3L	12	?	?			?	?	3000						
TOMAHAWK LAG	COUNTY OF	120	LAGOON 0S,1L	6	1,950	1966			1,000	1966	100						
TROCHU	TOWN	1010	LAGOON 4S,2L	12	?	?			?	?	1500						
TWILIGHT	??	90	LAGOON 0S,1L	12	1,000	1993			3,000	1985							
TWO HILLS	TOWN	1107	LAGOON 4S,2L	12	43,000	1978?			600,000	1978	1500						
VALHALLA	HAMLET	45	LAGOON 1S,1L	EVAP	8,000	1986			145,000	1986	?						
VALLEYVIEW	TOWN	2200	LAGOON 4S,2L	12						1976		450,000	1992	6000	887,000	1993	6000
VEGREVILLE	TOWN	5500	LAGOON 4S,6L	12	245,000	1977			1,338,000	1980	20000						
VERMILION	TOWN	4500	EXT. AERATION														
VIKING	TOWN	1109	LAGOON 4S,2L	6	5,500	1977			850,000	1977	3000						
VILINA	VOLLAGE		LAGOON 2S,2L	6													
VIOLET GROVE	HAMLET	50	LAGOON 0S,2L	36	6,000	1977			?	?	?						
VULCAN	TOWN	1407	LAGOON 4S,2L	12	?	?			300,000	1975	5000						
WABAMUN	VILLAGE	603	LAGOON 4S,2L	6	?	?			?	?	?						
WABASCA	HAMLET	2000	AERATED LAGOO	CONTIN.	CROWN				?	?	?	700,000	1984	1500			
WAINWRIGHT	TOWN	?	AERATED LAGOO		30,000	1977	10 ACRES		350,000	1978	7000	1,300,000	1993	10000			
WANDERING RIV	??	150	LAGOON 1S,1L	12		1983			774,641	1983	400						
WARBURG	VILLAGE	519	LAGOON 4S,3L	12	?	?			?	?	?						

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WARNER	VILLAGE	?	LAGOON 2S,1L	6	?	?			65,000	1966	700	30,000	1973	700			
WARSPITE	VILLAGE	75	LAGOON 0S,2L	12	?	1962			?	1962	150						
WASKATENAU	VILLAGE	256	LAGOON 2S,2L	12	?	?			200,000	1978	257						
WATINO	HAMLET	14	LAGOON 0S,2L GR	EVAP	28,000	1982			221,000	1982	150						
WEMBLEY	TOWN	1382	LAGOON 4S,2L	12	1,000	1957	28,000	1977				208,000	1977	1260			
WESTLOCK	TOWN	4700	LAGOON 4S,2L	7	200,000	1992			1,700,000	?	3000	?	?	10000			
WESTWIND	PARK	130	LAGOON	12	5,000	1977			25,000	1977	200						
WHITECOURT	TOWN	7000	A.S.		73,875	1977			1,200,000	1977	6000	1,500,000	1995	12000			
WHITELAW	HAMLET	?	LAGOON 1S,1L	12	3,000	1993			?	1980	600?						
WILLINGDON	VILLAGE	353	LAGOON 2S,2L	6	22,870	1976			221,074	1976	500						
WIMBORNE	HAMLET	50	LAGOON 0S,1L EV	EVAP	3,000	1981			2,500	1981	100						
WINFIELD	HAMLET	250	LAGOON 0S,2L	12	2,500	1964			46,380	1964	?						
YOUNGSTOWN	VILLAGE	245	LAGOON 0S,1L	?	?	?			?	1959	300						