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A TECHNOLOGY TRANSFER SEMINAR

SEMINAR PAPERS
ON
EFFLUENT IRRIGATION UNDER
PRAIRIE CONDITIONS

SPONSORED BY:

WESTERN CANADA WATER & SEWAGE CONFERENCE

SASKATCHEWAN ENVIRONMENT

ENVIRONMENTAL PROTECTION SERVICE

FEDERATION OF ASSOCIATIONS ON THE CANADIAN ENVIRONMENT

REGINA, SASKATCHEWAN
JANUARY 24-25, 1979

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WESTERN CANADA WATER AND SEWAGE CONFERENCE

A TECHNOLOGY TRANSFER SEMINAR

January 24 - 25, 1979
Regina Inn
Regina, Saskatchewan

Mr. Chairman, Ladies and Gentlemen:

Welcome to our province and to our capital city of Regina.

I'm sure that you will agree that at this time of the year and with the sort of weather we have been experiencing recently, Regina is an ideal community for detached observation and relaxed consideration of environmental issues. Environmental changes can take place rapidly in warmer climates and warmer seasons. But, during the average Regina winter, most of the environment stays conveniently changeless most of the time. You are certainly well protected from any immediate critical problems which might disrupt your thoughtful consideration of the big picture.

I'm also delighted to see the wide spectrum of delegates present at this conference. I see representatives of those most important people, the farmers who are the ultimate users of this technology. I see representatives of our municipalities, whose taxpayers are charged with the expensive duty of ensuring that nutrients from effluent are not discharged en masse into our province's already overloaded streams and

lakes. Finally, I'm happy to see so many consultants and designers whose ideas and expertise make this whole technology possible.

Water is essential to agriculture here in western Canada as it is everywhere on our planet. But Saskatchewan agriculture has distinct and special water problems which are peculiar to our relatively flat land and our relatively dry mid-continental location.

When we get more water than our poor drainage facilities can handle, we are vulnerable to flooding; for example, during the spring snow melt or whenever there is a very heavy cloudburst. On the other hand, because of relatively low rainfall, many areas need irrigation before they can fulfil their full growing potential.

In Saskatchewan, as in the rest of Canada, we are well into the bigger and bigger city stage. This, in turn, means that we have the same problem of sewage effluent disposal that other cities face elsewhere. But, once again, some of our problems are distinct and special.

The traditional picture of Saskatchewan, gained from riding the CPR or driving the Trans-Canada, is one long, flat, treeless, featureless and comparatively waterless plain. As anyone knows who has taken the

trouble to make a summertime side trip, this is a false picture. We have trees and we have lakes, even in grain-growing and ranching country in the southern half of our province.

But those southern lakes, beautiful though they may be, are small in comparison with the vast land mass around them. They are also shallow. Despite their small size and shallow depth, they must absorb all the nutrients that are draining steadily from some of the most nutrient-rich soils on earth. The normal supply of nutrients coupled with sunshine and hot weather can hardly help but produce profuse growths of water weeds and algae. If massive extra nutrients from community sewage effluents are added, the recreational and aesthetic possibilities of these lakes are clearly threatened.

Our rivers, draining and flowing over dry flat land, have special problems too. The streamflow varies widely from spring flooding to mid-summer zero flows. Since dilution is impossible at certain times and since farming is often conducted in the wide riverbed plains with their meandering channels, effluent discharge must also be intermittent and is sometimes inappropriate.

Our department is responsible for managing the supplies of surface and ground water and is also responsible for protecting water quality. Over the years, we've had to develop special policies to offset these special situations.

We have to be very, very careful that discharged wastewater doesn't create any extra problems for downstream users, such as speeding up the clogging process in lakes which naturally hover close to speedy eutrophication. We cannot risk dumping tons of extra nutrients into a surface water system already overloaded with natural nutrients.

It is not surprising that, here on the prairies, we are treating over 95 per cent of all community sewage, in comparison with the smaller percentage of sewage being treated in some other parts of Canada. But treating sewage for sanitary reasons alone is not enough.

It is possible, by expensive tertiary treatment, to remove much of the phosphorus which must be present before plant life can make use of other nutrients. But, as long as those other nutrients are in the effluent, ready to become nourishing plant food once phosphorus enters the watercourse farther downstream, we are only curing a nearby problem.

Obviously, we are very happy to see an alternative such as effluent irrigation, which can make productive, rather than destructive, use of all the nutrients and which does not simply shunt the nutrient problem to somebody else farther down the river.

We see another possible advantage which effluent irrigation can have over chemical treatment methods. That advantage arises when great quantities of sewage are involved. There is a limit to the number of lagoons which can be tolerated. There is a limit to the taxpayer money which can be spent on capital-intensive equipment and chemical processing. If we can change greater and greater amounts of sewage into an asset instead of a liability we will all be better off.

For some years past, Saskatchewan Environment has been co-operating with Saskatchewan Agriculture, our friendly federal competitors and a number of municipalities in effluent irrigation experimentation and research.

Starting back in 1974 at Davidson and carrying on up until 1977, we have seen effluent irrigation projects set up and operating in Davidson, Eatonia, Balgonie, Gull Lake, Wolsely and, biggest of them all, Swift Current. These communities, varying in size from around 550 up to more

than 14,300, had a combined population of almost 19,000 who were contributing to the available effluent.

The acreage irrigated ranged from some 26 at Davidson to 800 at Swift Current. I am delighted to see that our friend Mayor Dyer of Swift Current will be telling you at first-hand about their project. Up to the end of 1977, the total irrigated acreage in the province was over 1,000.

During 1978, another project began operation at Maidstone.

Shaunavon, Vanscoy, Dalmeny and Coronach and Moose Jaw are all considering possible effluent schemes. Because of the size of any Moose Jaw projects, there has been a lot of study and experimenting conducted to date.

The Moose Jaw project would be, of course, the biggest of them all. It will have to handle some 4,000 acre-feet of effluent wastes from a city of almost 33,000 people and it will use that effluent to irrigate and fertilize some 2,400 acres of nearby land.

A few moments ago I mentioned Mayor Dyer of Swift Current. He is typical of the many municipal officials who have shown interest in

effluent irrigation and who have taken the initiative to bring such projects to fruition. I hope their number will increase.

I also note that Mr. Rempel of Swift Current and Mr. Swenson of Baildon are on the agenda. Both of them are practicing farmers. Both of them typify the rising interest in effluent irrigation which can be seen among those farmers who are dedicated to seeing that most possible food value produced from our soils.

I would be remiss if I painted a single-coloured picture of enthusiasm, depicting effluent irrigation as a cure-all under all kinds of circumstances.

Despite our successful experiments to date, we still have some psychological problems to overcome before we get full public acceptance of effluent irrigation, let alone public enthusiasm.

Many of us have forgotten those bygone days when, like subsistence farmers elsewhere in the world today, our own forefathers carefully gathered their night soil and carried it back to their vegetable patches and berry bushes. In those days, human waste was recognized as one of the best possible fertilizers available for growing human food.

Instead, we have been brought up in a society which prefers to ignore smelly realities and which worships hygiene and sanitation. It's no wonder that there are still many people who reject the concept of spreading the contents of their toilet bowls over the fields where their food is growing and over the leaves which can be part of that food.

Common sense and education will sooner or later allow us to accept hygiene, sanitation and the older common-sense of our forefathers. But total acceptance of effluent irrigation by everyone is, admittedly, not here yet.

We also recognize that some parts of Saskatchewan's farm and range country have some inherent physical limitations. The total quantity of water available and the unconcentrated nature of their populations make any kind of irrigation, including effluent irrigation, impractical at the moment.

We have other locations, such as Regina, where the surrounding soils are already so heavy in texture that large quantities of effluent are not needed.

We also have many places where the basic water supply is too heavily mineralized to start with, or where the soil and topography make irrigation of any kind impractical.

Admitting, however, that effluent irrigation isn't the panacea for all the ills associated with effluent disposal and for transforming all of Saskatchewan's substandard soils into Californian Imperial Valleys, the proper use of this sytem, where practical, can be of immense value to both the community faced with the expensive problem of getting rid of effluent and the user who needs more moisture and more soil nutrition.

Speaking on behalf of Saskatchewan Environment and Saskatchewan's government, we are pleased to have been a co-sponsor of this conference and we wish you success with your important seminar.

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INTERNATIONAL AND NATIONAL DEVELOPMENTS IN LAND TREATMENT OF WASTEWATER

HARLAN L. MCKIM[1], THOMAS F. JENKINS[2], JAMES MARTEL[3]
ANTONIO J. PALAZZO[4]

INTERNATIONAL

During the week of 20 August 1978 the United States Army Cold Regions Research and Engineering Laboratory (CRREL) sponsored an International Symposium on the State of Knowledge in Land Treatment of Wastewater at Hanover, New Hampshire. One hundred papers covering the entire scope of land treatment technology were published in the proceedings (1). On 23-27 October 1978 the International Conference on Developments in Land Methods of Wastewater Treatment and Utilization was held in Melbourne, Australia. The proceedings of this conference, sponsored by the International Association on Water Pollution Research (IAWPR), contained 40 papers covering recent research results on the treatment of wastewater by land application and lagoons.

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The participants at both of these gatherings discussed many land treatment systems, some of which have been in operation since before the turn of the century.

A comprehensive report on the history of land application as an alternative treatment has been published by the United States Environmental Protection Agency (2). This report reviews the changes that have occurred in land treatment technology from the year 1531 to the present.

Two land treatment systems that have been in continuous operation for some time are the Board of Works Farm, Werribee, that treats waste from Melbourne, Australia, and the Wroclaw sewage farm in Poland. In the Melbourne system, raw sewage, at an average flow of 440 Ml/day, is treated using three methods of purification: land infiltration, grass filtration or lagooning (4,5,6,7). Selection of the land application method depends on the season.

Increases in N, P and K have been found in the herbage harvested from the site, and the concentration of heavy metals falls within the acceptable range for most common legumes and grass (3). Twenty-two thousand head of beef cattle and 30,000 sheep feed on the grass. Analyses of the kidney and liver tissues of these animals for heavy metals showed the content to be within the expected range for mammalian tissue (60).

In Poland, sewage represents over 50% of all the surface water flow during dry years. Therefore, application of sewage to grasslands and fodder root crops is necessary not only because of its fertilizer value but because it is the only water available for irrigation.

The Wroclaw sewage farm has been in continuous operation for 90 years (8). About 170,000 m^3/day of sewage is used for irrigation. At present, 1500 hectares of land are irrigated. Cattle are grazed on the grass and pasture land from April through November. When the grass is harvested from irrigated areas, the yields exceed 40,000 kg/ha on a fresh weight basis. The system has operated under proper management for 88 years and has never posed any hazard to the environment.

Researchers at Braunschweig, Germany, have been treating municipal wastewater for many decades (9). Currently, 300 ha of cropland are irrigated with these waters. Winter and summer cereals, potatoes, sugar beets and asparagus are among Braunschweig's principal crops. Except for asparagus, which is sprayed during the non-harvest months of June through December, vegetables and low growing fruits are not irrigated. All crops are processed prior to human or animal consumption. Cattle are not allowed to graze the grassland for three weeks following irrigation. Studies on heavy metals in the wastewater, soil, soil water and groundwater have also shown that concentrations are far below the maximum allowed under the Federal standards of Germany.

Scientists in Iran are successfully using sewage effluent to irrigate farmland (10). Alfalfa, corn and potatoes are the principal crops. There has been no incidence of underground water pollution under the present operating schedule.

In Britain, land treatment was the general method for purifying urban sewage in 1870 (11). But by 1970 all of the sewage farms had been abandoned because of high land costs.

The results of experiments conducted in Israel indicate that Rhodes grass is particularly effective in both utilization of applied nitrogen and in uptake of sodium chloride (12, 13). This grass could be useful in areas where salt buildup is a potential problem.

In Chile, experiments are underway to evaluate a system where approximately 4,500 ha of vegetables have been irrigated with wastewater. The system has been in operation for 40 years (14). The emphasis of the program is on heavy metals (Cd, Cr, Cu, Ni and Zn). The results show that Cd levels in the vegetable leaves are below 3 ppm Amounts of Cr, Ni and Zn in the leaves are in the normal range. Even though the levels of Cd in the wastewater are in the medium to high range (approximately 20 µg/l), no toxic effects on plant growth have been detected.

Results from the oldest land application system in New Zealand (15) indicate that 20 years of land application has markedly improved soil fertility. Leaching of nitrates from this system has been observed and is attributed to the practice of grazing sheep on irrigated pastures. Feces and urine from the animals return nitrogen directly to the soil and the only effective removal of nitrogen that occurs is when it is incorporated in animal tissue.

Animal and domestic wastewater is being utilized for its nutrient value in the Soviet Union. In most of the land application systems, the wastewater passes through a series of lagoons and is mixed with river water before it is sprayed on various types of crops. In many instances the wastewater is applied to grassland used to graze dairy

cattle. The data from these studies indicate that the crops grown on the farms and the milk produced do not pose a human health hazard (1).

Recent experiments on the use of sewage effluents in aquaculture have been conducted in India (16). Their results indicate that it is possible to produce valuable crops of fish and algae while producing irrigation water with a high biofertilizer value.

NATIONAL

Historically in the United States land application of wastewater from agricultural and domestic sources has been used to grow crops. Forage crops produced at land treatment sites are of high quality and are used as an animal food source. When wastewater is applied to various forest species, growth may be significantly increased (17). This increase in pulp production may provide an alternative energy source to replace diminishing oil and gas supplies. These benefits can make the concept of land application of wastewater a cost-effective alternative to other forms of wastewater treatment.

In the United States several land treatment systems have been in operation since the turn of the century (2). In the past ten years, however, Federal legislation (such as Public Law 92-500, the Water Pollution Control Act Amendments of 1972, and Public Law 95-217, the Clean Water Act of 1977) has given municipalities added incentive to utilize land treatment, by increasing the percentage of funding covered under the federal construction grants program. With this incentive

the cost of land treatment systems will be more competitive compared to conventional treatment processes. This should encourage the construction of more land treatment systems.

Pretreatment

Experiments conducted by the Cold Regions Research and Engineering Laboratory (CRREL) have demonstrated that land treatment can be used to produce excellent product water quality with pretreatment of the sewage to only primary levels (18, 19). Pretreatment beyond the primary level is not necessary from a process performance point of view. Secondary treatment can be justified only if disinfection is required prior to land application (20,21,22).

For small communities and recreational areas, storage ponds are usually the most cost-effective method of pretreating sewage before application to the land. In most instances the sewage is treated to secondary levels in the holding or storage ponds and the nutrient levels are low (23, 24). When this secondary wastewater is applied to land for its nutrient value, the crop yields may be low and fertilizer may need to be added to obtain a desirable plant yield. Therefore, it is important to establish treatment and utilization goals before final design of a treatment facility.

Methods of Land Treatment

Basically there are three methods of land treatment: rapid infiltration, slow infiltration and overland flow. All of these systems can

be designed and operated to remove BOD, suspended solids, phosphorus, nitrogen and trace elements. In rapid infiltration systems the wastewater is applied to a very deep permeable soil (Fig. 1). Soils that have an infiltration rate of more than 5.0 cm/hr can be considered (25). The water moves through the soil primarily under unsaturated flow. Mounding of the water beneath the system should not be a problem but will occur at high application rates. Usually the land area required for a rapid infiltration system is small because large quantities of wastewater can be treated on a minimum of land.

The slow infiltration (slow rate) mode of land treatment is the method used primarily when the infiltration rate of the soils is between 0.15 and 50 cm/hr (25). In slow infiltration systems the wastewater percolates slowly through the soil, with vegetative cover being an integral part of the treatment process (Fig. 2).

In overland flow systems the wastewater moves slowly over the surface of a very impermeable soil (Fig. 3). The permeability of these soil types is usually less than 0.25 cm/hr. Approximately 60% of the applied wastewater is collected downslope and is usually discharged to surface waters. Grass is usually the crop grown on overland flow systems.

Rapid Infiltration

When rapid infiltration systems are operated and managed properly they can provide long-term renovation of wastewater (26,27,28,29,30,31, 32,33). The primary design criteria for rapid infiltration systems are application rate and schedule. Application rate depends on the soil

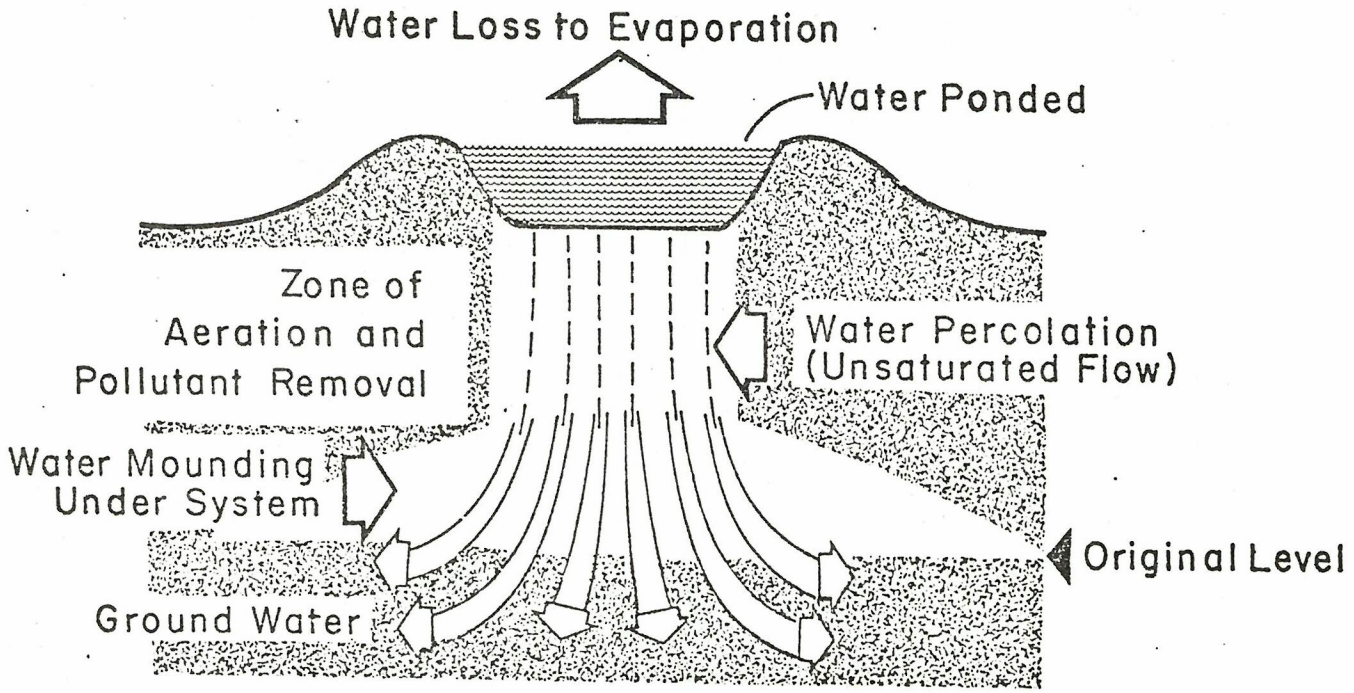


Figure 1. Rapid Infiltration.

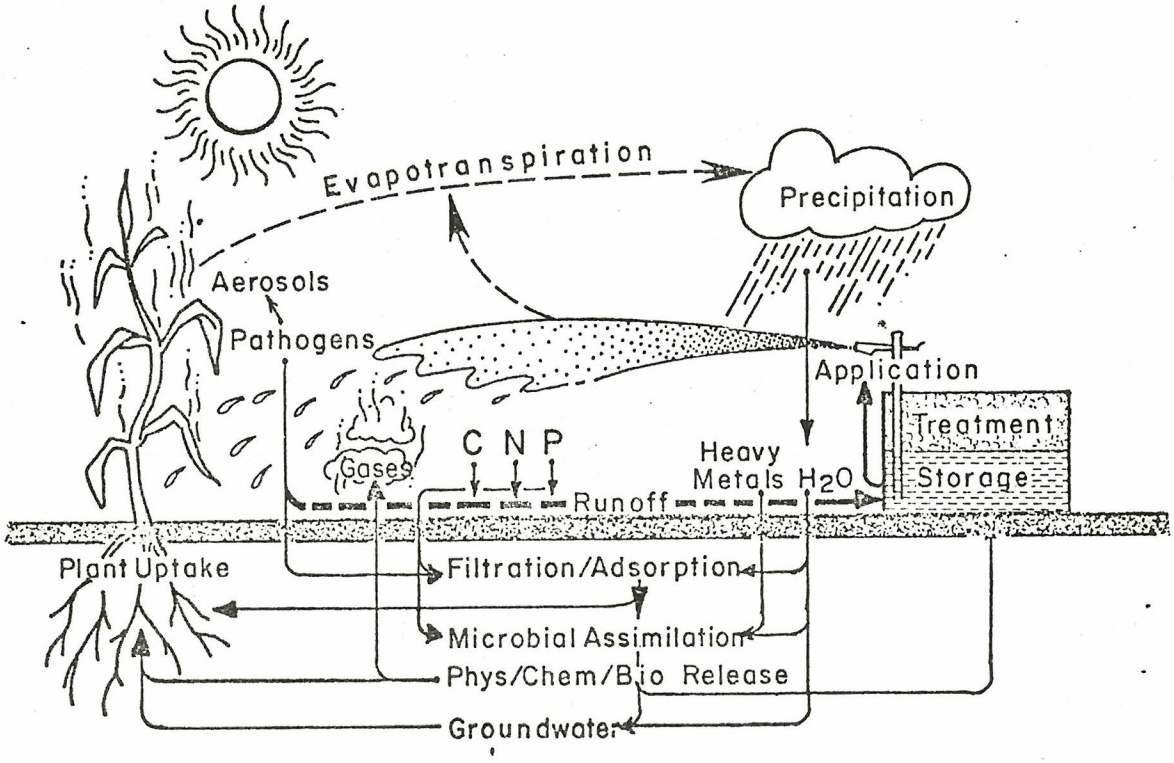


Figure 2. Slow Infiltration.

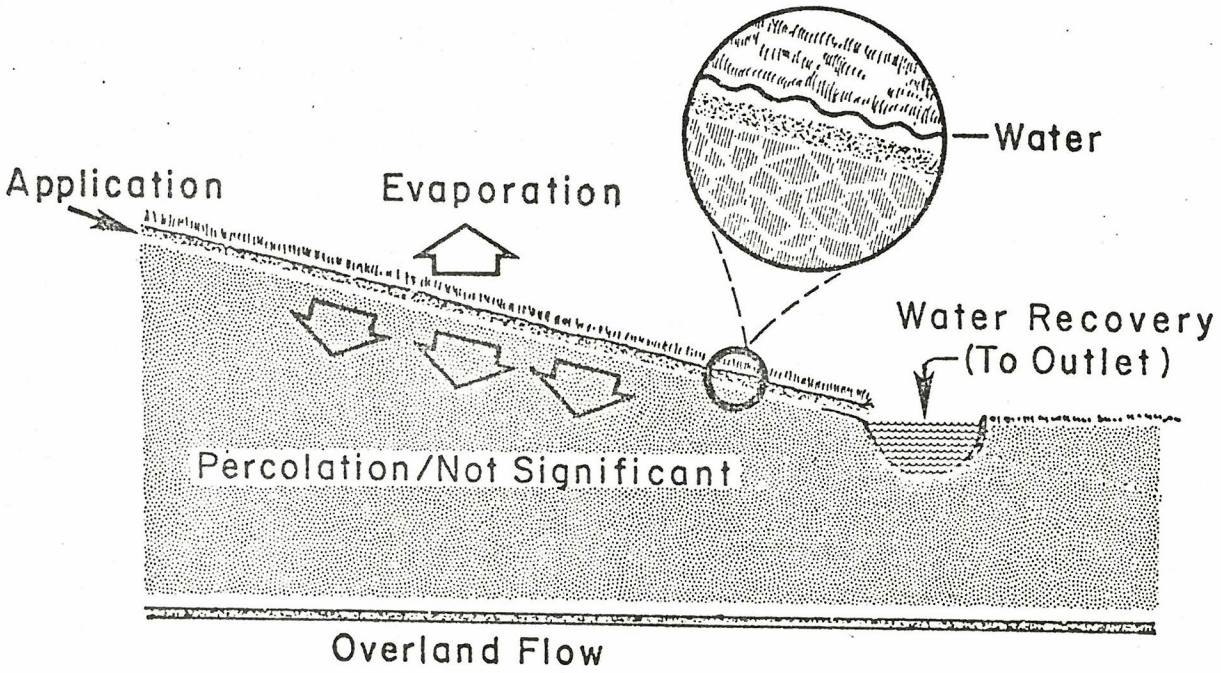


Figure 3. Overland Flow.

infiltration rate, wastewater solids content and desired percolate water quality. The length of the wastewater inundation period varies, depending on such parameters as geographical area, soil characteristics and climate. Also, adequate drying periods are required to ensure that the infiltration capacity of the soil is not permanently impaired.

At Fort Devens, Massachusetts, unchlorinated effluent from Imhoff tanks has been applied to 22 treatment beds for 30 years (34, 35). Currently, infiltration beds are flooded for a period of two days, followed by a 14-day drying period. Using this cycle, each treatment bed receives primary sewage effluent about 52 days each year. Given a mean annual flow of 5,061 m^3/day (1.34 mgd) and equal effluent distribution per unit area, the wastewater applied to the beds has averaged about 28.3 m/yr (93.8 ft/yr) over the last 15 years.

To ensure proper operation of the Fort Devens system the infiltration capacity of the soil is maintained by annually removing the top 0.3 m of the soil surface for each treatment bed. The excavated materials are replaced with locally available sand and gravel.

The average water quality characteristics of the primary effluent and groundwater obtained from wells adjacent to the Fort Devens treatment site are shown in Table 1. Wells were installed at depth intervals of 1.5 m so that water quality changes with depth could be observed (34,35). The data indicate that removal of phosphorus, BOD and nitrogen was more than 98 and 60 percent, respectively.

Results obtained from an experimental rapid infiltration site at Flushing Meadows, Arizona, have shown that a 9-day flooding and 12-day

Table 1. Effluent and groundwater chemical and bacteriological characteristics at Fort Devens, Massachusetts, land treatment site (after Satterwhite 34, 35).

A. Chemical and bacteriological characteristics of Imhoff tank effluent and annual wastewater additions to treatment beds.

Parameter	Effluent* Range	Mean
pH (standard units)	6.2-8.0	
Conductivity (μmhos)	402-700	511
Alkalinity (ppm $CaCO_3$)	116-245	155
Hardness (ppm $CaCO_3$)	22-60	41
BOD_5	30-185	112
COD	110-450	192
Total nitrogen	19-78	47
Organic nitrogen	11.5-32.8	23.4
NH_4-N	6.2-42	21.4
NO_3-N	0.4-2.8	1.3
NO_2-N	0.002-0.06	0.02
Total PO_4-P	6-16	11
Ortho PO_4-P	3-15	9
Chloride	75-210	150
Sulfate	27-72	42
Total coliform bacteria x 10^6/100 ml	18-53	32

* mg/l unless otherwise indicated.

B. Chemical and bacteriological characteristics of groundwater in selected observation wells (mg/l unless otherwise indicated).

Parameter	Well 3	'8	9	10	11	12	13	14
pH (standard units)	6.3	6.6	6.5	6.1	6.3	6.6	6.2	6.5
Conductivity (μmhos)	360	443	310	333	305	71	36	327
Alkalinity (ppm $CaCO_3$)	28	58	67	14	53	29	17	49
Hardness (ppm $CaCO_3$)	44	44	32	30	31	17	6	30
BOD_5	2.5	2.0	1.4	0.9	0.8	1.2	1.0	0.9
COD	19	15	8	10	9	10	13	11
Total nitrogen	19.5	19.8	10.4	20.3	12.1	3.7	1.9	9.7
Organic nitrogen	2.3	4.2	3.7	1.2	1.0	0.8	1.2	1.5
NH_4-N	1.3	4.5	3.2	0.5	1.0	0.3	0.3	0.4
NO_3-N	15.6	10.7	3.5	18.6	10.1	2.6	0.4	7.8
NO_2-N	0.3	0.4	0.02	0.02	0.02	0.01	0.01	0.02
Total PO_4-P	0.9	0.8	1.4	1.3	1.9	0.6	0.7	1.1
Ortho PO_4-P	0.2	0.1	0.4	0.1	0.2	0.1	0.1	0.1
Chloride	230	220	144	257	221	40	15	162
Sulfate	39	36	33	35	44	9	7	46
Total coliform bacteria (no./100 ml)	210	158	230	620	130	120	370	120

drying period with hydraulic loading rates of 60-75 m/yr resulted in nitrogen removal rates of 60 percent (30). The nitrogen in the applied effluent ranged from 20 to 40 mg/l, and the product water from the treatment site contained average concentrations of nitrate, ammonium and organic N of 8.6, 1.7 and 0.5 mg/l, respectively. The primary mechanism of nitrogen removal was identified as denitrification. Phosphorus applied in the effluent at Flushing Meadows averaged about 8 mg/l in 1977 and a reduction of 90% was found in the percolate water after 60 m of lateral water movement. Viruses were not detected in the water sampled at 6- to 9-m depths.

Both the Fort Devens and Flushing Meadows results have shown that rapid infiltration systems can be operated effectively with no detrimental effect to the groundwater. Again, it is important to emphasize that rapid infiltration systems should be operated and managed to maintain the initial infiltration rate of the soil.

SLOW INFILTRATION

Many slow infiltration land application systems have been successfully designed and operated to dispose of domestic and municipal wastewater (2,3,36,37,38,39,40). However, it is only recently that research on these systems has been conducted to maximize treatment and decrease operating costs.

Wastewaters contain on the average about 20 mg/l total nitrogen (N), 10 mg/l phosphorus (P) and 15 mg/l of potassium (K) (28). Normal plant requirements could be met with an application of 250 cm/ha per

year of wastewater application, which would supply the plants with 500 kg N/ha, 250 kg P/ha and 375 kg K/ha (42).

Many types of crops can be grown on slow infiltration land treatment systems (43,44,45). Two studies at Pennsylvania State University and the University of Washington have shown that a forest ecosystem can effectively renovate wastewater (46,47,17). Grasses, legumes and row crops have also been used at various land treatment sites and remove large quantities of nitrogen from wastewater (42,48,48).

The treatment efficiency of slow infiltration systems is dependent primarily on the management of the system. Design parameters such as the infiltration rate of the soil, type of crop selected, physical and chemical soil properties, and depth to groundwater will govern, in part, the cost of a system, but proper management of the system will ensure that the groundwater quality will be maintained.

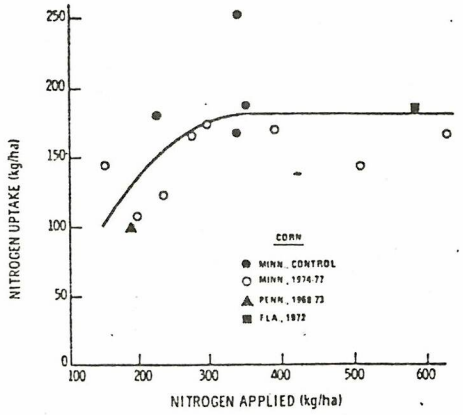
Over the past four years CRREL has been conducting extensive studies on the slow infiltration method of land treatment (36,48,18,50,51,52). Similar experiments have also been conducted at the United States Department of Agriculture Apple Valley Test Facility in Minnesota (43) and the University of Washington Pack Forest Research Facility (17). Results from these experiments documenting plant uptake of nutrients using various forage grasses are summarized in Table 2. These data indicate that 50-80% of the nitrogen applied can be utilized by the plant during the growing season. If wastewater application is continued during winter months, removal rates will be lower. Reed canarygrass, tall

fescue, blue grass and quackgrass removed the largest percentage of the nitrogen applied in the wastewater, whereas corn removed the least amount of nitrogen. This is primarily related to the longer growing season for forage grasses.

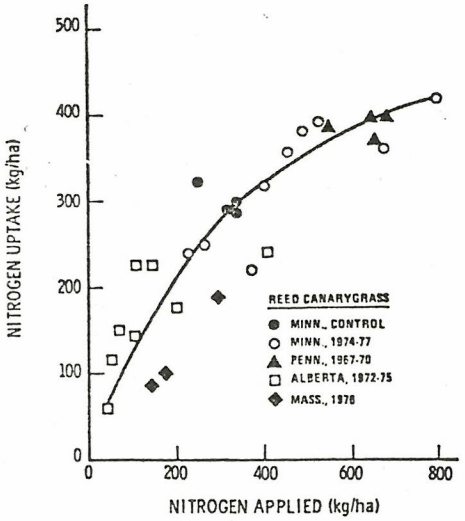
If the nitrogen loading rate is increased by increasing the amount of water applied to a site, the plant will use more of the nitrogen applied but at a decreasing rate (Table 3). This means that if nitrogen is applied at rates exceeding plant uptake, the amount of nitrogen that may enter the groundwater will increase and the potential for an adverse environmental impact will increase (50).

Results from research throughout the U.S. have been used to establish the relationships between nitrogen uptake and nitrogen applied for corn and reed canarygrass that can be used in the design of a slow infiltration land treatment system (Fig. 4). Under proper management, loading rates of greater than 600 kg/ha of nitrogen can be applied to a slow infiltration land treatment system planted with reed canarygrass, and 400 kg/ha of the nitrogen can be removed by the crop. The efficiency of crop removal increases with decreasing nitrogen loading to the system.

Phosphorus at concentrations normally found in wastewater (~10 ppm) does not pose a significant problem in slow infiltration systems, if the system is properly managed. A study of many existing systems has shown that the plants and soil can remove virtually all the phosphorus contained in the wastewater for the life of the system (53). A summary of phosphorus removal by various crops at several locations is shown in Table 4.



a. Total seasonal nitrogen uptake by corn irrigated with secondary municipal wastewater effluent.



b. Total seasonal nitrogen uptake by reed canarygrass irrigated with secondary municipal wastewater effluent.

Figure 4. Nitrogen uptake vs nitrogen loading relationship for corn and reed canarygrass. *After Clapp 1978.

Table 4. Crop dry matter yields and uptake of phosphorus for several crops at various locations as a function of application rate of secondary municipal wastewater effluent. After Clapp, et al. (29)

Crop	Location	Years	Rate	Yield	Applied	Uptake	Uptake
			cm/wk	t/ha/yr	--- kg/ha/yr ---		%
Corn*	Penn	1970	0.0	10.7	--	24	--
	Penn	1969-70	2.5	13.4	22	34	154
	Penn	1968-71	5.0	9.3	46	29	63
	Penn	1972-73	7.5	7.7	64	34	53
	Minn	1974-77	0.0	16.0	76	39	51
	Minn	1974-77	5.1	12.7	104	35	34
	Minn	1974-77	9.4	13.4	190	37	19
Reed Canarygrass†	Penn	1967-70	5.0	12.4	162	56	35
	Minn	1974-77	0.0	11.1	76	38	50
	Minn	1974-77	7.0	9.7	138	42	31
	Minn	1974-77	12.6	12.2	248	54	22
	Alberta	1972-75	3.0	5.8	27	26	96
	Alberta	1972-75	6.0	9.4	54	36	67
	Mass	1976	5.0	6.0	150	24	16
Smooth Bromegrass‡	Alberta	1972-75	3.0	6.0	27	23	85
	Alberta	1972-75	6.0	10.0	54	35	65
	Minn	1974-75	0.0	9.6	152	44	29
	Minn	1974-75	6.5	7.4	158	34	22
	Minn	1974-75	11.4	7.9	277	43	16
Timothy§	Minn	1974-75	0.0	8.8	152	34	22
	Minn	1974-75	6.5	7.6	158	32	20
	Minn	1974-75	11.4	8.6	277	40	14
Tall Fescue¶	Minn	1974-76	0.0	11.6	101	40	40
	Minn	1974-76	6.3	10.9	151	43	28
	Minn	1974-76	11.3	12.0	268	49	18
Mixed Forages**	NH	1974-75	5.0	10.2	94	32	34
	NH	1974-75	15.0	13.3	262	44	17

*Zea mays L. (Varieties: Penn - 'Pa.890-S' and 'Pa.602-A'; Minn - 'Minhybrid 4201,' 'Pioneer 3780,' 'Northrup King PX-488' and 'PX-476').

†Phalaris arundinacea L. (Varieties: Penn - not given; Minn - 'Rise,' and 'NCR-C1'; Mass - not given).

‡Bromus inermis Leyss. (Varieties: Alberta - not given; Minn - 'Fox').

§Phleum pratense L. (Variety: Minn - 'Climax').

¶Festuca arundinacea Schreb. (Variety: Minn - 'Kentucky 31').

**Phalaris arundinacea L., Phleum pratense L. (Variety: 'Climax', Bromus inermis Leyss. var 'Lincoln'.

The data show that a narrower range exists for P removal than N removal by crops. P removal ranged from 24 to 44 kg/ha and was not appreciably affected by increases in the application rate of P. Only about 25% of the P in normal wastewater can be taken up by the plant. This means that the remaining 75% of the phosphorus in the wastewater must be removed by soil adsorption and precipitation. Results from studies of existing systems that have been in operation for up to 80 years have shown only trace amounts of phosphorus in the percolate water from properly managed slow infiltration systems. This indicates that the soil can effectively remove phosphorus for many years.

Although not a pollutant, potassium is a required element for crop growth. Most grasses require more potassium than any other element except nitrogen, carbon, hydrogen and oxygen. The latter three are readily available to plants from the air. Concern over potassium limitations at land treatment sites and recommendations to fertilize these sites with potassium have been reported (45,52,54). Since excessive applications of potassium can alter the uptake of other elements by crops (55), discretion should be used when fertilizing. Results from experiments at CRREL have indicated that potassium imbalances were related to the N/K ratio of the wastewater applied (51). They noted that adequate potassium could be determined for the crop if the following equation was used:

$$K_f = 0.9\ U - K_{ww}$$

where:

K_f = the annual amount of potassium fertilizer applied in the spring, kg/ha

U = the estimated annual crop uptake of nitrogen, kg/ha

K_{ww} = the amount of potassium to be applied in the wastewater, kg/ha.

Overland Flow

For many years the overland flow mode of land treatment has been used for treating industrial wastes, especially from canneries. However, the use of this type of system to treat municipal wastewater is just developing (56,57,58). Results from a seven-year study conducted at Ada, Oklahoma, have shown that runoff water obtained from a site receiving raw domestic wastewater is similar to that discharged from advanced wastewater treatment plants (57). In addition, there was little difference in the runoff water quality from sites receiving either primary or secondary preapplication treatment (19).

Experiments at the U.S. Army Corps of Engineers Waterways Experiment Station have shown that, for lagoon effluent, effective treatment for reducing nitrogen at least 80 percent can be achieved at overland flow application rates of 2.54 cm applied over 18 hours during the spring, summer and fall (58). A lower application of 1.27 cm in 18 hours can be used during the winter season. Their data also show phosphorus reductions of 40 to 60 percent. This would mean in many instances that a pre- or post-treatment step for phosphorus removal will be required.

One of the major costs of any land treatment system is a storage facility required to hold wastewater flow during inclement weather. Storage costs are especially significant in the design of land treatment systems in cold climates. Experiments conducted at the CRREL overland flow test facility in Hanover, N.H., last year demonstrated that less storage may be needed than originally estimated. Tests using primary effluent showed that BOD removal could be maintained within secondary effluent standards until mid-December. Treatment efficiency was restored by mid-April, which indicates that approximately 4-5 months of storage was needed. Many northern states require 5 to 8 months of storage. The soil temperature at which BOD removal effectively ceased was 4°C (46).

The performance of the overland flow test facility is shown in Table 5. Both primary and secondary effluents were treated to 5.0 ppm nitrogen through October 1977. The data indicate that ammonium is more effectively removed than nitrate. This information suggests that using a preapplication process which nitrifies, such as extended aeration, could reduce the total nitrogen removal efficiency of the overland flow process.

Phosphorus removal ranged between 80 and 90 percent during the period from May to October 1977. However, phosphorus concentrations in the runoff averaged 2.2 ppm. Fecal coliform counts were high, indicating that disinfection prior to discharge may be required.

Table 5. Average quality of applied wastewater and runoff - May 1977-October 1977, Jenkins et al. (46).

Parameter	Applicant Concentrations		Runoff Concentrations	
	Primary	Secondary	Primary	Secondary
N(T)N (mg/l)	36.6	33.5	5.4 (94%)*	8.0 (87%)
NH_4N (mg/l)	33.1	27.3	3.2	2.6
NO_3N (mg/l)	0.5	5.1	1.6	5.2
P(T)P (mg/l)	6.3	5.9	1.9 (89%)	2.2 (80%)
BOD_5 (mg/l)	85.3	53.2	11.2 (91%)	4.6 (95%)
SS(T) (mg/l)	74.6	30.2	6.7 (97%)	3.8 (96%)
SS(V) (mg/l)	60.7	21.7	5.2	3.2
C(O)C (mg/l)	89.2	57.0	29.0	26.0
Cond (μmhos/cm)	524	519	329	324
pH (pH units)	7.4	7.5	7.7	7.6
Fecal coliform (#/100 ml)	7.9×10^4	1.8×10^4	6.3×10^2	18
K (mg/l)	12.4	11.9		

* numbers in parentheses refer to mass percent removal.

CONCLUSION

Studies throughout the world have shown that land treatment is an effective method of treating municipal wastewater without adversely affecting the environment. However, the complexity of the soil continuum and plant ecosystem makes the design and construction of these systems very site-specific. Once the system has been constructed, proper management and operation will ensure that the product water quality will meet design specifications.

Research conducted by CRREL has focused on the planning, design and management problems associated with land treatment of wastewater. It has been determined that pretreatment is necessary beyond the primary level only if the effluent requires disinfection before discharge.

Research on rapid infiltration has shown that it can be used to treat wastewater throughout the year. Management practices which maintain the soil infiltration capacity are required.

In slow rate systems nitrogen removal by the vegetation is dependent on nitrogen loading rate and plant species. Reed canarygrass can remove 400 kg N/ha per year when the nitrogen loading rate is 600 kg/ha per year, whereas corn alone can remove a maximum of 175 kg N/ha per year.

Data obtained from both slow and rapid infiltration systems have shown that the plant and soil system can effectively remove 90-95% of the applied phosphorus. Of this amount 25% can be removed by plants.

In some cases, the limiting factor for nutrient removal at vegetated land treatment sites may be potassium. The use of a simple equation can provide an estimate of the amount of supplemental potassium that is needed.

In overland flow systems, ammonium is more effectively removed than nitrate. Treatment efficiency in overland flow systems is dependent on soil temperature. Wastewater should not be applied at temperatures below $4^{\circ}C$. Preliminary test results indicate that the storage volumes required by many states for overland flow systems may be overly stringent.

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EFFLUENT IRRIGATION DEVELOPMENTS IN CANADA

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presented

at

Technology Transfer Seminar on
Effluent Irrigation Under Prairie Conditions

January 1979

Canadian experience with the application of liquid wastes to land has been very limited. Climatic conditions, although they do not preclude such land application, cause the acceptability of the method to be severely reduced when compared with many areas of the U.S.A. The severe winter conditions in Central and Eastern Canada impose very basic restrictions on the length of the irrigation season, while the amount of precipitation on the West Coast imposes limitations on the amount of liquid that can be applied per unit land area.

Since regulations that govern the disposal of wastewaters are generally Provincial in nature and scope, the variations in such regulations are often just as important in determining regional acceptance of effluent irrigation as are varying climatic conditions. For example, British Columbia regulations for municipal wastewater stipulate the maximum allowable seasonal application rate as a percentage of the average potential net seasonal evapotranspiration, and as well state the requirements for effluent storage to accommodate the flows during the non-growing season. Such ground rules are directed more toward optimizing the agricultural use of the water than to disposing of waste, and hence the overall unit costs of wastewater disposal tend to rise dramatically in areas where a short growing season or wet climate prevails. If Provincial regulations allow application rates substantially in excess of evapotranspiration needs, the cost of land disposal is more easily kept competitive with conventional water disposal.

Present Usage of Irrigation Disposal

The accompanying table lists available data on the amount of wastewater being irrigated in Ontario and the three western provinces. It is quite probable that the totals for each listed Province probably have some inherent errors; however, the

EFFLUENT IRRIGATION DATA

	Domestic & Municipal Effluent			Industrial Effluent		
	No. of Systems	Annual Volume (mil.gal)	Irrigated Area (acres)	No. of Systems	Annual Volume (mil.gal)	Irrigated Area (acres)
ONTARIO	6	34	288	60	950	2400
SASKATCHEWAN	6	400	880	1	7	180
ALBERTA	12	765	1500	11	692	2750
BRITISH COLUMBIA	3	1300	1800	12	153	150

relative annual flows and irrigated areas are considered quite valid.

Some obvious trends appear in the tabulated data. The perceived usefulness of irrigation disposal in Ontario is essentially limited to industrial waste dischargers, and a large proportion of that industrial wastewater irrigation arises from food processing industries. The two Prairie Provinces for which data is shown are much more inclined toward irrigation disposal of municipal wastes than is Ontario. However, the sizes of the communities involved are generally very small; the one exception being Swift Current with a connected population of about 14,000. Disposal of industrial wastes by irrigation in Alberta is practised to about the same extent as in Ontario, but fertilizer plants and gas processing plants are the most prevalent users of this disposal method in the western province. Saskatchewan has developed very limited land application of industrial wastes, with such disposal being essentially restricted to agricultural wastes.

British Columbia's experience is restricted to three community systems and a handful of small food processing plants; however, as can be seen from the Table, the municipal systems are substantial, with the two larger being Vernon (population 20,000), and Cranbrook (population 15,000).

Design Differences Across Western Canada

The temperature, precipitation, and geographic characteristics of a given region have a direct influence on the process design and the operation of an effluent spray irrigation system. It should not seem unusual, therefore, if systems in Ontario, the Prairies, and British Columbia are somewhat different in acceptability, concept, and operation.

Ontario is blessed with a fairly short growing season (with the Niagara Peninsula being somewhat of an exception), and due to the precipitation which occurs during that short season, the need for extra water to enhance crops is not great. One would expect, therefore, that the acreage required to dispose of a given daily flow from a municipality would be relatively high when compared with a dry area with a long growing season. It is not surprising that the data in the accompanying table shows a high ratio of irrigated area to total annual volume of domestic effluent. If this ratio is indicative of Ontario needs, the economics of spray irrigation of municipal effluents would not be generally favourable.

The greater acceptability of land disposal for industrial wastes in Ontario is understandable when one considers the nature of the industries involved. Most of them are food processors, and as such are either seasonal in nature, and hence do not require overwinter storage of effluent, or the effluent is low volume high strength with the land requirement therefore representing a small cost per unit of productivity.

In the Prairie region the situation is somewhat different in that precipitation during the growing season is not as plentiful as in Ontario, and the relative humidity is lower. Systems can therefore be designed to accept more irrigation liquid per unit area each year. Such a concept is indicated in the municipal data shown in the Table, where the area provided per unit of annual waste discharge is considerably lower than the Ontario experience.

The British Columbia experience is somewhat unique, in that all of the land application systems for municipal wastes are located in a very dry part of the province, having substantially less than 10 inches of precipitation during the growing season.

Additionally, the growing season is somewhat longer than that experienced in the Prairie Provinces. Data shown in the Table reflects these conditions in that less land is indicated to be required for disposal of a given volume of wastewater.

Physical geography affects the economic viability of effluent irrigation schemes by influencing factors such as pumping costs, over-winter storage costs, and type of irrigation equipment that is usable. Generally speaking, these factors seem to have a more negative influence in British Columbia than in the flatter regions in Canada.

At the present time, the range of acceptable crops for land irrigated with effluent is uniformly narrow across Western Canada. Animal forage crops are grown on most of the land so irrigated, with limited cereal oil crops and experimental crops for potential human consumption occupying some sites.

Developing Trends in Effluent Irrigation

It is apparent that interest in effluent irrigation is strong in Western Canada. Nearly all of the municipal system that use this method of disposal have to be developed since about 1974. The continuation of this trend is essentially inevitable for two very good reasons:

1) the discharge of wastes to water bodies has begun to cause unacceptable quality changes in many parts of Western Canada - even when fairly sophisticated pre-treatment is provided;

2) the high-concentration impurities in most wastewaters (i.e., C, N, P) are beneficial to the fertility of many soils. In addition, the water itself is often capable of improving crop yields.

These two stated reasons for considering land disposal of effluent do much to convert our thinking on wastewater management from a position of "effluent disposal" to one of "resource utilization".

One must be careful, however, not to look upon this new-found management tool as a panacea for our waste disposal needs in Western Canada. There are still going to be many situations where this method is either technically or economically unsound. It would appear that the Prairie Provinces have a higher potential for widespread use of this technique than either British Columbia or Ontario - amenable land is generally available close to communities, the topography is such that high pumping costs are not a major factor in the overall economics, and over-winter storage facilities can be readily constructed.

By comparison, the British Columbia situation appears to be fairly restrictive with regard to the acceptability of irrigation disposal of effluent. In a large portion of the Province, topography mitigates against such systems because of pumping costs required to reach available land for irrigation and storage, while other areas have precipitation patterns that make the practice of irrigation itself unnecessary, and even inadvisable.

Probably one of the main research thrusts that needs to be pursued involves the evolution of standards of operation that will allow a wider range of crops to be planted in effluent irrigation plots. Without the availability of markets for the crops being produced, the practicability of the resource utilization concept collapses, and there is no longer the same compelling reason to practice land disposal instead of water disposal of effluent.

LAND APPLICATION OF MUNICIPAL WASTEWATER IN ALBERTA

INTRODUCTION

The proper treatment and disposal of municipal wastewaters is an integral part of the Province of Alberta's overall environmental protection program. Provincial standards for municipal wastewater treatment and disposal are based on a number of considerations which include:

1) current municipal wastewater treatment and disposal technology;
2) the cost of treating and disposing of municipal wastewaters; and
3) the sensitivity and uses of the receiving environment.

In general, there are a number of municipal wastewater treatment methods, primarily biological, which are capable of producing effluents which meet the quality criteria established by the Province. Ultimate disposal of treated effluents is primarily to surface receiving waters.

Biological treatment processes employed to treat municipal wastewaters, evolved, in part, from sewage farms. The application of municipal wastewaters to farmland provided an inexpensive disposal method combined with the benefit of crop irrigation and soil enrichment. Scarcity of land, increased wastewater volumes and costs led to the development of wastewater treatment plants which replaced sewage farms.

With public and government emphasis being placed on reuse and productive utilization of hitherto wastes and with the increased concern regarding nutrient addition to surface water, land treatment and disposal of municipal wastewaters is again receiving attention as a method of wastewater treatment and disposal.

The purpose of this document is to provide some guidelines which should be used if land treatment and disposal of municipal wastewaters is being considered. It is the position of the Standards and Approvals Division that where land treatment and disposal of municipal wastewaters is practicable, land application should be evaluated as a treatment and disposal alternative.

The environmental approval procedure for land application systems will be the same as for conventional municipal wastewater treatment systems. A Permit to Construct and Licence to Operate will be required for each system. The Municipal Engineering Branch, Standards and Approvals Division should be contacted at the conceptual stage of a project to ensure that all necessary approvals are obtained.

TECHNICAL AND SOCIAL CONSIDERATIONS

Land application as a method of treating and disposing of wastewaters entails the use of the soil, the covering vegetation and the soil matrix. Land application systems may also be used to produce a renovated water which can be collected for discharge to surface waters. The use of land application as a method of treating wastewater can increase the productivity of land through the addition of moisture and nutrients.

A concern regarding land application as a method of wastewater treatment is the possible harmful effects of certain wastewater contaminants on vegetation, soils, surface waters and groundwaters. To avoid adverse environmental impacts, many factors such as soil and crop characteristics

and wastewater makeup must be considered in designing a land application system. Consequently, a land application system for treating municipal wastewater must be specifically designed for a selected site. The detailed design for one site cannot normally be used at another location.

A multidisciplinary approach to defining and evaluating land application alternatives is required. The main technical areas to be considered by a proponent when investigating land application are: hydrogeology; soils science; agronomy; and engineering. Other disciplines that may also be relevant, depending on the method and place of application are: public health; toxicology; environmental planning; regional planning; hydrology; soils microbiology; soils physics; plant pathology; irrigation engineering; farm management; and agricultural economics.

The use of land for the application of municipal wastewaters can have major social ramifications, especially when land requirements are large. Public involvement in land application projects is therefore usually necessary. It is the responsibility of the proponent to ensure that the necessary steps are undertaken to assure public acceptance of the land application system.

METHODS

Land application of wastewater generally involves either irrigation, high rate irrigation, or infiltration-percolation.

IRRIGATION is a suitable disposal alternative in regions where additional mositure is required for optimum crop production. Application rates are based on the net consumptive use of the crop taking into account moisture deficiencies, application efficiencies as well as leaching requirements. The objective of wastewater irrigation is the maximization of crop production as well as the treatment and disposal of that wastewater.

HIGH RATE IRRIGATION is primarily a method of effluent treatment and disposal but with the side benefit of increasing crop production. In high rate irrigation, loading rates are higher than for the irrigaton process and much of the water percolates below the root zone. The potential negative impact on vegetation, soil and groundwater is greater than for the irrigation process.

In the INFILTRATION-PERCOLATION process, wastewater is applied at high rates for several days to weeks and allowed to infiltrate and percolate into the soil. A rest period is then required for the infiltration and treatment capacity of the soil to be restored. The infiltration-percolation process can be used for wastewater treatment when soil and geologic conditions provide rapid infiltration and high permeability. This process may have a deleterious effect on both groundwater and surrounding surface water.

The irrigation process has the highest potential of the three land application systems for removal of most wastewater contaminants. Because of the lower loading rates, the irrigation process involves the largest land area. As a result, adverse impacts on the soil groundwater and vegetation are minimized.

GUIDELINES FOR DESIGN

Land application is, by nature, site specific because of the wide range of design possibilities that are available. However, in considering design possibilities, the following guidelines should be followed:

1) IRRIGATION

a) Primary treatment and storage ponds shall be provided unless otherwise specified. Primary treatment is considered as a level of treatment rather than a specific treatment process. The criteria for primary treatment is outlined in Table 1.

TABLE 1

CRITERIA FOR PRIMARY TREATMENT

(including anaerobic lagoons)

Parameter	% Removal	Effluent Value
1. BOD (5-day at 20 degrees C)	25-45	100-150 mg/l
2. Coliform Bacteria	40-60	$25X10^6$ /100 ml
3. Suspended Solids	35-65	100-150 mg/l

b) Application rates and land area requirements will depend on crop uptake of moisture or nutrients, the controlling factor shall govern. Adequate buffer areas shall be included in land area requirements.

c) The area to be used for irrigation and the storage ponds shall be sufficiently large such that effluent discharge will not be necessary:

i) outside the growing season (except for fall irrigation);

ii) during and for at least 7 days prior to the harvesting of crops;

iii) during and for 30 days prior to grazing by dairy cattle;

iv) during and for 7 days prior to pasturing by livestock other than dairy cattle.

d) Spray or flood irrigation methods may be considered.

e) Crops deemed acceptable for irrigationinclude forage crops, coarse grains, turf and oil seed crops, and timber stands.

f) Disinfection of wastewater prior to land application will be required where warranted by public health concerns, e.g., golf courses, parks, etc.

g) A higher level of wastewater treatment shall be provided when the municipality does not own or control the land which is to be irrigated. The level of treatment required will be as per Alberta Environment's "Recommended Standards for Water Supply and Sewerage" and shall be consistent with the water quality requirements for the receiving water.

2) HIGH RATE IRRIGATION

a) Guidelines a) to f) inclusive for the irrigation process apply to the high rate irrigation process.

b) The municipality must own or control the land to be irrigated.

c) Detailed site, groundwater, and soil evaluations are necessary.

d) All tailwater runoff is to be collected and returned to the headworks.

e) Subsurface drains may be required.

3) INFILTRATION-PERCOLATION

a) Properly designed infiltration-percolation systems will be considered as a complete treatment and disposal process.

b) A minimum of two wastewater holding basins are required to provide storage during the rest period and to allow for periodic basin maintenance.

c) Detailed multidisciplinary investigations are required and shall include, but are not limited to, the following areas: hydrology; hydrogeology; subsurface; topography; climate; etc.

d) Subsurface groundwater flow must be well defined if this process is to be considered.

e) Subsurface drains may be required.

FINANCIAL ASSISTANCE

Where land application is an economical method of sewage treatment, it will be given full consideration under the Alberta Municipal Sewage Treatment Assistance Program. However, any other financial assistance for irrigation will be evaluated on it's own merit by the Department, considering fiscal limitations, environmental benefits, and the application of best practical technology. A preliminary investigation is necessary to show that the scheme has merit. The findings must be submitted to the Department and approved before any detailed investigations are undertaken.

NOTE

This policy paper is a draft document. It is expected that the final policy document will be published and promulgated in April of 1979.

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SEWAGE-EFFLUENT IRRIGATION
SASKATCHEWAN'S REGULATORY APPROACH

Through The Water Resources Management Act, 1972, the Minister of Environment has the general supervision, control and regulation of all matters concerning waterworks, sewage works, water quality and its impairment by pollution. Further, the Act provides that no person shall construct or operate a waterworks or sewage works unless an approval is given and these approvals can be subject to terms and conditions.

Applicable regulations are the Water Pollution Control Regulations (88/68) which define exempted works, approval requirements and certain design and operating considerations. In general works requiring approvals include municipalities, industries not discharging to municipal systems, government facilities and private operations having greater than 4000 gallons/day sewage flow. Neither the Act nor the regulations specifically refer to effluent irrigation. However, control is exercised through the issuance of approvals to construct works and to operate.

The Department considers the use of suitably-treated sewage effluents for crop irrigation an acceptable and sometimes desirable practice, provided the operation is designed and operated to avoid public health and other environmental problems.

While providing recycling of our valuable water resource, effluents are an inexpensive water source, contain useful plant nutrients, and normally will increase crop yields.

Effluent irrigation is generally considered for one or more of the following:

a) to avoid effluent dishcarge across privately-owned lands or into intermittent watercourses;

b) as an alternative to nutrient or phorphorus removal, where required;

c) as an alternative to exceptionally-high treatment requirements; and

d) to provide a water supply to a nearby owner for irrigation purposes.

In co-operation with Saskatchewan Agriculture, Conservation and Land Improvement, which provides soils and irrigation practice advice, Sewage Effluent Irrigation Guidelines was published in 1976 as a supplement to the Environment's Sewage Works Design Criteria. The purpose of the supplement was to acquaint prospective designers and users with design and operating guidelines, approval requirements and available assistance.

Although construction approval is required only where the owner of a sewage works owns the land and/or the irrigation equipment, approvals to operate issued to the owner of the sewage works cover the operation of effluent irrigation irrespective of who owns or operates that portion of the works.

Currently, the following policy/guidelines are used when assessing an effluent irrigation proposal:

a) Effluents should receive an equivalent of a secondary degree of treatment. Secondary cells of facultative lagoons are considered suitable for irrigation purposes.

b) Effluent irrigation can be used for forage production, tree nurseries or other applications where low public health risk is involved.

c) Adequate preliminary studies on ground water table and quality, soil chemistry and characterics, and effluent quality to ensure that minimum adverse effects occur.

d) Sites should avoid spray drift on roads, recreational areas and private lands and generally should be at least 300 feet from habitation or wells.

e) Appropriate agreements are required between owners of the sewage treatment facility and the irrigated land. Provision should be made for liability, use restrictions, monitoring and conformance to operating requirements.

f) For very large projects, an environmental impact assessment would be required.

The operator of the sewage works is responsible to ensure that the irrigation system is being operated in accordance with good irrigation practice to restrict runoff and protect the soil. Additionally, the operator is generally required to construct monitoring wells, monitor water levels and water quality in the wells, collect and analyze soil samples for salt, nutrient and trace element levels, obtain effluent quality analysis and maintain records respecting crops, yields, irrigation volumes and application rates.

In Saskatchewan, engineering and technical assistance for implementing irrigation systems has been available from Saskatchewan Agriculture. To date, this has included all preliminary evaluations, design, operating recommendations, monitor well installations, as well as sample collection and analyses.

Most effluent irrigation systems in the province are operated by private land owners. In most cases, 10-year agreements have been made between the owner of the sewage works and the irrigators. Irrigation equipment is usually owned by the landowner. The headworks of the system are normally owned by the community.

Financial assistance for effluent irrigation is available from Saskatchewan

Agriculture under their assistance policy for irrigation development, under the provincial Municipal Water Assistance Act, the provincial Water Pollution Control Assistance Act and under the Qu'Appelle Implementation Agreement.

It is recognized that as experience and knowledge accumulates, modifications and/or improvements to controls will be necessary. The use of easily amended guidelines and the case-by-case approval approach permits revisions and amendments to reflect current concerns and state-of-the-art.

R. A. McDonald, Director
Water Pollution Control Branch
Saskatchewan Environment
January, 1979

EFFLUENT IRRIGATION - REGULATORY APPROACH IN MANITOBA

At the outset of my presentation today, I would like to take this opportunity to thank those agencies responsible for organizing this technology transfer seminar and those persons who have devoted many hours to ensuring that all runs smoothly.

The subject matter is, of course, very topical and of very much interest to us, as the control agency in the Province of Manitoba, particularly since the traditional method of disposing of treated effluent into surface water courses is being questioned more and more by the concerned public. Perhaps if time permits, examples can be given later to illustrate this concern.

With respect to regulatory control, the operational tool in the Province of Manitoba is the Clean Environment Act promulgated in 1968 and since revised a number of times, as recently as 1977. The Act states,

> "No person, directly or indirectly, shall cause, suffer or permit the contamination of air in excess of prescribed limits."
>
> "No person, either directly or indirectly, shall cause, suffer or permit the contamination of water in excess of prescribed limits."
>
> and,
>
> "No person, either directly or indirectly, shall cause, suffer or permit the contamination of soil in excess of prescribed limits."

The key phrase in these prohibitive clauses, of course, is "in excess of prescribed limits". The Act then goes on to detail how the limits may be prescribed -- said limits can be prescribed either in a regulation filed under the Act or in a Clean Environment Commission Order issued pursuant to the Act. We are all, I'm certain, familiar with the mechanics of filing regulations, however, it is worthy of note that all draft regulations developed by the Environmental Management Division are fully circulated for comment prior to finalization. Said circulation includes all provincial government departments, all municipal offices, consultants and, of course, any affected industry, trade associations, etc. Every effort is made to incorporate recorded concerns into the final regulation. By way of example, the Prairie Petroleum Association had a major input into the final edition of our "Storage and Handling of Gasoline and Associated Products" regulation which was designed to prevent contamination of groundwater with gasoline. We have not, as yet, considered the possibility of developing a regulation prescribing limits for the discharge of sewage effluent to soil.

The second method of prescribing regulatory limits on effluent discharges to soil is, as previously mentioned, by Clean Environment Commission Order. The Clean Environment Commission is a quasi-judicial body appointed by the Lieutenant-Governor-in-Council, pursuant to the provisions of the Clean Environment Act. Said Commission has a chairman, who is a full time civil servant, plus a number of citizen appointees, currently a farmer, two pharmacists and two university professors. For an explanation of how the Clean Environment Commission proceeds to prescribe limits, I refer you to the flow chart attached hereto, as Appendix "A".

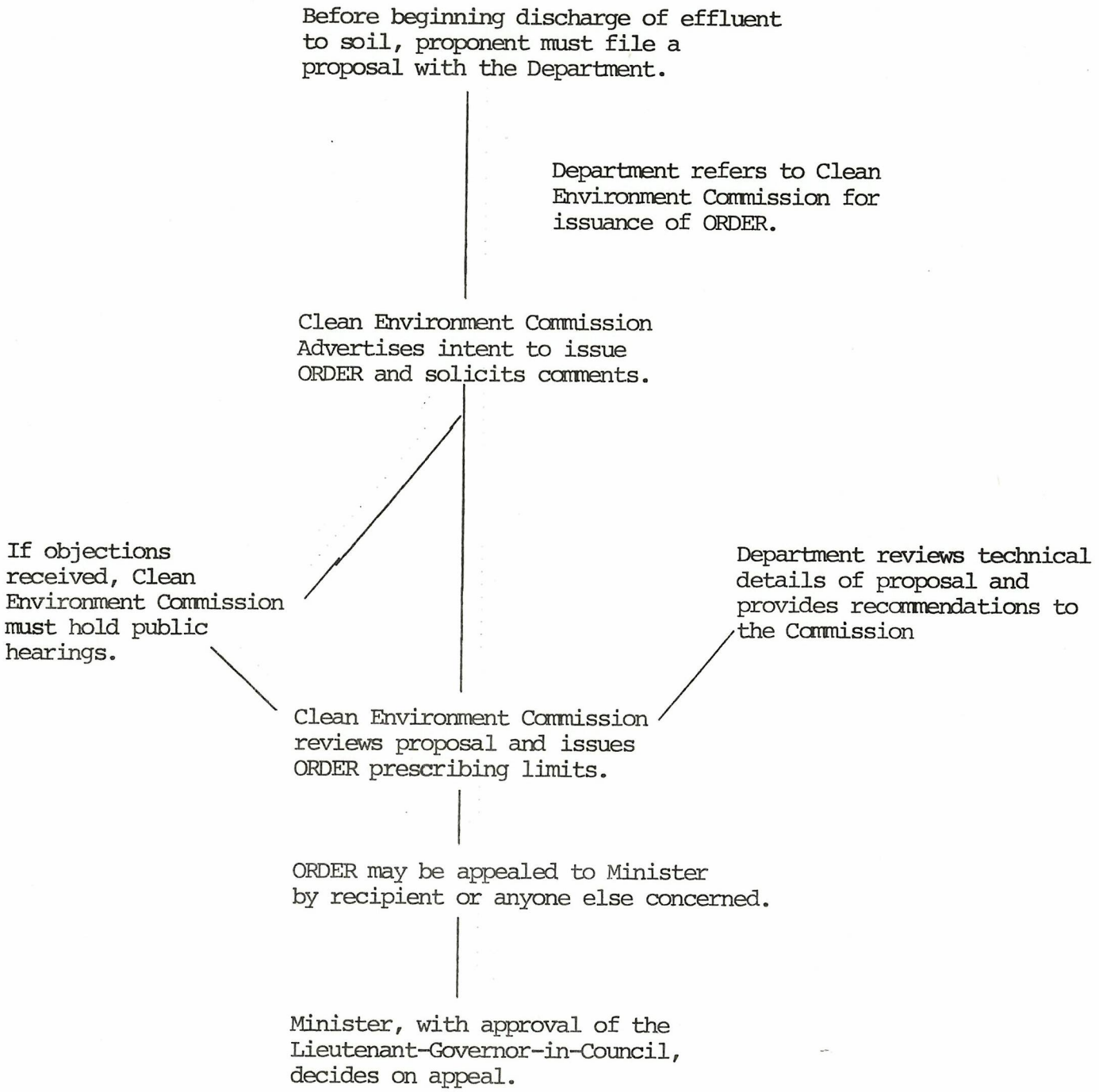
Current Situations in Manitoba

At the present time, there are no discharges of effluent from municipal treatment systems onto the land. All discharges continue to go to surface water courses. We had received two proposals, wherein the effluent was to be utilized to irrigate golf courses, however, in both cases the proposals were withdrawn for reasons of economics and practicality and the discharges were routed to surface waters. We are currently in the throes of dealing with an appeal where municipal effluent was permitted to be discharged into a rather sensitive recreational water course and those persons who are appealing are convinced that the discharge should be onto land. However, the municipal corporation has not been able to locate nearby landowners who will accept the effluent.

There are, of course, a couple of industrial operations disposing of wastes into soil and, as well, the City of Winnipeg disposes of sludge from its treatment facility on land north of the City, much to the consternation of adjacent residents.

C. Orcutt
Chief, Environmental Control Program
Department of Mines, Resources and
Environment, Manitoba

Appendix "A"


Before beginning discharge of effluent to soil, proponent must file a proposal with the Department.
Department refers to Clean Environment Commission for issuance of ORDER.
Clean Environment Commission Advertises intent to issue ORDER and solicits comments.
If objections received, Clean Environment Commission must hold public hearings.
Department reviews technical details of proposal and provides recommendations to the Commission
Clean Environment Commission reviews proposal and issues ORDER prescribing limits.
ORDER may be appealed to Minister by recipient or anyone else concerned.
Minister, with approval of the Lieutenant-Governor-in-Council, decides on appeal.

PUBLIC HEALTH CONCERNS FOR EFFLUENT IRRIGATION

Are there legitimate and real concerns about the risks to individuals posed by effluent irrigation. The answer must be an unequivocal yes. It is hoped that the proceedings of the conference will assist in delineating these risks and presenting solutions. I wish to concentrate on the risks and allow others to present the solutions.

The disposal of man's wastes on the land is an ancient practice. Nightsoil has been carefully collected and applied to the soil for the growing of crops in many areas of the world at one time or another. This practice was and is accompanied by the perennial transmission of parasitic diseases to man and animals. In Israel recently, the inadvertent irrigation of vegetable crops with raw wastewater resulted in 200 people developing cholera.

This centuries old association of man and his wastes has faciliated the adaptation of a wide varietv of parasites to the oral-fecal route of transmission. Viruses, bacteria, protozoa and metazoa all utilize this route. Two of the more notable examples are Polioviruses and Salmonella typhi. Typhoid fever plagues areas of poor sewage control, polio areas of good sewage control.

In order to illustrate some of these concerns, a study was carried out on the risk of communicable diseases associated with wastewater irrigation. Cases of disease which are considered to be waterbourne from kibbutzim using wastewater irrigation were compared with kibbutzim not using this method. In the summer, cases of dysentery, salmonellosis, infectious hepatitis, typhoid fever and influenza-like illness were all higher in wastewater irrigation areas. In winter when irrigation did not take place, there were no differences. The conclusion was made that these illnesses were related to effluent irrigation.

This situation is not directly applicable to the prairie situation however, as the retention time of these nondisinfected oxidation pond effluents was only three to seven days. In Saskatchewan, effluent is placed in cells capable of receiving 210-230 days flow. However, these dry hot sunny weather conditions are somewhat comparable.

Remembering that conditions here are not necessarily comparable to other areas, the health risks to the farmer, the consumer and the bystander are not really known. There are no good studies of human health risks comparable to the Israeli experience to quote. Therefore, most of the concerns and their solutions are conjectural until such studies are done.

The farmer is at greatest risk in effluent irrigation as he will be in most direct contact with water and irrigated areas. Most protozoal cysts or tapeworm eggs would spread via the ingestion of contaminated, uncooked fruits and vegetables. By restricting irrigation to exclude such crops, this risk would be less. However, there would be a risk of transmission when pipes were being handled or if this water was inadvertently used for drinking in a field. The cysts and eggs do not tolerate freezing or drying well, but may survive in storage areas if they did not completely freeze and would survive for some time after irrigation. Nevertheless, with very minimal precautions there would not likely be a problem. If the farmers handling the delivery systems were careful to wash their hands and other contaminated areas after each operation, the risk of oral fecal spread of most bacteria would also be low. Most pathogenic bacteria do not survive well under storage conditions. However, some bacteria will survive all but the most rigorous treatment. The number may well be too low to constitute an infective dose in most instances. A note

of caution about sampling problems must also be mounted. The reductions noted in some of the Salmonella may be due to dilution factors. Under some conditions an infective dose may become available.

As well as concern about contamination while handling equipment, there is concern about aerosols generated by spraying. Viruses have been demonstrated several meters downwind. With the size of prairie farms, however, several meters is not likely to be significant either. It must be noted however, that infective doses via the aerosol route are frequently much less than via the oral route.

The consumer is probably the least at risk from microbiological hazards from effluent irrigation as fruits and vegetables normally eaten raw will not be irrigated using this water. Errors have occurred in the past however, and with the increase in market gardens, continuing surveillance will be necessary.

To summarize the microbiological risks, the use of lagoons for long periods of time greatly decreases any risks present. However, there is the potential for infections particularly if there is a system malfunction. There are no immunizations which will offer any substantive protection at this time.

There are other public health concerns however. The potential contamination of agricultural land and crops due to chemicals is a potential threat. When heavy metals are present in small amounts, they are not harmful and in fact are necessary trace elements. However, with higher concentrations they could exert a direct toxic effect or be passed up the food chain to man. Several other classes of compounds are of concern, a recent suitable example being P.C.B.'s. If these had been discharged into sewage and then onto the land the

effects could have been disastrous as they would be concentrated in cow's milk and affect many people, notably babies.

Nitrates have long been a problem in Saskatchewan. Putting more nitrate-rich fluid on the land could increase the levels found in well water. Although the drinking water standard for nitrates is 10 mgm/l, levels up to 40 mgm/l are considered safe for babies, there having been no cases reported in Saskatchewan with nitrate levels below 90. Breastfeeding is the safest course, but the nitrate level is not expected to be a problem.

Sewage control has been one of the major advances in public health in the 1800's and 1900's. Properly applied, effluent irrigation should not increase the risk of sewage borne diseases and may well reduce it even further. However, ongoing studies of areas using this method will be the only method of determining the ultimate safety to farmer, neighbor and consumer.

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January 17, 1979

Seminar on effluent irrigation under prairie conditions

HEALTH CONCERNS - RISKS TO LIVESTOCK

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INTRODUCTION

Livestock that eat plant material from land irrigated with effluent may be at risk from two components of the effluent: infectious micro-organisms, the subject of this presentation, and toxic chemicals.

Of the many species of bacterium, virus and parasite that may be present in effluent, only a few are capable of infecting and of causing significant disease in animals. The occurrence of these pathogenic organisms, some of which are zoonotic (transmissible between animals and man) in the untreated sewage from a community will depend in part on their prevalence in the human and animal populations contributing to that sewage; their occurrence in the effluents from sewage treatment plants will depend on the efficiency of the treatment procedures used and their occurrence on the irrigated plant material will depend on the organisms' ability to survive the techniques used for effluent distribution and on environmental factors such as climate and plant structure. There is little information on the survival of pathogenic organisms in crops harvested from irrigated pastures.

In general, there is a great reduction in the numbers of infectious organisms present in sewage as it progresses from the raw state to the irrigated pasture. It is known, however, that some important bacteria and parasite eggs will survive in significant numbers and will therefore be a potential threat to animal health.

THE IMPORTANT ORGANISMS

The organisms of greatest potential importance are the bacterium Salmonella, the rotaviruses and the helminth parasite Taenia saginata. All these may be transmitted from man to animals; in the case of T. saginata, the

"beef tapeworm" of man, infection of cattle is essential for the continuation of the parasite's life cycle. Both Salmonella and T. saginata may be returned from animals to man following the ingestion of meat or milk from infected livestock.

Salmonella

Salmonella may find their way into sewage from human or animal sources. In Canada, human salmonellosis is seen as a continuing problem (for instance, 22 outbreaks affecting 620 people in 1974[1]) and there are many symptomless human carriers. In livestock in this country, with the exception of poultry, the organism is recognized relatively rarely. Salmonella will survive several of the commonly used sewage treatment procedures (activated sludge, settlement tanks with biological filters[2]) and may multiply in the effluent[3]. In other countries, isolated outbreaks of salmonellosis have occurred in cattle associated with access to rivers contaminated with treated sewage containing Salmonella of human origin[4,5] and the organism has been recovered from waterways containing treated effluent from poultry processing plants[6]. If the Salmonella survives through to the pasture, its persistence there will vary with environmental conditions; it has been reported that in the prairies in summer, two days of bright sunlight will render pasture "safe" for cattle[7]; elsewhere, however, longer survival has been reported[8,9] but often in numbers insufficient to cause infection in grazing animals. Information on this survival time will help decide the best interval between irrigation and grazing. It seems unlikely that the organism would survive harvesting and storage or processing of the pasture crop. Transmission of Salmonella to livestock via effluent irrigation has not yet been reported in Canada, but there is a slight risk of occasional problems.

Other bacteria

Another enteric bacterium, Escherichia coli, is much more common in man and animals than is Salmonella, but there is presently little information on its significance as a zoonosis or the possibilities of its transmission via effluent irrigation.

Mycobacterium tuberculosis, when present in sewage, would probably survive the treatment and distribution procedures and therefore pose a threat to livestock feeding from effluent-irrigated pastures. In Canada, however, the infection is generally extremely rare in the human population and thus the risk to animals associated with this route of transmission is probably negligible.

Rotaviruses

The rotaviruses infect man and a wide range of livestock, often causing significant enteric disease, particularly among children and young animals. Under experimental conditions, rotaviruses of human origin have infected pigs, calves and lambs[10]. Although it is known that other viruses that infect humans, but not animals, may survive sewage treatment[11], there is no information for rotaviruses. In this country their transmission to livestock via effluent irrigation should be considered a slight and unproven risk.

Taenia saginata (beef tapeworm)

Eggs of the tapeworm parasite *Taenia saginata*, present in the faeces of infected people, are known to be very resistant to environmental conditions and will survive many of the commonly used sewage treatment procedures[12]. The parasite's larval stage, *Cysticercus bovis*, in cattle, is an important problem because infected carcasses must be frozen before consumption and this reduces their value. Infection with the adult tapeworm is rare in the human population of Canada, except among immigrants newly arrived from areas of the world where the infection is common. Recently, however, there have been outbreaks of bovine cysticercosis in Canada[13] and the United States[14], associated with promiscuous defaecation by *T. saginata*-infected feelot attendants and in England associated with grazing cattle on effluent-irrigated pastures[15].

Despite these incidents, this infection is only a slight risk to cattle on the Canadian prairies grazing effluent-irrigated pastures.

SUMMARY

In the Canadian prairies, the human population is relatively free from zoonotic infections, sewage treatment is relatively advanced and the climate is generally unfavourable for pathogenic micro-organisms. For these reasons, disease in livestock associated with effluent irrigation is unlikely to be a significant problem unless there are major changes in these characteristics of our area of the country.

Experience elsewhere in the developed world suggests that outbreaks of effluent-associated livestock disease will generally be isolated and will probably result from "unusual" circumstances.

With regard to prevention, it is important to gather and put to use information on the survival capability of the potentially dangerous organisms during the local sewage treatment and distribution procedures and on the pastures to be used for animal feed.

In summary, we in the prairies should be well aware of the risks to livestock associated with effluent irrigation but we should not be excessively concerned, at least at present.

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DISPERSAL OF SEWAGE MICROORGANISMS DURING SPRAY IRRIGATION AND RESPONSE OF SOIL MICROFLORA TO EFFLUENT APPLICATION

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Swift Current, Saskatchewan and Lethbridge, Alberta.

1. INTRODUCTION

In the semiarid areas of Western Canada, cities and town have become increasingly interested in crop irrigation with sewage effluent as an ecologically and environmentally more meaningful method for disposal of wastewaters. In Saskatchewan, six communites are already recycling liquid wastes through agriculture and another seven communities are currently planning and preparing for effluent irrigation. Results from studies with forage crops at Vernon, B.C. (Oldham, 1974), Taber, Alberta (Bole and Bell, 1978) and Swift Current, Saskatchewan (Biederbeck, 1978) have indicated marked yield increases and gradual soil enrichment with valuable plant nutrients as a result of effluent irrigation.

However, no matter how agronomically beneficial effluent irrigation may be, this type of wastewater recycling can only gain governmental approval and broad public acceptance if potential health hazards for man and animals due to enteropathogens are minimized. Although numerous diseases may be transmitted through sewage, relatively few are of significance in Western Canada. According to recent reports (B.C. Pollution Control Branch 1975) the incidences of typhoid and paratyphoid fever, cholera and poliomyelitis are very low. Furthermore, tuberculosis has already been eradicated from Canadian dairy cattle. Of primary concern are the causative agents of salmonellosis and shigellosis which are frequently present in raw sewage. Fecal indicator bacteria, particularly fecal coliforms, have similar survival characteristics as salmonellae (McFeters et. al., 1974), the predominant group of enteropathogens in sewage. They can therefore be used to monitor and assess the dispersal and survival of potentially pathogenic bacteria during sewage treatment and crop irrigation with effluent.

In 1973, microbiological studies were initiated at Swift Current, Saskatchewan and at Taber, Alberta in support of irrigation of forages with sewage

effluent. In addition to monitoring sanitary levels in irrigation liquids and on irrigated crops it was also deemed necessary, with regard to groundwater quality and soil fertility, to assess microbiological changes in the irrigated soil. Consequently, the objectives of our microbiological studies were:

1. To monitor pathogens and principal bacterial indicators in lagoon effluents;
2. To determine bacterial population changes during effluent pumping and spraying;
3. To determine the survival characteristics of fecal coliform bacteria on irrigated forage plants;
4. To assess the quantity, distribution and survival rate of coliform bacteria in irrigated soils; and
5. To determine the effects of effluent irrigation on the indigenous soil microflora.

2. EXPERIMENTAL SITES AND METHODS

Swift Current - The 6 ha site, located northeast of the city, is a high well-drained area with clay loams of the Birsay association, Chernozemic Brown great group, underlain by glacial till. The test area was seeded in 1973 to Roamer alfalfa and provides for three different treatments: irrigation with sewage effluent, irrigation with creek water and a dryland check strip. Non-chlorinated effluent from an aerobic secondary lagoon of the city's sewage system is sprayed onto the forage with a 335-m side-roll wheel-move sprinkler system.

Taber - Forage plots (150-m^2 each) with alfalfa and with several grass species were established in 1971 on reasonably level land near the town lagoons which are located north of the Oldman River. The soil is a Cavendish loamy sand,

Chernozemic Brown great group, underlain by a relatively impermeable subsoil. The plots are irrigated with a solid-set system with nonchlorinated effluent from an aerobic secondary lagoon.

Analytical Methods - Analyses for bacterial pathogens in effluent at Swift Current were conducted by the provincial Public Health Laboratory in Regina. Salmonella sp. in the effluent at Taber were estimated using the Moore's swab technique and enrichment culture as described by Bell (1976). Coliforms at Taber and coliforms and fecal streptococci at Swift Current in liquid and soil samples were enumerated by most probable number (MPN) methods using multiple-tube fermentation techniques with increasingly selective broths for the presumptive and confirmed tests, according to standard methods (American Public Health Association, 1971). Initially, a small number of randomly selected coliforms from the confirmed tests were subjected to the complete test by subculture on eosine methylene blue agar and by Gram stain and microscopic examination to check that they were gram negative bacilli. Numbers of viable bacteria and actinomycetes in soil samples were determined by spread-plating, in quintuplate, appropriate soil dilutions onto pre-poured soil extract agar and subsequent incubation for 14 days at 20C. Viable fungi were enumerated by soil dilution plating onto rose bengal streptomycin agar and incubation for 6 days at 20 C prior to colony counting.

3. POPULATION DYNAMICS OF FECAL INDICATOR BACTERIA AND BACTERIOLOGICAL QUALITY OF LAGOON EFFLUENTS.

At Taber, unidentified Salmonella species were repeatedly detected by Bell (1976) in the lagoon effluent and MPN counts indicated a season mean population of about 13 salmonellas per 100 ml. Thus forage irrigation with this effluent could pose a slight hazard of salmonellosis to livestock consuming that forage.

However, it is pertinent that the salmonella population in the Taber lagoon effluent was numerically only equal to 0.1% of the fecal coliform population and that the infective dose for salmonellosis is reported to be very high, i.e. $> 10^6$ (Taylor and Burrows, 1971).

At Swift Current, effluent from the secondary lagoon was repeatedly sampled during 1973 and analyzed for presence of three groups of enteropathogenic bacteria viz. Salmonella sp., Shigella sp. and Staphylococcus sp. All analyses were consistently negative. The effluent was therefore judged to be safe for crop irrigation and for handling of irrigation equipment by field staff.

Populations of nonpathogenic fecal indicator bacteria in lagoon effluents can vary very widely between different locations, between different years at the same location and also between different sampling dates within the same year and at the same location. A summary of fecal coliform counts from several years of monitoring at Taber and Swift Current (Table 1) demonstrates the extreme variabilities. A comparison of the extreme minimum with the extreme maximum count at Swift Current during 1976 indicates a greater than 4,000-fold population change occurring within one irrigation season. However, the season mean number of fecal coliforms at Taber varied relatively little within three consecutive years and averaged at roughly 166,000/100 ml. The abnormally high counts at Swift Current during 1976 reflect the prolonged malfunctioning of the lagoon system at Swift Current, when, due to complete plugging of the connecting pipe between the primary and the secondary lagoon, raw sewage was pumped directly into the secondary lagoon cell for over two months until the hydrostatic pressure differential between the two cells became high enough to unplug the underground connecting pipe. Disregarding the very unusual 1976 counts, the season mean number of fecal coliforms at Swift Current during the other three years did not

Table 1. Fecal Coliform Populations in Secondary Sewage Lagoon at (a) Taber and (b) Swift Current

Year	No. of Samplings	Fecal Coliforms/100 ml Effluent		
		Minimum	Mean	Maximum
	(a) TABER LAGOON			
1975	42	2,000	121,000	920,000
1976	47	2,000	186,400	1,600,000
1977	44	2,000	190,000	1,400,000
3-yr. mean		2,000	165,800	1,307,000
	(b) SWIFT CURRENT LAGOON			
1975	6	190	8,500	30,000
1976	6	390	320,000	1,600,000
1977	6	3	13,000	75,700
1978	15	28	3,800	17,000
4-yr. mean		153	86,300	431,000

vary greatly and averaged at 8,400/100 ml. The data from our intensive coliform monitoring suggest that season mean counts of fecal coliforms can be used for the comparative evaluation of the bacteriological quality of lagoon effluents from different towns or cities. Thus a comparison of 3-yr. average fecal coliform numbers from lagoon effluents at Moose Jaw, i.e. 703,000/100 ml for 1975

to 1977 (Montbriand and Craig, 1978), with the 166,000/100 ml at Taber and the 8,400/100 ml at Swift Current demonstrates very persistent and large differences in the level of sanitary quality of effluent at these three communities. The superior bacteriological quality of the effluent at Swift Current is generally attributed to a very well designed lagoon system that provides three very large and very shallow aerobic lagoon cells for rapid sedimentation and fermentation.

In many parts of North America, regulatory agencies have established bacteriological guidelines that serve to determine the suitability of sewage effluents for crop irrigation. These guidelines vary widely from a very restrictive low mean of $\leq$ 2.2 coliforms/100 ml or 23 coliforms/100 ml limit of single sample (Lennette and Spath, 1978) to a rather tolerant high mean of 5,000 coliforms/100 ml or 20,000 coliforms/100 ml limit of single sample (Finstein, 1973) according to the type of crop being irrigated. The limits are logically very strict for spray irrigation of produce eaten raw and much more tolerant for seed, fodder and fiber crops. In Saskatchewan, the Water Pollution Control Branch has not yet established any bacteriological limits, but it will not permit the use of raw or untreated sewage for crop irrigation.

According to the above-mentioned numerical coliform limits neither the effluent from Moose Jaw and Taber nor even that from Swift Current could be considered to be bacteriologically safe for crop irrigation. Yet, based on our extensive studies of coliform distribution and survival characteristics during and after effluent irrigation (to be discussed later on) and in consideration of the prevailing climatic conditions on the prairies, we judge the effluent at Taber and Swift Current to be perfectly safe for irrigation of forages and cereals as long as certain recommended agronomic practices are being followed to avoid excessive bacteriological contamination.

In view of the extremely high variability in number of enteric bacteria in sewage effluent it may be more meaningful to consider the median rather than the arithmetic mean of a set of population estimates to be evaluated for sanitary criteria. As shown in Figure 1, the median of fecal coliforms at Swift Current

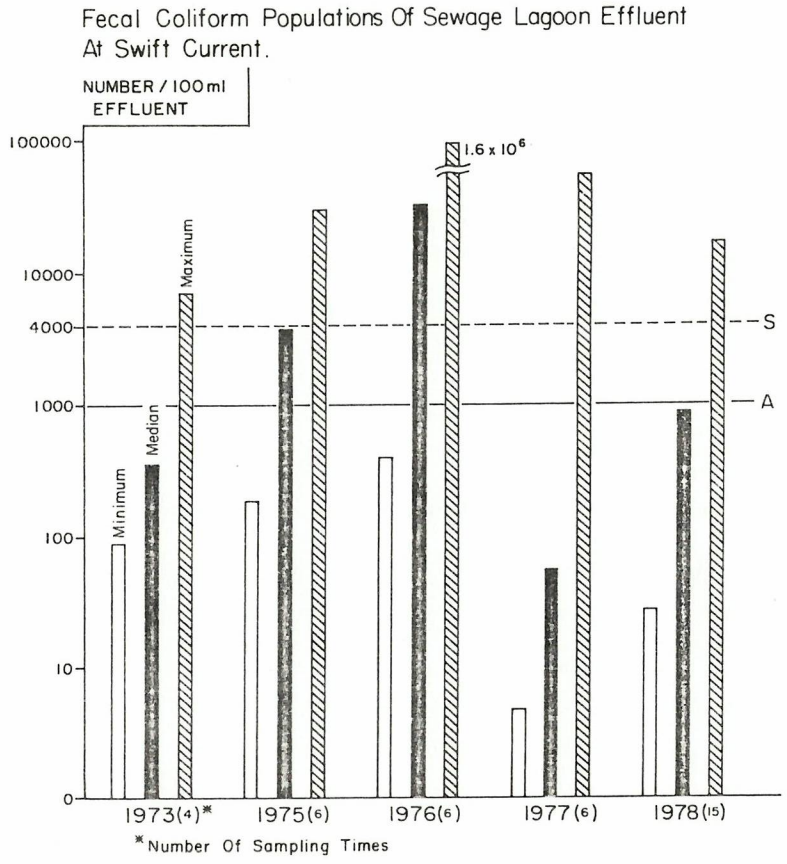


Figure 1

exceeded the aforementioned limit of 5,000/100 ml only in 1976 when the secondary lagoon was loaded with raw sewage. In all other years, the population median was well below this limit. Monitoring of total coliforms in the same effluent (Figure 2) indicated a similar degree of variability of population estimates among years and between minima and maxima. However, the season mean number of total coliforms (data not shown) was generally eight-fold that of fecal coliforms. Populations of fecal streptococci were generally low in the effluent at Swift Current, particularly in 1977 and 1978 when the median was $<$ 10/100 ml (Figure 3).

Total Coliform Populations Of Sewage Lagoon Effluent At Swift Current.

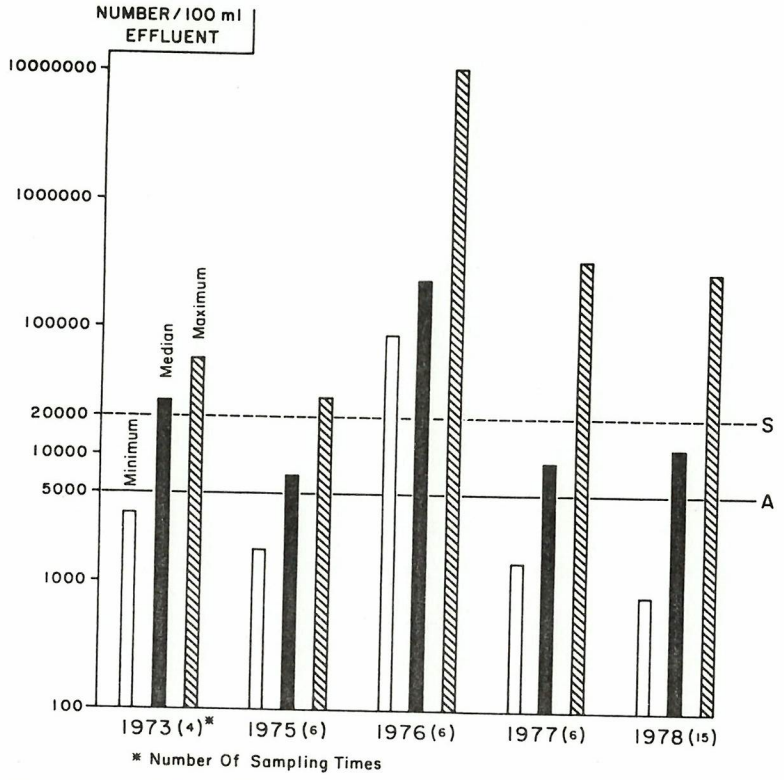


Figure 2

Fecal Streptaccoci Populations Of Sewage Lagoon Effluent At Swift Current.

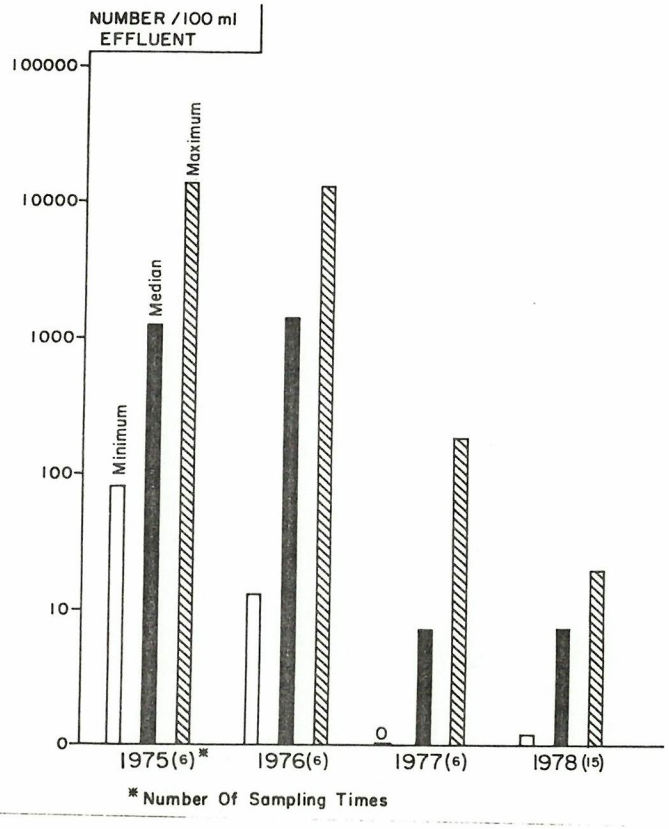


Figure 3

Although these gram positive cocci are also considered to be indicators of fecal pollution of water (Finstein, 1973) they appear to play only a minor role in effluent originating from human as opposed to animal wastes as indicated by the very wide average ratio of 40:1 between fecal coliforms and fecal streptococci at Swift Current.

In 1974, Dr. R. Cullimore from the Water Research Institute at the University of Regina conducted a quantitative and qualitative survey of the algal flora of secondary lagoon effluent at Swift Current, in response to our initial concerns about the possible presence of potentially toxic blue-green algae (Cyanophyceae). His studies showed that the effluent flora was always dominated by high numbers of harmless green algae (Chlorophyceae) and that blue-green algae were only present in June and July and then only in very low numbers. Most of the effluent algae appeared to die off rapidly after spray irrigation, but some became assimilated into the normal soil flora. The algal flora on the alfalfa foliage increased in numbers and diversity until late summer. Throughout the growing season blue-green algae represented less than 1% of the phyllosphere flora and their numbers did not increase with repeated effluent irrigations. This suggested that blue-greens can adhere to alfalfa, but provided their population levels in the effluent remain low the risk of toxicity to animals fed this forage is very remote.

4. REDUCTION OF FECAL BACTERIA IN EFFLUENT DURING PUMPING AND IRRIGATION.

To minimize environmental pollution from spray irrigation with sewage effluent and to avoid health hazards associated with the formation of aerosols and the handling of irrigation equipment by farmers it is desirable to find simple ways and means of removing enteropathogens from the effluent during irrigation. When the bacteriological quality of nonchlorinated effluent from

the secondary lagoon at Swift Current was monitored in 1973 it was discovered that passage through an irrigation pump destroyed certain microorganisms. The microbial density in dip samples drawn directly from the lagoon was considerably higher than the density in line samples drawn simultaneously at a sampling port behind the pump (Table 2). Apparently, some microbial cells were physically

Table 2. Effect of Irrigation Pump Pressure on Microorganisms in Sewage Lagoon Effluent (October 1, 1973)

Type of organisms and culture conditions	Mean ± S.E.[1] /100 ml liquid		Loss of viability (%) during passage through pump
	Dip samples from lagoon	Line samples[2], from main pipe	
Bacteria on plate count agar, 48 h at 20 C	5,260,000 ±140,000	3,770,000 ±130,000	28.3
Bacteria on plate count agar, 24 h at 35 C	5,190,000 ± 90,000	2,810,000 ± 60,000	45.9
Bacteria on soil extract agar, 14 days at 20 C	879,000 ± 19,000	832,000 ± 64,000	5.3
Fungi on rose bengal Streptomycin agar, 6 days at 20 C	10,470 ±280	5,650 ±120	46.0
Total coliforms by multiple-tube fermentation, 48 h at 35 C	10,600 ±1,500	4,000 ±900	62.3
Fecal coliforms by multiple-tube fermentation, 24 h at 44.5 C	863 ±121	297 ±33	65.6
Fecal streptococci by multiple-tube fermentation, 48 h at 35 C	350 ±76	32 ±2	90.9

1/ Mean ± standard error of three replicates

2/ At a pressure of 60 psi

damaged during the instantaneous pressure change from atmospheric to 60 psi in the impeller of the centrifugal pump or during the sudden pressure release at the sprinkler nozzle. It is interesting that the intestinal bacteria of human and animal origin, such as coliforms, fecal streptococci and others that develop best near body temperature (e.g., plate count at 35 C), were found to be much more susceptible to the detrimental effects of pumping than the bacteria indigenous to water and soil that grow best at 20 C. The sanitary significance of this phenomenon is demonstrated by the fact that according to some U.S. recommendations (Finstein, 1973) the dip-sampled effluent would have been assessed as unsuitable for crop irrigation because it contained more than the recommended limit of 5,000 total coliforms per 100 ml, while the effluent drawn behind the pump would have been considered safe.

In view of the sharp reduction in the number of viable fecal coliforms and fecal streptococci found during the pumping of effluent from the lagoon, laboratory experiments were undertaken to determine whether these bactericidal effects of pumping could be reproduced under controlled conditions. The effect of frequency of pressure change, effluent pH and temperature, chlorination, and bacterial growth phase on the destruction of fecal indicator bacteria during pumping of effluent was assessed by running four simulation experiments with a small pump in the laboratory. Samples of lagoon effluent were sterilized by auto claving to eliminate the indigenous microflora and then inoculated by adding known numbers of cells from pure cultures of either fecal forms or fecal streptococci. After transferring 3000 ml through the experimental pumping system at a maximum pressure of 50 psi three subsamples were taken from the inoculated effluent for bacteriological analysis.

When the effluent was subjected to repeated pumping at 50 psi and room te mperature fecal coliforms and fecal streptococci decreased linearly with increasing number of passages through the pum (Fig. 4). The bactericidal effect

of effluent pumping was clearly cumulative. The reduction in fecal coliforms and fecal streptococci was 40 and 33% respectively after three passages as compared

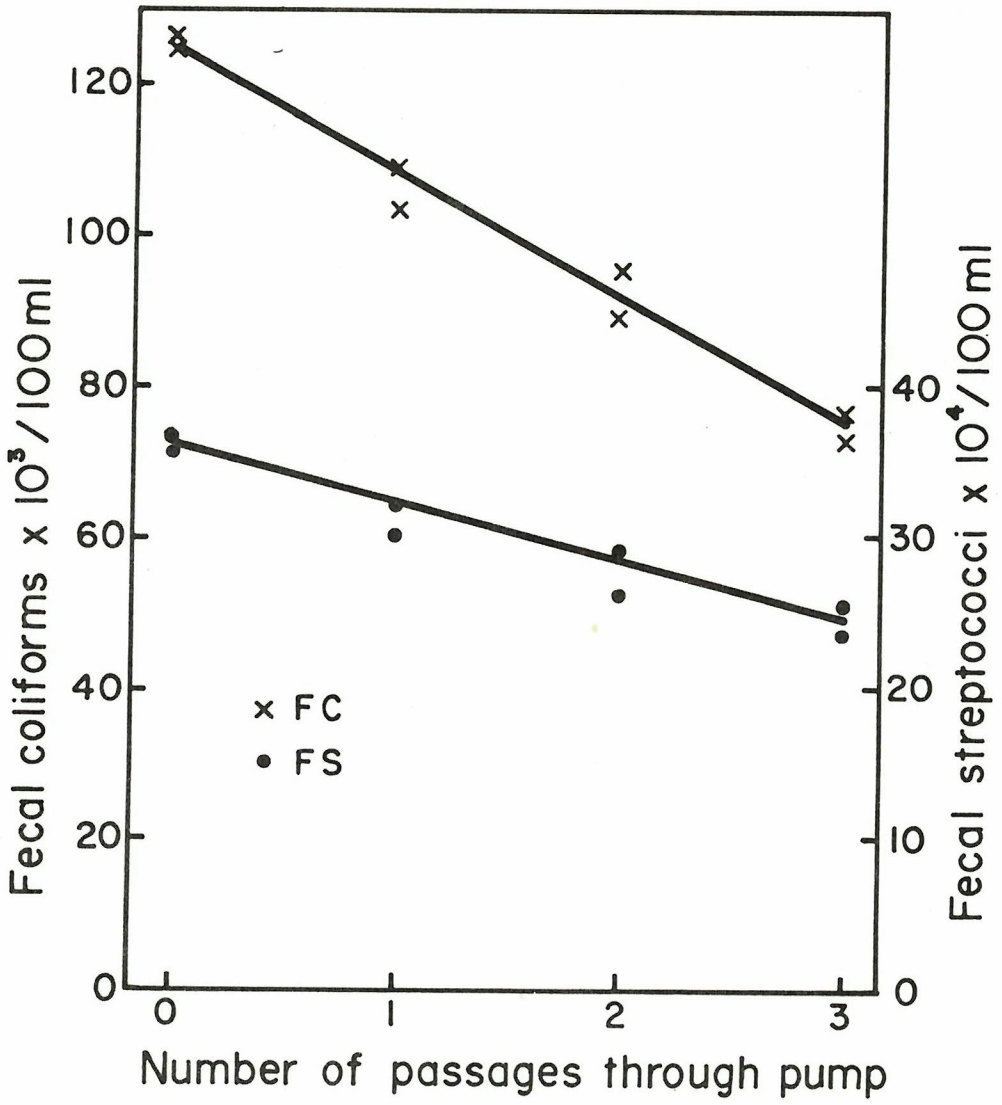


FIGURE 4.

Effect of repeated pumping on fecal coliforms and fecal streptococci in sewage effluent.

to 15 and 14% after one passage. Thus fecal coliforms were more susceptible than fecal streptococci to destruction by pumping.

Stressing the enteric bacteria prior to pumping by means of very weak chlorination of the effluent (0.6 ppb residual Cl_2 concentration) markedly increased the destruction of fecal coliforms but not fecal streptococci during subsequent pumping (Biederbeck, 1979). This divergent behaviour was not surprising because fecal streptococci are reputed to be considerably more resistant to chlorination than fecal coliforms.

In another experiment, the possibility of an interaction between the age

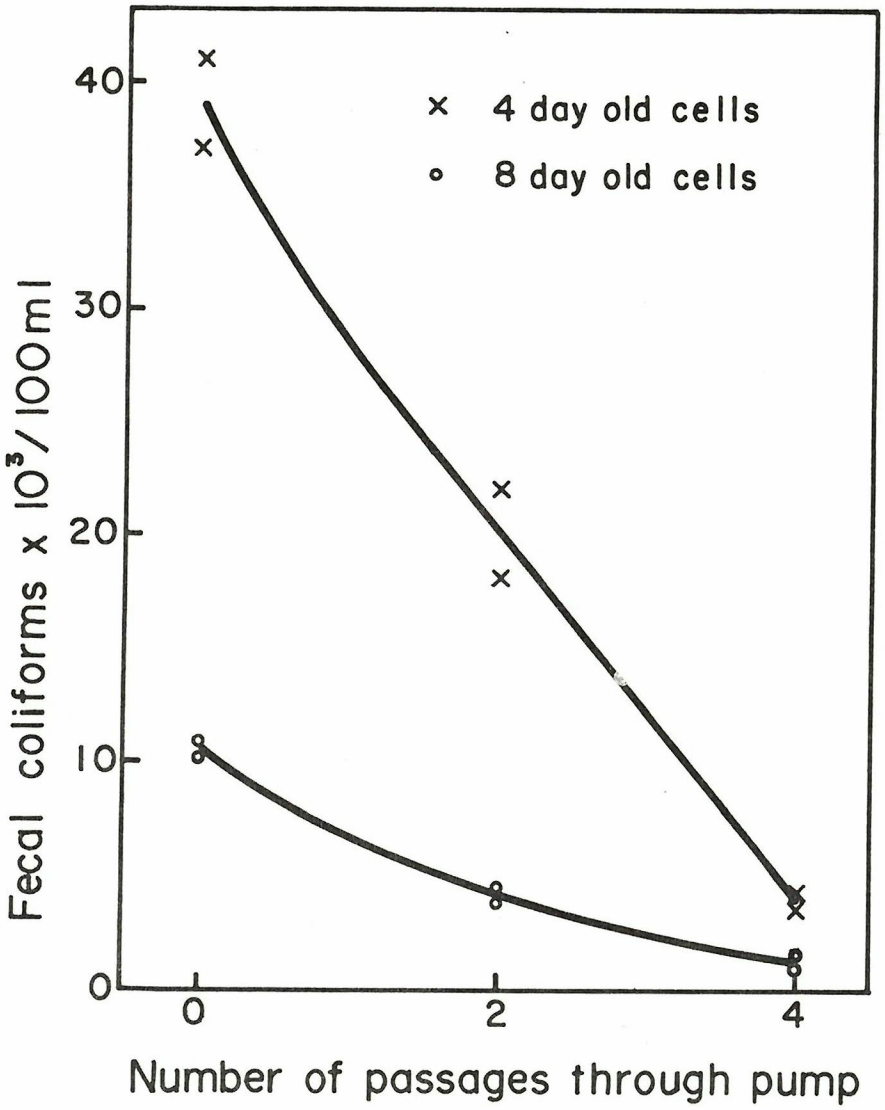


FIGURE 5.

Effect of age of cells and repeated pumping on fecal coliforms in sewage effluent.

of bacterial cells and the bactericidal effect of pumping was investigated by seeding one portion of effluent with fecal coliform cells from the maximum stationary growth phase and another with cells from the death phase just prior to effluent pumping. The survivor curves (Fig. 5) show that there was no difference in the total percentage kill of fecal coliforms between cells of different age. Both populations were reduced by 90% after four passages through the pump. The older cells were initially slightly more susceptible to pressure shock because that population decreased by 60% with two pumpings while the younger cells declined by 49%.

The laboratory simulation studies have shown that within the range of experimental conditions used, the percentage of fecal coliforms killed by pumping was not markedly affected by changes in temperature and pH of the effluent or by differences in the number and age of cells added (Biederbeck, 1979). However, it was not possible to pinpoint the exact cause of the observed destruction of fecal indicator bacteria during the pumping of sewage effluent. The hydrodynamic effects to which the effluent-contained cells were subjected are believed to include not only a strong pressure shock and possible oxygenation and bubble formation, but also some sheering action and cavitation phenomena occurring within the centrifugal force field of the impeller. These effects could be analogous to those of a French press where sheering action and cavitation are thought to be largely responsible for the very effective disruption of microbial cells (Zo Bell, 1970).

The bactericidal action associated with the pumping of wastewater is without doubt of considerable sanitary significance. However, the results of our simulation experiments are of a rather theoretical nature and should be followed up by more field testing and by studies on the effect of different types of pumps, operating pressures and other factors that may affect the extent of bacterial

destruction; but, they do provide a basis for further exploitation of the bactericidal effect of pumping as a management technique in wastewater irrigation.

5. AERIAL DISPERSAL OF FECAL BACTERIA DURING EFFLUENT IRRIGATION.

Spray irrigation of effluent will result in the formation of aerosols (fine mist). Aerosols have been defined as particles in the size range of 0.01 to 50 um that are suspended in air. When an airborne water droplet is created, the water evaporates very rapidly under average atmospheric conditions resulting in the die-off of many of the microorganisms contained in the original droplet (Sorber and Guter, 1975). Aerosols containing bacterial and viral pathogens may be infectious on inhalation or on contact with material on which the airborne droplets have settled. During sprinkler irrigation of sewage effluent, approximately 0.1% of the liquid is aerosolized (Hickey and Reist, 1975). Thus, there is a possibility of producing a potential health risk by effluent irrigation. In a recent study in Israel (Katzenelson et al., 1976) the incidence of enteric diseases (salmonellosis, shigellosis, typhoid fever and infectious hepatitis) originating from exposure to aerosols was found to be from two to four times higher in those communities using non-disinfected effluent for spray irrigation as compared with those communities that did not practice effluent irrigation.

There is little quantitative information available on the spread of bacterial aerosols from land application of effluent by sprinkler irrigation and the only published U.S. field study that monitored airborne coliforms led to the conclusion that hazards from effluent sprinkling were limited to direct contact with unevaporated droplets (cf. Hickey and Reist, 1975). Furthermore, the spread and survival of coliforms and enteric pathogens are greatly affected by climatic factors with both being drastically shortened by exposure to sunlight, low relative humidity, and high temperatures.

The survival and dispersion of fecal bacteria in effluent aerosols was not investigated at Taber or Swift Current because this type of monitoring was deemed unnecessary under the prevailing operational and climatic conditions. In view of the very small fraction of effluent that is aerosolized, the very high infective dose, i.e. $> 10^6$, required for salmonellosis (Taylor and Burrows, 1971), the generally acceptable bacteriological quality of the local effluents, and the hot and dry summer climate it was concluded that the potential for health hazards associated with bacterial aerosols from effluent irrigation would be extremely low at Swift Current as well as Taber and at most other towns and cities within the semiarid prairie region. The possibility for disease transmission through aerosols can be minimized further by maintaining an adequate buffer zone between irrigation sites and areas of public access and also by refraining from irrigating with effluent at night and during humid days.

6. ELIMINATION OF FECAL COLIFORM BACTERIA FROM FORAGES AND GRAINS IRRIGATED WITH EFFLUENT.

In western Canada, effluent used for crop irrigation is primarily applied to forages such as alfalfa, grasses and grass-alfalfa mixtures. Unfortunately, some of the pathogens that can occur in sewage, such as salmonella and certain parasites, can infect livestock as well as man. Thus, the survival characteristics of fecal organisms on the irrigated foliage must be considered to minimize any health hazards to livestock consuming this forage. At Taber, Bell (1976) has conducted extensive field studies to determine how long fecal coliforms, indicators of the salmonella group of enteropathogenic bacteria, survive on alfalfa irrigated with sewage effluent.

During periods of fine weather, i.e. bright sunlight, low humidity, and high temperatures, fecal coliform populations on the foliage were reduced rapidly within the first 24 hours (Table 3). However, no decrease in fecal coliforms was

Table 3. Survival of fecal coliforms on alfalfa irrigated with sewage effluent during fine weather early, mid, and late in the growing season, (Bell, 1976).

Hours after irrigation stopped	No. fecal coliforms/ g dry weight	Kill	Mean daily temperature	Relative humidity	Hours of exposure bright sunlight
		%	°C		
		Early season			
1	1,116	---	21.1	34	1
24	< 2.47	> 99.8	22.7	42	9.2
48	< 1.86	> 99.9	18.9	44	20.2
		Mid season			
1	1,540	---	16.7	43	1
24	6.3	99.6	17.8	37	10.2
30	3.3	99.8	17.8	37	10.2
48	< 1.8	> 99.9	12.3	65	18.8
		Late season			
1	1,720	---	14.4	56	1
6	38	98	14.4	56	5.9
24	0.9	> 99.9	15.5	52	9.5
30	0.7	> 99.9	15.5	52	15.5
48	0.8	> 99.9	17.8	20	19.0

detectable for the first 25 hours following irrigation during a period characterized by wet, overcast conditions for the first 50 hours (Table 4). From these studies Bell (1976) concluded that exposure to 10 hours bright sunlight was adequate to destroy all the fecal coliforms present in raw sewage. This means that, even in the event of sewage treatment failures such as lagoon short-circuiting while alfalfa was being irrigated with sewage effluent in the semiarid prairie region, livestock would be adequately protected from possible salmonella and other entero-

Table 4. Survival of fecal coliforms on alfalfa irrigated with sewage effluent during cold, wet weather (Bell, 1976)

Hours after irrigation stopped	No. fecal coliforms/ g dry weight	Kill	Mean daily temperature	Relative humidity	Hours of exposure bright sunlight
		%	°C		
1	367	---	10	95	0
20	>1,370	---	9.4	90	0
26	>1,550	---	9.4	90	0
44	460	>58.0*	10.6	65	2.8
50	865	> 21.0	10.6	65†	7.3
74	18.4	>98.0	14.4	52	16.8
98	2.57	>99.7	15.6	56	27.7
122	1.3	>99.9	17.8	48	40.4

*Based on mean population over first 26 hours (1,096).

†Sixteen millimeters of precipitation, as a persistent drizzle, recorded in first 50 hours.

pathogenic infection if at least two sunny days elapse between the cessation of effluent irrigation and the harvesting or consumption of the forage.

In subsequent field studies at Taber (Bell and Bole, 1976) the survival characteristics of fecal coliforms on reed canarygrass were determined in order to develop a recommendation for sunlight decontamination of sewage-irrigated grasses. As indicated by the observed population changes (Table 5) the grass was readily recontaminated during rainfall because contaminated soil was splashed onto the foliage, and the number of fecal coliforms was not reduced during cool, damp periods. These data also demonstrate that exposure

Table 5. Persistence of fecal coliforms on reed canarygrass irrigated with sewage lagoon effluent

Hours after irrigation stopped	Fecal coliforms/ 100 ml effluent	Fecal coliforms/g dry matter	Hours of exposure to bright sunlight
14 July	1.3×10^4		
1		291	1
23		13	13.3
47 (10.1)†		1,225	21.9
71		12.5	34.7
95		15.3	49.5
21 July	3.5×10^4		
1		640	1
23		28	13.4
47 (5.2)†		520	21.6
71		319	34.5
95		11	44.5
28 July	4.9×10^4		
1		1,547	1
20		719	8.1
44 (12.1)†		40	11.3
68 (3.7)†		93	11.3
92 (11.8)†		35	14.8
116.5		4.3	27.3
140.5		6	36.8
164.5		9	49.4

† Rainfall (mm) during preceding 24 hours.

to 50 hours bright sunlight under semi-arid prairie conditions was sufficient to destroy virtually all those fecal coliforms present on the grass after irrigation with effluent. Similar times were required for the

elimination of fecal coliforms from contaminated bromegrass and orchardgrass. Average weather data for the Lethbridge area indicate that, during the May-to-September growing period, this recommendation is satisfied in 1 week, assuming that at least 75% possible hours of bright sunlight occurs. This sunlight period required for decontamination of reed canarygrass is considerably longer than the 10 hours previously shown to be adequate to eliminate fecal coliforms from alfalfa. This difference between species is believed to be due to the presence of leaf sheaths on the grass in which effluent could collect and be protected from the bacteriocidal effects of bright sunlight.

Studies conducted in British Columbia indicate that drying treatments, such as converting grass to hay before feeding, will effectively reduce residual coliform populations and thus increase the safety margin for livestock as long as the effluent-irrigated forage is not baled when wet (Oldham, 1974).

In September 1978, grains grown under effluent irrigation on the V. Rempel farm at Swift Current were sampled immediately after swathing and analyzed for residual numbers of fecal coliforms and fecal streptococci. The rapeseed as well as the oats were found to be virtually free of contamination with fecal bacteria when examined 7 and 19 days, respectively, after irrigation with sewage effluent containing about 15,000 fecal coliforms/100 ml (Table 6).

The failure to detect any survival of significant numbers of fecal bacteria indicates that these grains had been exposed to sufficient solar radiation and desiccation to ensure the complete elimination of sewage-contained enterics prior to harvest. However, more detailed field studies on the survival characteristics of fecal coliforms on grain crops are required before a recommendation for adequate sunlight decontamination can be developed.

Table 6. Survival of fecal bacteria on small grains irrigated with effluent at Swift Current

Grain crop	Days since last irrigation	Fecal Coliforms	Fecal Streptococci
		Mean No.*/g dry weight	
Rapeseed	7	0	2.0
Oats	19	1.3	0

* From 3 replicate samples

7. PERSISTENCE AND DOWNWARD DISPERSAL OF FECAL BACTERIA IN SOILS IRRIGATED WITH EFFLUENT.

It is only natural that soil becomes heavily polluted with fecal micro-organisms when crops are irrigated with effluent. The question of public health concern is how long will these alien organisms survive in the soil environment and how deep will they penetrate into the soil profile. In soil enteric bacteria may survive for periods varying from a few hours to several months, depending on the type of organism, type of soil, moisture holding capacity, moisture and organic matter content, pH, temperature, sunlight, rain, bacterial density in the effluent being applied, and predation and antagonism from the resident microbial flora of the soil (U.S. E.P.A. Manual, 1977). Studies at Taber (Bell and Bole, 1978), have shown that when effluent is applied to forages at rates equal to crop requirements most of the fecal coliforms were retained in the surface 8 cm of the Cavendish loamy sand (Table 7). When effluent was applied at weekly intervals there was no buildup of coliforms in the surface soil nor did any coliforms penetrate the profile below 69 cm. Die-off of fecal coliforms in this loamy sand under a stand of reed canarygrass occurred in two phases: an initial rapid phase in which 90% of the bacteria died within 48hours of irrigation and a subsequent slower decline over about 2 weeks as the remaining 10% were eliminated.

Table 7. Fecal coliform population of Cavendish soil irrigated with sewage lagoon effluent and of the applied effluent begun 26 April (week 1) and terminated by 30 June (week 10)

Depth sampled	Time in weeks									
	Before irrigation			Irrigation period				After irrigation		
	1	2	3	4	5	6	7	8	9	10
cm	no./g dry soil									
0-8	*[+]	*	*	38	33	9	130	9.2	0.5	-[‡]
8-23	*	*	*	0.7	*	*	12	10	0.6	-
23-38	*	*	*	*	*	*	26	7.2	1.2	-
53-69	*	*	*	*	*	*	0.4	0.4	*	-
84-99	*	*	*	*	*	*	*	*	*	-
114-130	*	*	*	*	*	*	*	*	*	-
	no./ml									
Effluent				1,300	490	310	1,300			

[+]Below limit of detection 0.21

[‡] Not determined

However, after a fall irrigation (Table 8), fecal coliforms died off more slowly than after irrigation of the growing crop. The lower death rates observed in fall can be attributed to lower soil temperatures, since calculated daily death rates for 15 and 10°C, respectively, were 33 and 25%.

Short-and long-term effects of effluent irrigation on the survival and distribution of enteric bacteria in the Birsay clay loam under a stand of alfalfa at Swift Current were determined by periodic sampling of the

Orthic soil type for microbiological analyses. Although enteric bacteria were enumerated in all soil samplings throughout the 1973 and 1975 irrigation seasons in order to assess short-term effects, the results from a three-week period in 1975 will suffice to illustrate their behaviour in soil. Examination of surface soil sampled two days before, one day after and 19 days after the second effluent irrigation during midsummer of 1975 indicated that the number of total coliforms in the irrigated soil was generally more than 30 times greater in the top 2.5 cm than in the 2.5-15 cm depth and that there were small but persistent numbers of coliforms in the dryland soil (Table 9).

Table 9. Effect of effluent irrigation* on total coliforms in Birsay Orthic soil

Site	Depth cm	Mean number/g soil			Decrease between irrigations %
		June 22	June 25	July 13	
Effluent irrigated	0-2.5	121,500	906,300	123,900	86
	2.5-15	51	26,800	1,500	94
Dryland	0-2.5	118	85	71	-
	2.5-15	4	11	4	-

* 5.84 cm of effluent containing 13,000 total coliforms/100 ml was applied on June 24, 1975.

Effluent irrigation effected a sharp increase in coliforms at both depths, but during the subsequent 19 days of slow drying there occurred a killing of roughly 90% and numbers approached pre-irrigation levels.

The fecal coliforms population underwent similar changes between irrigations but their numbers were much smaller than numbers of total coliforms (Table 10), attesting to the greater specificity and sanitary significance of fecal coliforms as pollution indicators.

Table 10. Effect of effluent irrigation* on fecal coliforms in Birsay Orthic soil.

Site	Depth cm	Mean number/g soil			Decrease between irrigations
		June 22	June 25	July 13	%
Effluent irrigated	0-2.5	128	144,700	26,700	82
	2.5-15	0	322	95	71
Dryland	0-2.5	0	4	8	-
	2.5-15	0	0	1	-

* 5.84 cm of effluent containing 6,100 fecal coliforms/100 ml was applied on June 24, 1975

In half of the dryland samplings and one sampling of irrigated soil, no fecal coliforms could be detected. It is interesting that the fecal coliforms population in the Birsay soil decreased rather slowly after irrigation (Table 10) when compared to the very rapid die-off observed by Bell and Bole in the Cavendish soil at Taber (cf. Table 7). The much slower death rate at Swift Current than at Taber is probably due to the large difference in soil texture and vegetation cover between the two project sites. Fecal coliforms retained near the surface of the Birsay clay loam under the very dense canopy formed by the alfalfa foliage were considered to be less exposed to the lethal effects of sunlight and rapid desiccation.

The number of fecal streptococci at the surface of the Birsay clay loam did not increase in response to the second irrigation (Table 11), primarily because at this time the effluent contained very few fecal streptococci and also because a high number of these organisms had survived since the first irrigation 12 days earlier. However, the fecal streptococci population at both soil depths did decrease, although more slowly than the coliforms, between

Table 11. Effect of effluent irrigation* on fecal streptococci in Birsay Orthic soil

Site	Depth cm	Mean number/g soil			Decrease between irrigations
		June 22	June 25	July 13	%
Effluent irrigated	0-2.5	80,200	21,400	7,500	65
	2.5-15	74	460	211	54
Dryland	0-2.5	2,200	606	117	-
	2.5-15	2	2	14	-

*5.84 cm of effluent containing 223 fecal streptococci/100 ml was applied on June 24, 1975

irrigations. Again, as with the coliforms, there was little if any occurrence of downward movement of these enteric bacteria through the soil profile under effluent irrigation.

In general, well over 95% of all three types of enteric bacteria, monitored in the applied effluent, were retained in the surface 2.5 cm of the Birsay clay loam. Thus, the efficiency of bacterial removal by "soil filtration" was very high and agreed closely with studies from Rumania (reviewed by Gerba et al., 1975) where the application of coliforms labelled with radioactive phosphorus

demonstrated that 92 - 97% of these bacteria were retained in the first centimeter of soil while 3 - 5% were detected at depths between 1 - 5 cm.

The absence of any permanent buildup or marked downward movement of fecal bacteria under long-term effluent irrigation at Swift Current was confirmed by monitoring fecal coliforms in deep soil cores sampled each spring and fall for a period of three years (Table 12).

Table 12. Long-term effect of effluent irrigation on downward dispersal and persistence of fecal coliforms in Birsay Orthic soil at Swift Current.

Sampling date	Sampling depth	Mean number/gram O.D. soil†		
		Irrigated soil	Dryland soil	Increase due to effluent irrigation
October 1975	1=0-2.5 cm	811	7.8	803
	2=2.5-15 cm	190	*	190
	3=15-30 cm	7.4	*	7.4
	4=30-60 cm	**	*	0
May 1976	1	7,972	12	7960
	2	19	*	19
	3	1.1	*	1.1
	4	*	1.2	-1.2
October 1976	1	195	9.4	186
	2	41	5.5	36
	3	6.7	1.1	5.6
	4	1.2	*	1.2
May 1977	1	2.7	*	2.7
	2	1.2	*	1.2
	3	*	*	0
	4	*	*	0
November 1977	1	*	*	0
	2	*	*	0
	3	*	*	0
	4	*	*	0
May 1978	1	*	*	0
	2	*	*	0
	3	*	*	0
	4	*	*	0

† Below limit of detection <0.18
‡ Mean from two soil cores.

Although effluent irrigation did cause an increase in the number of fecal coliforms in the top 15 cm of soil in 1975 and 1976, this increase was relatively short-lived as indicated by the failure to detect any fecal coliforms in the irrigated soil in fall 1977 and spring 1978. Furthermore, these coliform counts clearly demonstrate that there was only negligible downward movement of enteric bacteria to the 30 cm depth and none below that. Thus, any possibility of bacteriological groundwater contamination from effluent irrigation onto this clay loam was eliminated. In the Cavendish loamy sand at Taber, fecal coliforms penetrated somewhat deeper into the soil profile but without creating any risk of groundwater pollution. There are, however, some published reports of much greater downward dispersal of fecal coliforms in lighter textured soils and under considerably higher irrigation rates (Dazzo et al., 1972; Reneau and Pettry, 1975).

8. RESPONSE OF SOIL MICROFLORA TO EFFLUENT IRRIGATION.

It is important to know the extent of changes in the indigenous soil microflora brought about by repeated applications of sewage effluent because the magnitude of the soil biomass has a direct effect on nutrient mineralization rates and the "sanitizing effect" of biologically active soils caused by strong competition for available substratesand by antagonism toward as well as predation of enteric bacteria entering the soil environment.

At the Swift Current effluent irrigation project site soil dilution plate counts were made throughout the 1975 irrigation season (Fig. 6) in all three treatments. The results show very clearly that the microbial population in the top 2.5 cm increased very sharply in response to each irrigation, similar to the response to rainfall in dryland soil (Campbell et al., 1973),

and that the increases in effluent irrigated soil were considerably greater than in creek water irrigated soil. As the surface soil dried between irrigations the bacterial population decreased markedly but generally not to the

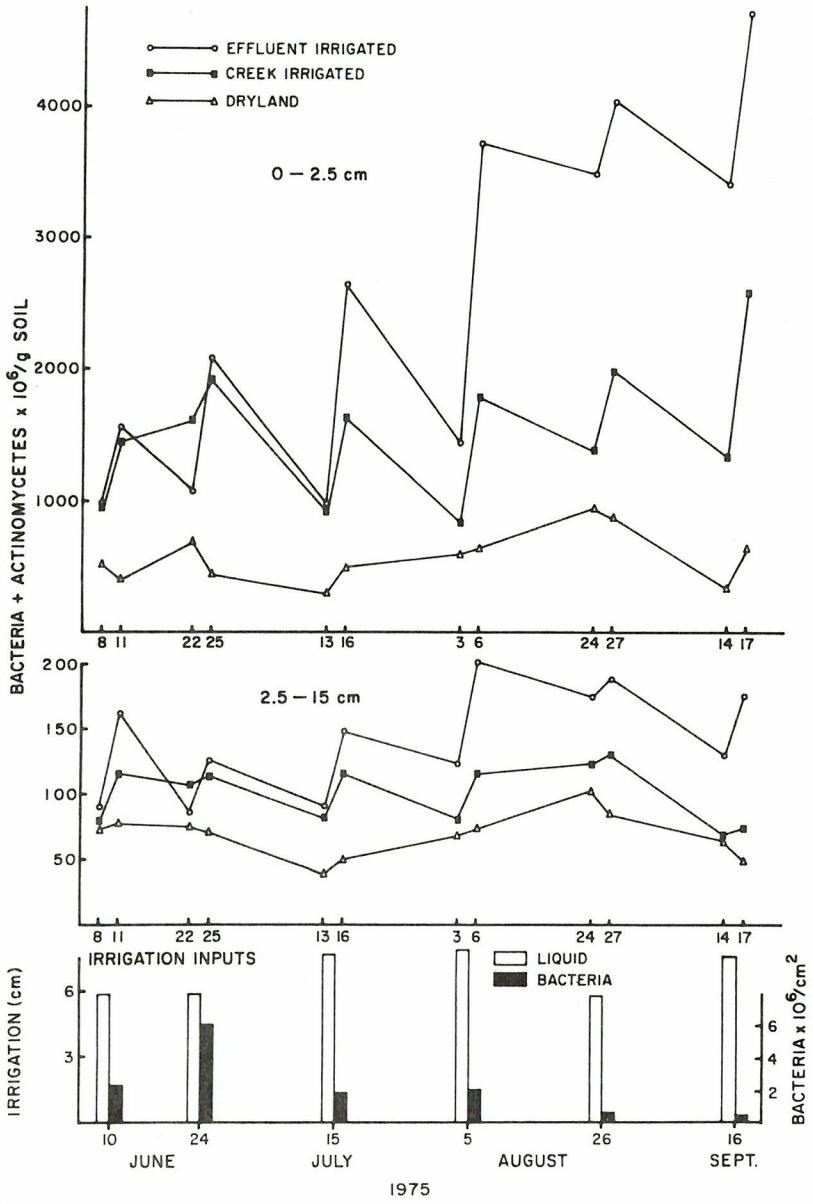


Figure 6

Effect of irrigation with effluent and creek water on microbial populations near the surface of Birsay Orthic soil.

pre-irrigation level. Thus it appears that irrigation, particularly with e effluent, exerted a cumulative effect on the soil microbial population boosting the number of viable bacteria to levels of over 4 billion cells per gram of soil. The magnitude of these population increases can only be fully appreciated when one realizes that even direct microscopic counts of bacteria in nearby dryland soils yielded total counts of less than 2 billion cells per gram of surface soil (Campbell and Biederbeck, 1976). There is no doubt that the observed population increases were due to multiplication or growth of indigenous soil microorganisms rather than the addition of alien organisms to soil via irrigation, because the bacterial inputs accounted always for less than one percent of the soil bacteria at the surface (Fig. 6). In the 2.5-15 cm depth, bacterial population changes were considerably less extensive but followed a pattern similar to that observed at the soil surface (Fig. 6).

The long-term effects of effluent irrigation on the indigenous soil microflora were assessed by microbiological analyses of deep cores taken each spring one month before the start and each fall one month after cessation of irrigation. The results obtained during the first three years demonstrate that the fungal population in soil under effluent irrigation was markedly higher than in dryland soil at each sampling, but only to a depth of 30 cm (Fig. 7). Below 30 cm, there were generally no significant differences between fungal numbers in effluent irrigated and in dryland soil. The greatest stimulation of fungal growth was observed in the surface layer (0-2.5 cm) where the fungal population, even one month after the last irrigation season, was still boosted to the unusually high level of 4 million propagules per gram of soil. This is an increase of more than 600% over the respective population in dryland soil.

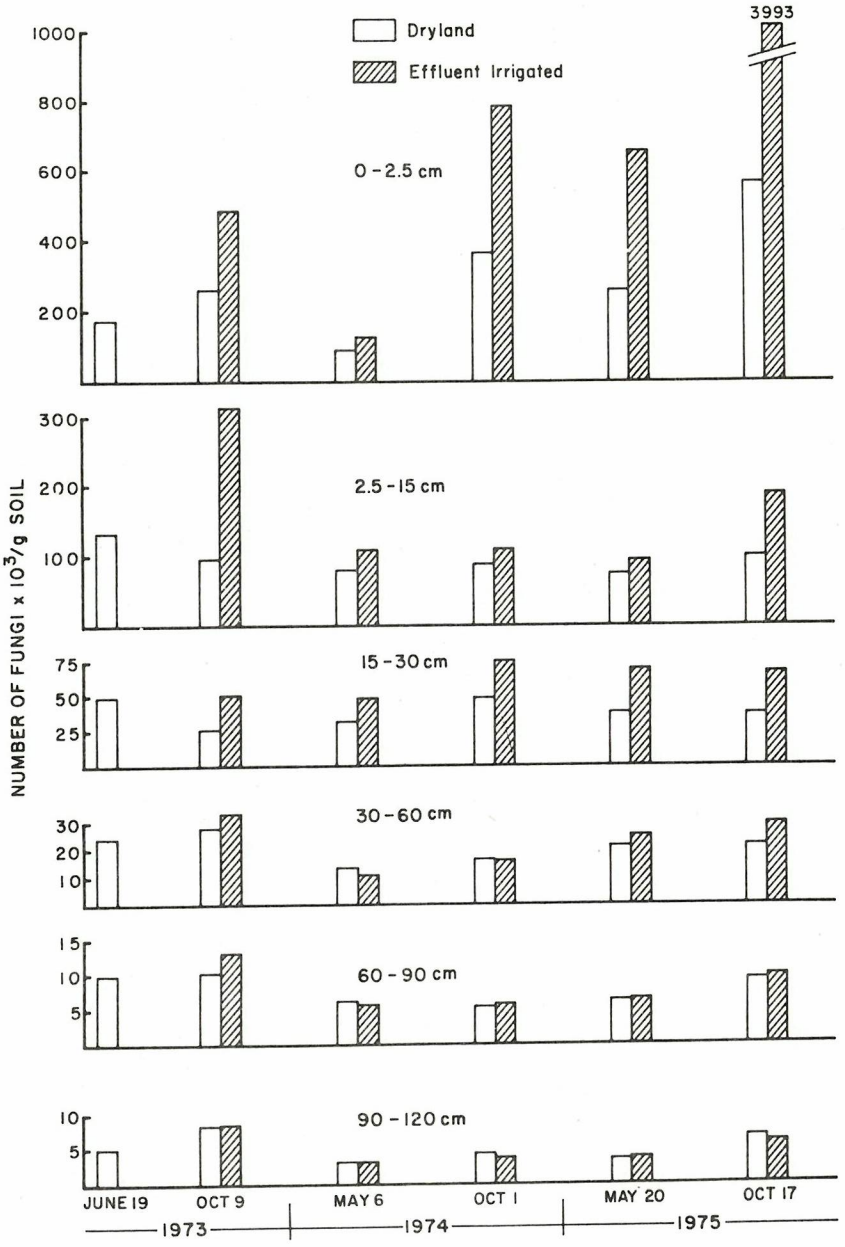


Figure 7.

Fungi at different depths in dryland and effluent irrigated Birsay Orthic soil

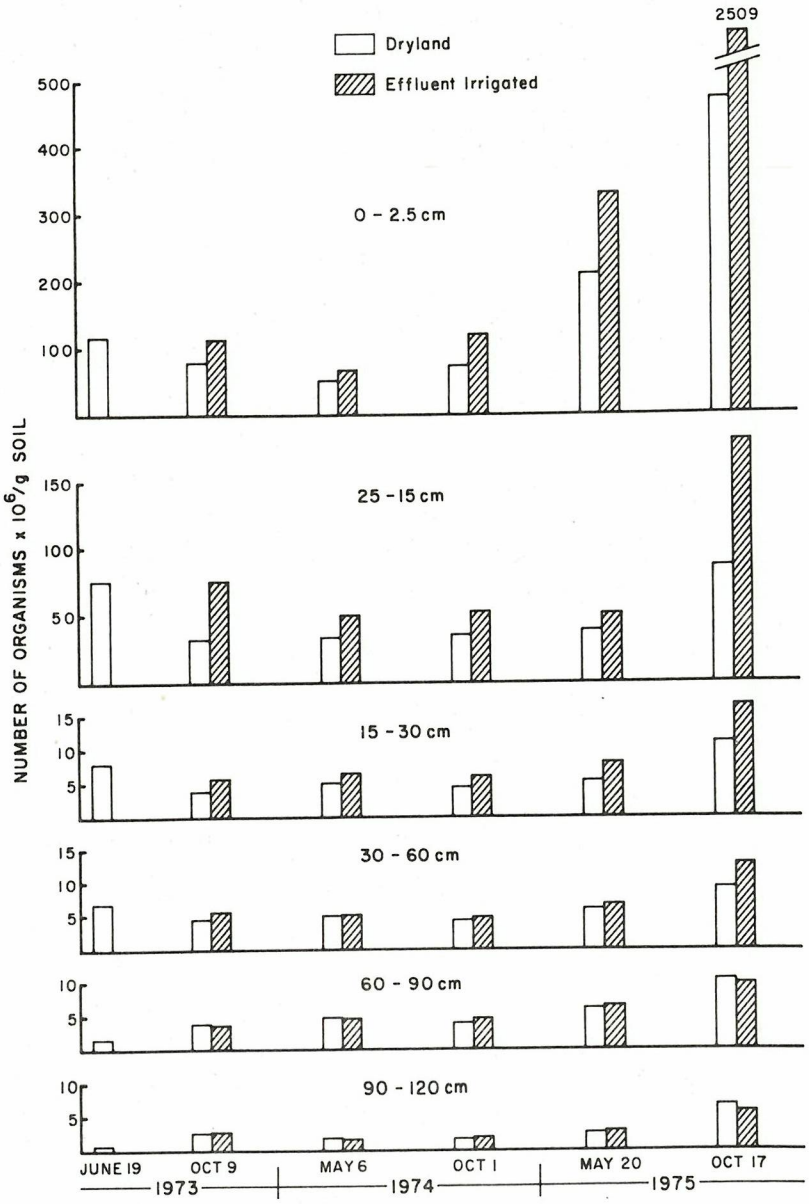


Figure 8.

Viable bacteria plus actinomycetes at different depths in dryland and effluent irrigated Birsay Orthic soil

The differences in numbers of viable bacteria plus actinomycetes between dryland and effluent irrigated soil were generally smaller than those observed for fungi, but they were still very noticeable to a depth of 30 cm (Fig. 8). At greater depth, there were again very few significant differences.

9. SUMMARY AND CONCLUSIONS

The results of extensive sanitary and soil microbiological studies conducted at Swift Current, Saskatchewan and at Taber, Alberta as part of pilot projects on crop irrigation with municipal sewage effluent can be summarized by the following conclusions:

1. Populations of fecal bacteria in effluents from secondary sewage lagoons varied extensively between locations, years and within each irrigation season.
2. Although the mean number of coliform bacteria did periodically exceed recommended guidelines for bacteriological quality of effluent used for crop irrigation these wastewaters were still considered to be safe for irrigation of forages under the climatic conditions of the semiarid prairies which are generally very conducive to the rapid destruction of fecal bacteria by means of solar radiation (U.V. rays) and desiccation.
3. A large proportion of the undesirable enteric bacteria can be killed by rapid pressure changes normally occurring within the irrigation pumping system. The bactericidal pressure shock effects associated with effluent pumping were found to be cumulative and could be enhanced by very weak chlorination. The sanitary importance of these bactericidal effects warrants further investigation.
4. Fecal coliforms are effectively eliminated from alfalfa irrigated with effluent by exposure to bright sunlight for 10 hours. On the prairies this condition can be readily met with a substantial margin of safety for livestock by 2 days of sunny weather interspaced between irrigation and haying or grazing. A longer period

of exposure to sunlight, about 50 hours, was required to eliminate fecal coliforms from reed canary and other grasses.

5. Under properly managed irrigation with effluent, well over 90% of the fecal bacteria were retained near the soil surface and there was only negligible downward dispersal of coliforms in a clay loam and a loamy sand. Most of the enteric bacteria added to soil with effluent were found to die-off rather quickly between irrigations and no short-or long-term buildup of fecal coliforms occurred in irrigated soil.

6. Populations of indigenous soil microorganisms increased considerably more in response to irrigation with effluent than to irrigation with "fresh" water, demonstrating that the organics and nutrients in the effluent were primarily responsible for the strong stimulation of microbial growth.

7. The effluent-associated soil population increases extended to a depth of 30 cm and persisted for long periods of time i.e. between irrigation seasons and over several years.

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SALT CONCENTRATION AND MOVEMENT

IN IRRIGATED SOIL

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1. INTRODUCTION

The disposal of sewage effluent in the form of irrigation on crop has received increasing interest among farmers as well as civic authorities in the Canadian Prairies. In addition to agricultural benefits from the use of sewage effluent as a source of water and nutrients for increased crop production, effluent irrigation can, in many cases, be the best disposal alternative for treated sewage effluent from a municipality.

In 1973, the Research Station, in co-operation with the City of Swift Current, established a pilot project to examine the suitability of using sewage effluent as a source of irrigation water. With the average electrical conductivity of 2.5 mmhos/cm, the sewage effluent at Swift Current is characterized as a salty water. Soil salinity is a major concern when the effluent water is to be used for irrigation. Careful management to prevent salt accumulation in the crop root zone is one of the primary prerequisites for a permanent, successful irrigation with sewage effluent.

Because soluble salts in soil are transported by water, the most effective way for the removal of salt from soil is by means of water which passes through the root zone of the soil. It has been known for generations that to prevent the build-up of salt in the root zone, irrigation must provide water for growth of crops and at the same time allow enough water to pass through the soil to leach out the excess salt. However, maintaining a favorable salt balance in the soil requires efficient and proper irrigation methods. If the leaching fraction (LF, the fraction of applied water that drains below the root zone) is too small, the salt will accumulate and concentrate in the soil to a level which may adversely affect the crop yield. On the other hand, if the leaching fraction is too high, overuse of water not only wastes the valuable source of

water but also adds to the drainage problems. Water application should be controlled to maintain a favorable salt balance in the soil, but without excessively wasting the water and without materially adding to the drainage problems.

The purpose of this paper is to discuss salinity distribution within the root zone in relation to the degree of leaching. Knowledge of salt accumulation and movement in soil is essential in the search of a more efficient management when the saline water is to be used for irrigation.

2. CROP SALT TOLERANCE

The response of plant growth to salinity is an important parameter in determining the amount of water which must be leached through the root zone to keep a favorable salt balance for crop production. Without specific ion effect, the effect of salinity on plant growth is mainly associated with the high ion concentration of the soil solution which makes it difficult for plants to absorb water in the soil.

The most common method of measuring the salt content of soil solutions or irrigation water is to determine the electrical conductivity (EC), expressed as a unit of mmhos/cm. Conductivity has the advantage of simplicity since it can be measured readily in the field or laboratory by using a portable electrical conductance meter.

In assessing the problem of plant growth, the salinity level of the soil solution must be evaluated. It is difficult to extract the soil solution from a moisture soil within the range of water content available to plants. It has been demonstrated, however, that salinity levels of the soil solution and their resultant effects upon plant growth may be correlated with salinity levels of

soil moisture at saturation. The quantity of water held in the soil between field capacity and the wilting point varies considerably from relatively low levels for sandy soils to high values for soils high in clay content.

The U.S. Salinity Laboratory Staff (1954) have developed the technique of using a saturation extract to meet this need. Demineralized water is added to a soil sample to a point at which the soil paste glistens as it reflects light and flows slightly when the container is tipped. The water content at this point is called the saturation percentage. When the saturated paste is filtered, the resultant solution is referred to as the saturation extract. The salt content of the saturation extract may then be measured by determining the extract's capacity to conduct an electrical current. The symbol for electrical conductivity of the saturation extract is ECe. The water content at the saturation percentage is reasonably related to the soil texture. For many soils, it is roughly twice that of the soil at field capacity and four times that at the wilting point. Thus, the electrical conductivity of the soil water at field capacity is about two times that of the soil saturation extract, i.e., EC_{sw} (at field capacity) = 2 ECe

Tolerance of crops to salinity is generally expressed in terms of the electrical conductivity of the saturation extract of the root-zone soil at which a specified relative reduction in crop yield is experienced as compared with yield under nonsaline conditions. After evaluating the salt tolerance data for the various crops, Mass and Hoffman (1977) reported that, in general, crop yield was not decreased significantly until a threshold salinity level was exceeded, and that yield decreased approximately linearly as salinity increased beyond the threshold. They have provided a salt tolerance list including more than seventy crops, in which two essential parameters sufficient for expressing salt tolerance are listed: (1) the threshold salinity

level, (2) the percent yield decrease per unit salinity increase beyond the threshold. Figure 1 shows curves relating yield to ECe for crops of different salt tolerance.

Most of the data on tolerance of plants to salinity have been obtained from artificially salinized field plots where salinity was maintained essentially uniform with depth throughout the root zone by irrigating with different saline water at high leaching fraction. This technique assured that unambiguous conclusions could be drawn since all roots were exposed to the same level of salinity.

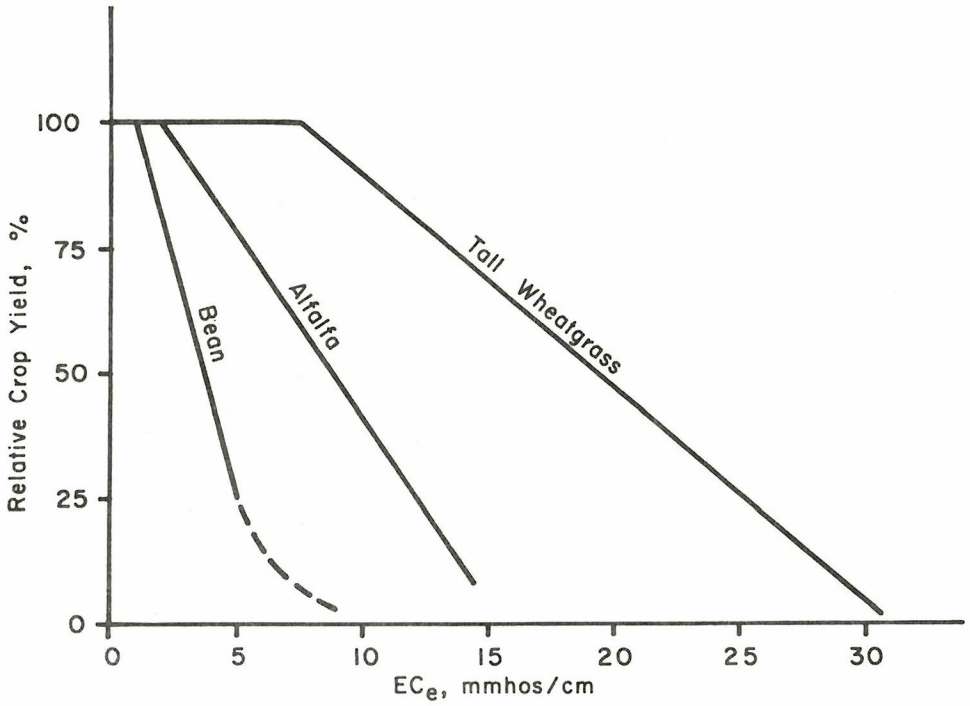


Fig.1 Salt Tolerance Curves for Sensitive (Bean), Moderately Sensitive (Alfalfa), and Tolerant (Tall Wheatgrass) Crops. (Maas and Hoffman, 1977)

3. LEACHING REQUIREMENT - OLD AND NEW GUIDELINES

Salts move and accumulate in soil, largely as a result of the movement of water. To prevent salt accumulation, and consequent decrease in crop yields, irrigation must be managed to remove as much salt as is brought in to the root zone by the irrigation water. This is the so-called salt balance concept. A complete salt balance equation is given as,

$$\Delta S_{sw} + \Delta X_c = V_{iw}\, C_{iw} + S_m - V_{dw}\, C_{dw} - S_p - S_c \qquad (1)$$

where $\Delta S_{sw} + \Delta X_c$ is the change of the quantity of salt in the soil water (S_{sw}) and exchangeable cations (X_c); V_{iw}, V_{dw} and C_{iw}, C_{dw} are volume and salt concentration of irrigation (iw) and drainage water (dw); S_m is the amount of salt brought into the soil solution from weathering and dissolution of soil minerals; S_p is the quantity of soluble salt applied in the irrigation water that precipitated in the soil after application, and S_c is the amounts of salts removed by the crop.

Equation (1) applies to the time of dynamic adjustment of the soil chemistry to the steady-state condition. For a long-term, permanent irrigation project, the steady-state condition is the case that needs to be considered. At the steady-state condition, there is no more change of the salt content in the soil solution, and no more change of cations in the exchangeable soil complex. The amounts of salt added (due to dissolution) and the salts that are lost from the soil solution (salts that are precipitated in the soil and removed by the crop) are usually small compared with the amounts brought in with the irrigation water or removed by drainage and are, therefore, assumed to be negligible. The salt balance equation at the steady-state condition, thus, can be simplified as,

$$V_{iw}\, C_{iw} - V_{dw}\, C_{dw} = 0 \qquad (2)$$

thus the leaching fraction (LF) = $\frac{V_{dw}}{V_{iw}} = C_{iw}/C_{dw}$. When the maximum permissible C_{dw} for a certain kind of crop is specified, the minimum permissible LF, which is the leaching requirement (LR) is determined. Since salinity of irrigation water and soil water are usually expressed by their electrical conductivity (EC), the leaching requirement is usually given as,

$$LR = EC_{iw}/EC_{dw} \tag{3}$$

From equation (3), it is clear that the leaching requirement depends on the salt content of the irrigation water as well as the salt tolerance of the crop, which is taken into account in the selection of permissible value of EC_{dw}.

Because the relationship between EC_{dw} and the salt tolerance of the crop has not been well defined, it has been recommended that the ECe at a 50% reduction in crop yield could be used as an estimate of EC_{dw} in equation (3) to calculate the leaching requirement (U.S. Salinity Lab. Staff, 1954; Bersten, 1964; Bower et al., 1970). As an example, if alfalfa irrigated with water of EC = 2.0 mmhos/cm, because ECe at at 50% yield reduction for alfalfa is 8.3 mmhos/cm (see Fig. 1), $LR = EC_{iw}/EC_{dw} = 2/8.3 = 0.24$. Since

$$LR = \frac{V_{dw}}{V_{iw}} \tag{4}$$

and the amount of irrigation water (V_{iw}) can be partitioned into consumption use by crops (V_{cu}) and drainage water (V_{dw}), substitution of $V_{cu} + V_{dw}$ for V_{iw} in equation (4) yields

$$V_{iw} = \frac{V_{cu}}{1 - LR} \tag{5}$$

Therefore, if alfalfa needs 61 cm of water during the growing season, this mean, total water supplied should be 80 cm to satisfy the leaching requirement of 0.24.

Though the recommended method calculating the leaching requirement was obtained from the experience that it provides sufficient leaching to give essentially full crop yield, it cal also be shown that with this estimate of EC_{dw},

the maximum salinity of the percolating water draining from the root zone would be approximately equal to the salt tolerance value for 90% to 95% yield for many crops.

Recently, the leaching requirement recommended in the earlier guidelines has been challenged by several researchers (Bernstein and Francois, 1973; Schilfgaarde, et al., 1974; Rhoads, 1974). They pointed out that when a crop is irrigated with somewhat smaller LF values, a steady-state salinity profile tends to develop that increases gradually from a level near the surface, controlled by the salinity of the irrigation water, to a level near the bottom of the root zone, determined primarily by the LF. Because the crop extracts most of its water supply from the upper layers of the soil where the salt concentration is lowest, as a result, a lower leaching fraction can be used without fear of significant reduction of yield.

Based on their findings, the above authors proposed a minimum leaching requirement, in which the tolerance of crop, represented by EC_{dw}, is taken as the maximum salinity of the percolating drainage water that can be tolerated. At this salinity, the crop could no longer extract water and so this maximum EC_{dw} would represent a theoretical 100% loss in yield of crop. For alfalfa, the zero yield value is ECe = 15 mmhos/cm (see Fig. 1). Because the electrical conductivity of the soil saturation (EC_{sw}) at field capacity is about two times that of the soil saturation extract, the salinity level at which alfalfa roots can concentrate the soil solution should be $EC_{dw} = EC_{sw} = 2ECe = 30$ mmhos/cm. Thus, if alfalfa irrigated with water of $EC_{iw} = 2.0$ mmhos/cm, the minimum leaching requirement would be $LR = EC_{iw}/EC_{dw} = 2/30 = 0.066$, that is about four times lower than those resulting from previously recommended practices. Bernstein and Francois (1973) grew alfalfa in suction hysimeters in the greenhouse and reported that a salt balance can be maintained in the root zone using this

minimum leaching requirement (LF = 0.066), with a yield reduction of about 8% as compared to that of LF = 0.24.

The minimum leaching requirement concept may not be directly applicable in the field because the stringent management requirement (Schilfgaarde, et al., 1974), but leaching factors well below those suggested in the earlier guidelines may be feasibile in terms of continuing to produce high yield. Advantage would be reduced water demands, reduced drainage cost, and reduced total salt load in return flow. Ayers (1977) developed new guidelines for managing saline water for irrigation based on the minimum leaching requirement concept. He claimed that if this minimum leaching requirement was achieved, it is believed that salts in the root zone can be controlled within tolerance of the crop and at near 85% to 100% production level.

Knowledge of salt distribution in the root zone and their resultant effects on crop yield is essential in selecting the most suitable leaching fraction for managing saline water for irrigation.

4. SALT DISTRIBUTION IN SOIL

When the plant roots absorb water, the salt concentration of the remaining soil water must increase. It will continue to increase as the water moves downward through the active root zone. Thus, in general, the salinity profile in soil increases with depth when steady state is achieved. Figure 2 shows the salinity profiles obtained after a long period of time when alfalfa, grown in greenhouse lysimeters, was irrigated at the indicated LF values with irrigation water having EC_{iw} = 2.0 mmhos/cm (Bernstein and Francois, 1973). The root zone salinity, expressed in terms of the electrical conductivity of the soil water, EC_{sw}, was determined 1 day after irrigation.

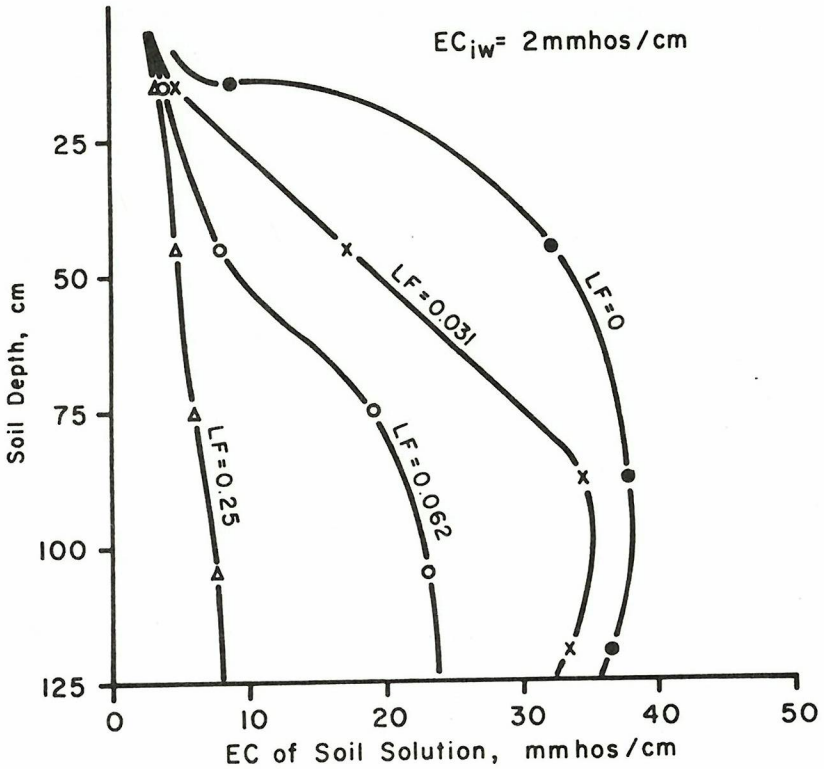


Fig. 2 Effect of Leaching Fraction on Soil Salinity (Bernstein and Francois, 1973)

Steady-state salinity may be approached very slowly, expecially when the leaching fraction is low. Achievement of steady state at LF = 0.062 in the above experiment required about 20 irrigations and a total water application of 325 cm. At the time the measurement was taken, the steady-state salinity profile was not achieved at LF = 0.031. At LF = 0, salts would continue to accumulate as a salt balance could not be maintained.

The above experiment shows that depending upon leaching fractions, salinity profiles may be rather uniform and change relatively little with depth as it is indicated in the high leaching fraction of LF = 0.25, or they may be highly nonuniform with salinities varying from concentrations approximately that of the irrigation water near the soil surface to concentrations many times higher

at the bottom of the root zone as those shown in the low leaching fractions. The results from this experiment also indicated that with LF = 0.062, alfalfa yields reduced only about 8% compared to with LF = 0.25, but at LF = 0.03 and LF = 0, yields declined drastically as the result of increasing salt accumulation in upper layers of the soil.

An equation relating the steady-state salinity profile to the salinity of the irrigation water (EC_{iw}) and the leaching fraction (LF) has been derived, based on the steady downward flow condition. The equation is given as,

$$EC_{sw} = \frac{EC_{iw}}{1 - (1 - LF)\,\frac{x}{d}\,(2 - \frac{x}{d})} \qquad (6)$$

where EC_{sw} is the electrical conductivity of the soil solution, d is the depth of the root zone and x is the depth.

The derivation of the equation, similar to that used by Raats (1974), will not be discussed in this paper. The equation was derived based on the following assumptions:

(1) Steady-state water flow condition

(2) No precipitation or dissolution of salts in soil

(3) Convective transport of salt by water, neglecting diffusion effect

(4) 40% of crop water uptake coming from the upper quarter of the root zone, 30% from the next quarter, 20% from the third quarter and 10% coming from the lower quarter of the root zone

(5) Linear relationship between the concentration and the electrical conductivity of the soil solution.

Figure 3 shows the steady-state salinity profiles as a function of the leaching fraction and the salinity of the irrigation water calculated from Equation (6) and based on an assumed 200-cm root zone. The results clearly indicate that at steady-state conditions, salinity profiles increase gradually from a level near the surface, controlled by the salinity of the irrigation

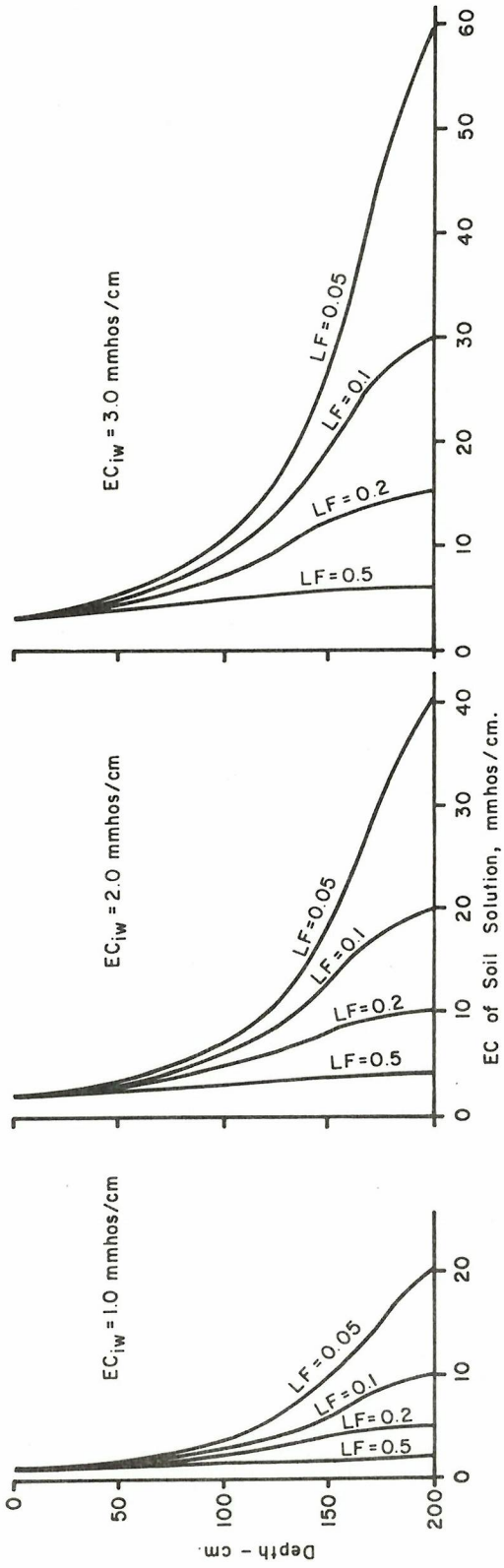


Fig.3 Calculated Steady-State Soil Water Concentration as Function of Leaching Fraction.

water, to a level near the bottom of the root zone, determined primarily by the leaching fraction

In Figure 4, the calculated steady-state salinity profiles, expressed as the electrical conductivity of the soil saturation extract, ECe, were compared to the experimental results obtained by Bower, et al. (1969). The calculated curves agree well to the measured distributions.

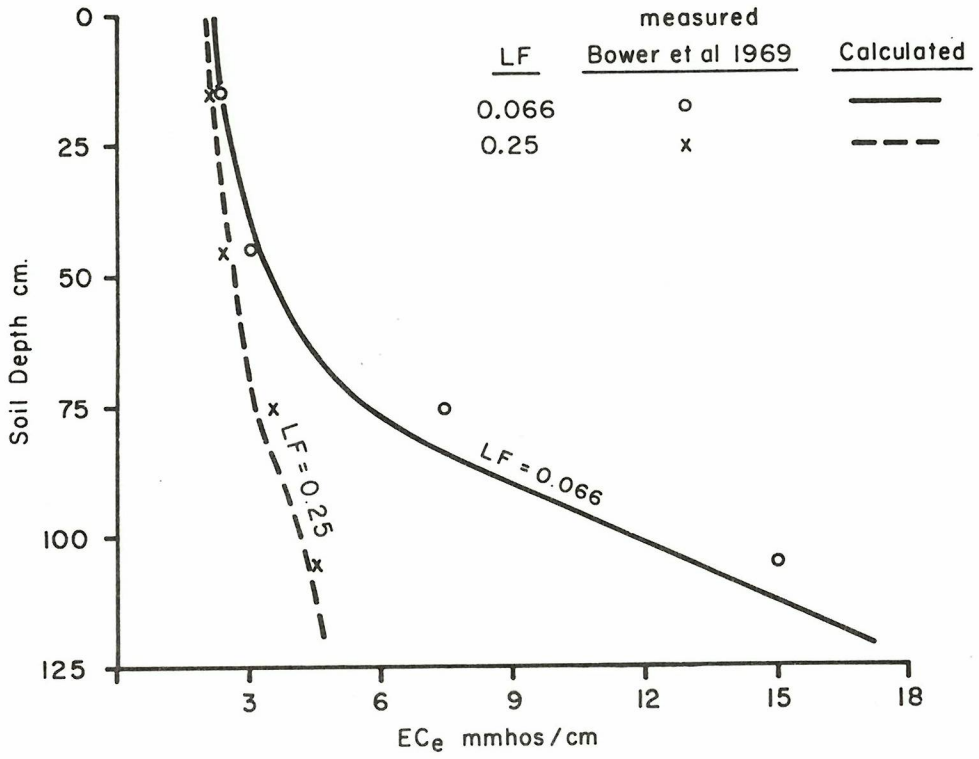


Fig. 4 Calculated Steady-State Salinity Profiles, Compared to Experimental Results.

Although Equation (6) is derived primarily based on the steady-state flow condition, it is applicable to the longtime average or quasi-steady-state conditions. Results of current study (Roats, 1977) also indicate that diffusion and dispersion affect the salinity profile significantly only if the leaching fraction is very small.

5. SUMMARY

An equation relating the steady-state salinity profile to the salinity of the irrigation water and the leaching fraction was presented. The results show that when a crop is irrigated with saline water, at the steady state, salinity profiles increase gradually from a level near the surface, controlled by the salinity of the irrigation water, to a level near the bottom of the root zone, determined primarily by the leaching fraction. Because the crop extracts most of its water supply from the upper layers of the soil where the salt concentration is lowest, leaching fractions well below those recommended in the old guidelines can be used without fear of significant yield reduction.

Because soluble salts in soil are transported by water, salinity, therefore, can be controlled if the quality of the irrigation water is satisfactory and if the flow of water through the soil can be controlled. If it were possible to maintain a moisture distribution in irrigated soil such that water flow would be continuously downward, there would be relatively little trouble from salinity on irrigated farms. Permanent irrigated agriculture can be maintained even using rather salty water with proper management.

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SOIL CHEMISTRY - HEAVY METAL ACCUMULATION AND TRANSFER IN EFFLUENT IRRIGATED SOILS

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The colloquial term 'heavy metal' has been applied (Lagerwerff, 1967) to the following metals, aluminum (sp. gr. 2.7), cadmium (sp. gr. 8.7), copper (sp. gr. 9.0), iron (sp. gr. 7.9), lead (sp. gr. 11.4), manganese (sp. gr. 7.4), mercury (sp. gr. 13.6), nickel (sp. gr. 8.9), and zinc (sp. gr. 7.1). These metals are present in soils and some have essential roles in plant nutrition. They become soil pollutants along with arsenic, boron and molybdenum when for some reason they alter significantly in the amount or form and thus upset the balance of soil composition. Soil pollution, therefore, has been defined (Rennie, 1966) as follows: any substance that is common or foreign to the soil system which in addition to soil either directly or indirectly adversely affects the productivity of the soil is termed a soil pollutant. Soil productivity includes both yield parameters and the quality of the food products produced.

At the onset it must be stated that interest in contamination problems has originally caught many soil scientists off-guard. Previously it was not considered important to know the normal levels of non-essential elements such as mercury in the soil. Neither was the significance of mercury levels known nor the form of mercury which was used by plants. Methods had to be developed to measure even the total amount of these elements in soil, but it was well known that the total value of an element in the soil had very little relation to plant uptake values. Similarly, government, food, and drug administrations have had to scramble to provide information on toxic effects in animals and possible effects in man. Maximum permissible levels had to be worked out for food and water. In

many cases, the maximum permissible levels in human diets is extrapolated from the "no observed adverse effect level" in animals with a safety factor of 100 being employed. Figure 1 taken from Oser (1971) stresses

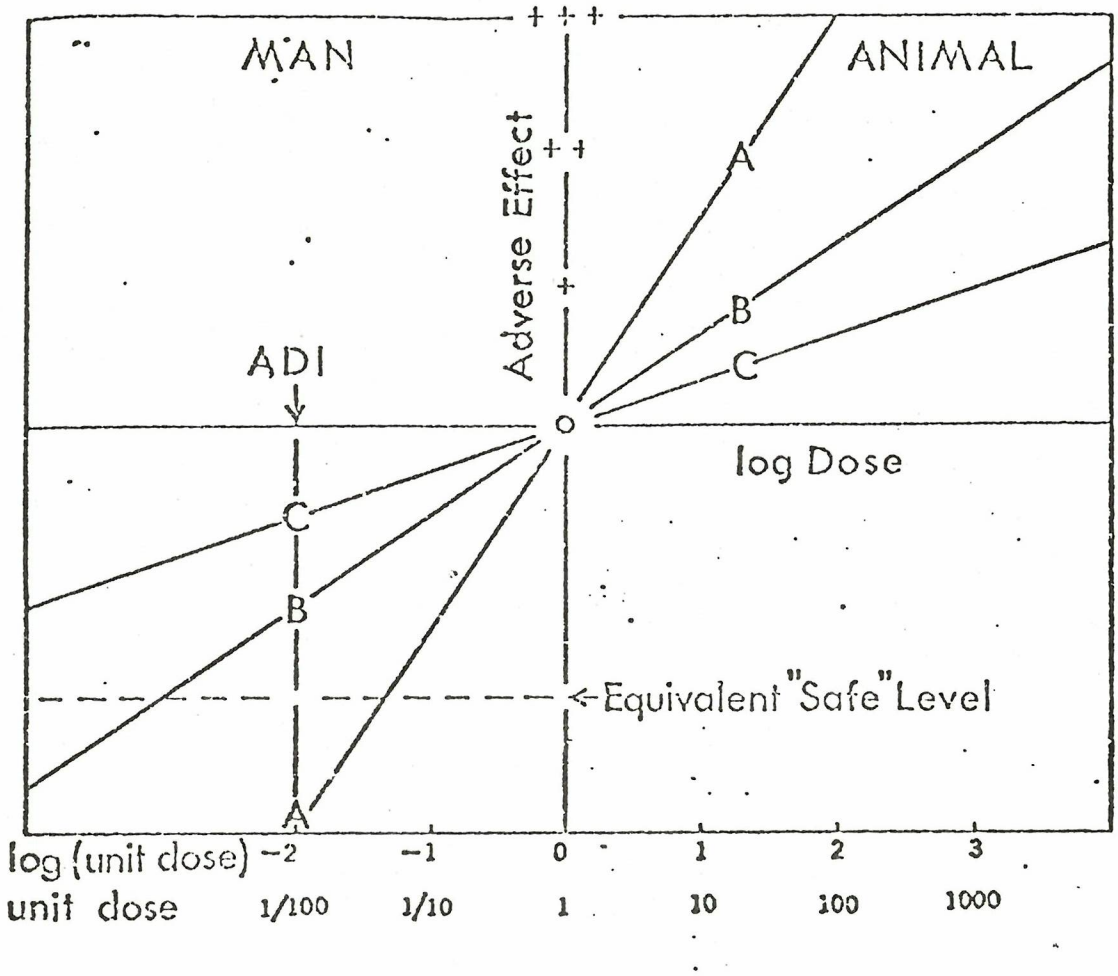


Fig. 1 Relation of factors used in extrapolation of safe intake levels. Ordinate represents degrees of severity, or incidence, of the effect. (from Oser 1971)

the fact that the acceptable daily intake (ADI for man) calculated using a safety factor of 100 of the "no effect" level in animals is more reliable when the slope of the gradient is steep than when it is gradual. Maximum permissible levels in food and drinking water of a number of elements has been established for some time. However, this careful type

of approach means that the agronomist who is accustomed to work in elements in the parts per million range is required to work in the nanograms per gram region and to examine elements whose soil chemistry is virtually unknown. To do this, reliable techniques have had to be developed.

As far as this seminar is concerned, we are interested in the elements that are supplied to the soil in sewage effluent. Because nearly all sewage wastes and refuse contain levels of microelements and heavy metals higher than those present in soils, agronomists are studying the long term effects of waste applied microlements. Some of these such as zinc, copper, boron, and iron in wastes may serve to correct plant deficiencies. Alternatively, repeated or unwise use of wastes may lead to phytotoxicities of zinc, copper, nickel and boron. Further certain non-nutrient microelements, cadmium, lead and mercury, present in some wastes are of concern to agronomists, nutritionists, and environmentalists because of the hazards to animal health.

Metals are deposited in soils in a variety of forms. Once there they are subjected to numerous chemical and microbiological transformations. The reactions that occur depend on the properties of the soil and can be affected by environmental conditions. Equilibrium relationships are altered and shifted by changes in environmental conditions.

Some of the equilibria involved when metals are added to the soils are shown graphically in Fig. 2. The common contaminants (Zn, Cu, Mn, Fe, Pb, Cd, Hg, Ni, Co, Cr, Mo, Se, and As) are added to the soil in water soluble forms or as organometallic complexes. One of the first reactions that they undergo is that of precipitation with the initial precipitates often being amorphous with high surface areas. This causes an initial high solubility which usually decreases as the amorphous forms become more crystalline. These precipitated minerals then govern the concentration

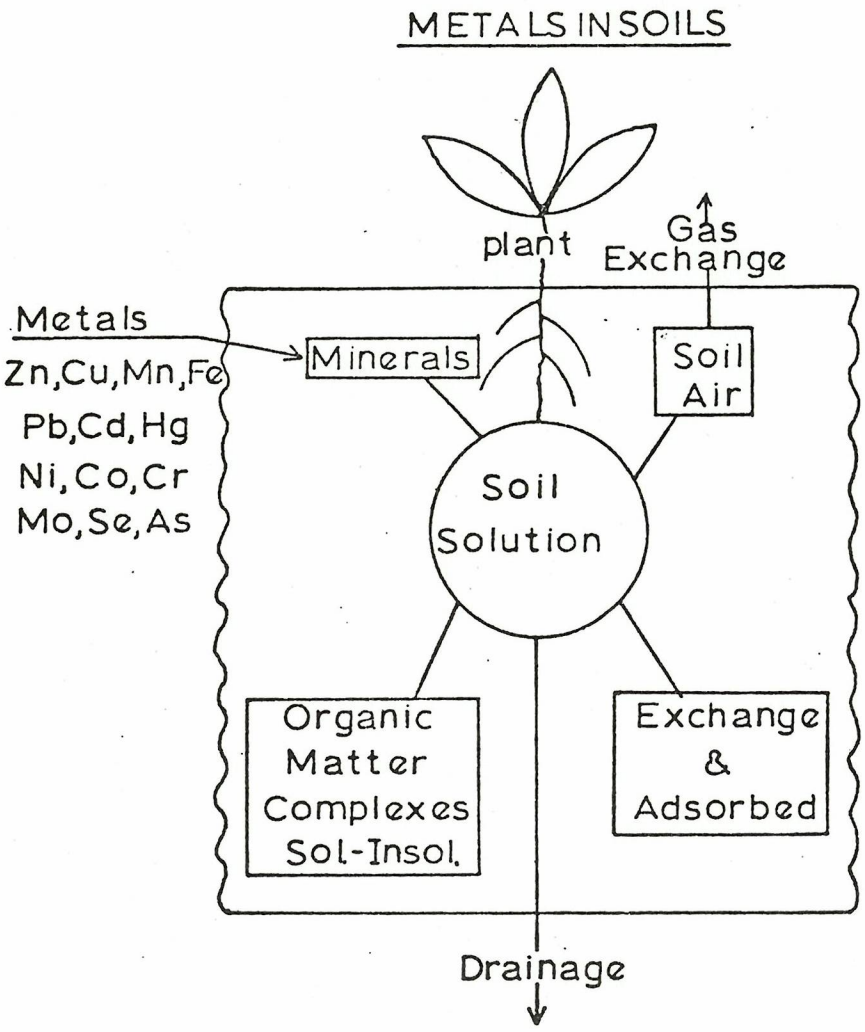


Fig 2. Schematic representation of equilibria involved when metals are added to soils (Lindsay, 1975).

of metals in the solution. Metals in solution (as charged ions) can participate in surface adsorption and exchange reactions depending upon their ability to compete and displace ions already held there. Others interact with the organic matter in the soil to form chelates and may be able to move through the soil as a chelate much more rapidly than they can as an ionic species, e.g. iron chelates. Other compounds may be transformed to organometallics through the action of the microbial population in the soil and again their ability to move through the soil or to be taken up by plants will depend on the properties of the organo-

metallic ions so formed, e.g. methylmercuric ions are more mobile in soils than mercuric ions.

Some metals such as mercury and selenium form volatile compounds that can escape to the atmosphere. To do this the mercuric ion has to be reduced to the metal form which has a gaseous phase and can diffuse through the soil pores to the atmosphere.

As the intent of this talk is to focus on the fate of metals in an irrigation effluent solution, it must be realized that in many cases more irrigation water will be put on the soil than the plants will use. This may be necessary to ensure the downward movement of salts and to prevent the accumulation of a saline solution in the rooting zone. With the movement of the alkali earth and alkali metals you can remove some of the heavy metals in the drainage water. This will depend on the strength of the other reactions depicted in the diagram in Fig. 2. In some cases, the movement of ions in drainage water is assisted by the formation of an organic metal complex while it will be retarded by the presence of ions that are held on the exchange complex or in an adsorbed form.

As far as the uptake of these metals by plants is concerned, the first consideration will be the concentration or activity of the ions in the soil solution. This plus the ability of the ions to move in the soil will decide on the concentration of ions at the root surface. Plant uptake of these ions will not necessarily be related to concentration alone as there can be blocking mechanisms to ionic uptake at the root surface or in the root itself (Gracey and Stewart, 1974; Hogg et al., 1978a, b).

One of the most important environmental factors that governs the concentration of ions in the soil solution is pH. Fig. 3 shows the concentration of zinc in solution as it would be affected by pH. This

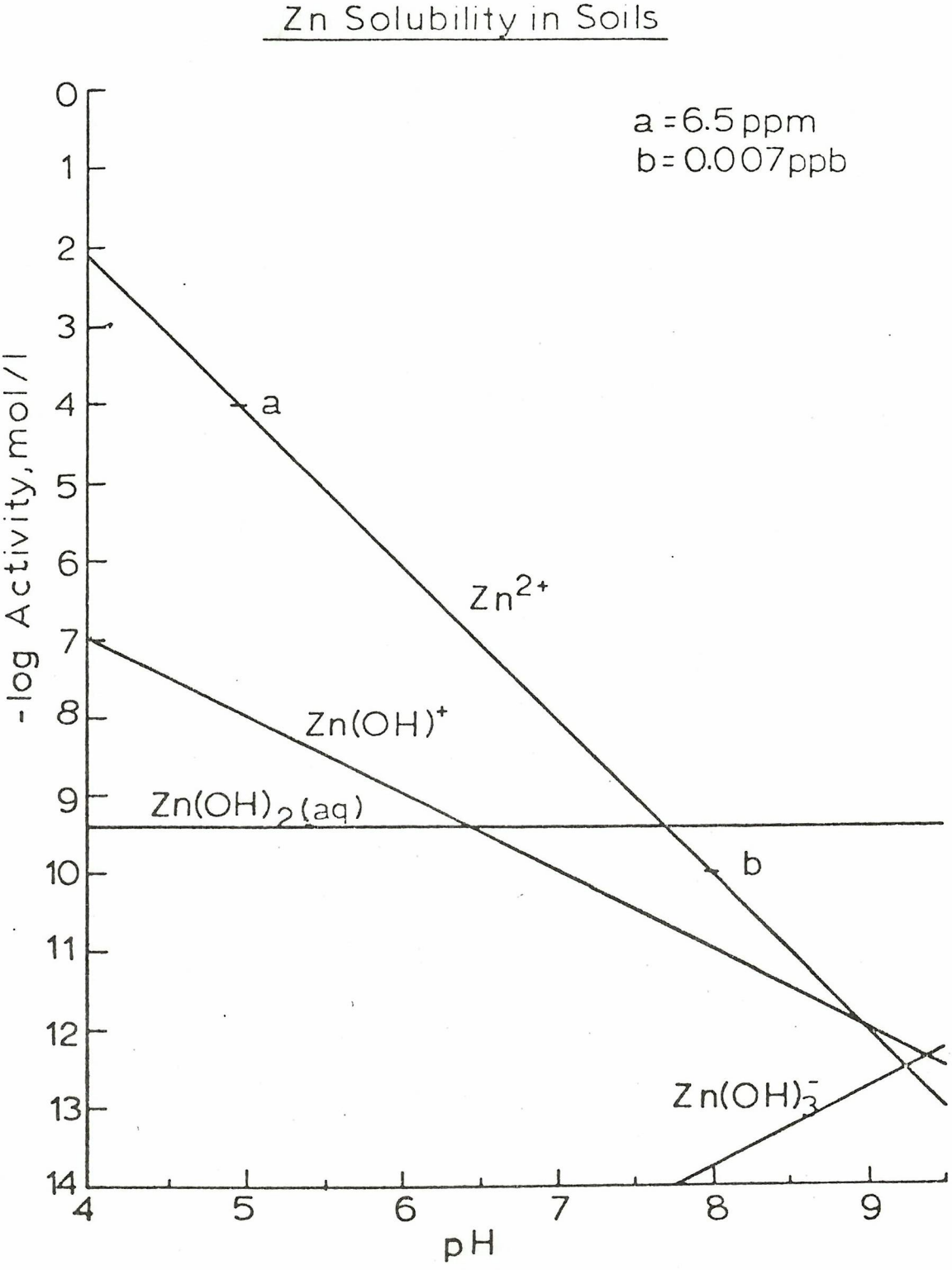


Fig. 3—Soluble Zn species in solution in equilibrium with soil Zn.

type of result is common with many of the micronutrient cations where the availability and uptake of ions may be markedly reduced by raising the pH by such practices as liming the soil or adding sewage effluent high in Ca and Na. The converse of this may be found with the micronutrient anions as exemplified by the availability of molybdenum with pH (Fig. 4). It can be seen that raising the pH of the soil increases the amount of molybdenum in the soil solution.

Addition of Organic Wastes and Wastewater on Land

Nearly all sewage waters and wastes contain levels of micronutrients higher than those present in soils and agronomists have studied the long term effects of waste applied microelements. Some microelements, zinc, copper, boron and iron in wastes may serve to correct plant deficiencies. Alternatively, repeated or unwise use of wastes may lead to phytotoxicities of zinc, copper, nickel or boron. Further, certain non-nutrient micro-elements cadmium, lead and mercury, present in some wastes are of concern to agronomists, nutritionists and environmentalists because of their hazard to animal or human health. High concentrations of other micro-nutrients such as molybdenum present in wastewaters may induce copper deficiencies in animals eating the herbage produced on the irrigated land. During the course of this paper, I intend to summarize some of these results and to try to put it in the context of the prairie environment.

Most of our information on the heavy metal content of sewage wastes comes from analysis of sewage sludge (Table 1) rather than sewage effluent as in many cases the concentration of some elements in the latter is too low to measure accurately. The concentration in sewage effluents would be approximately 1000 times smaller.

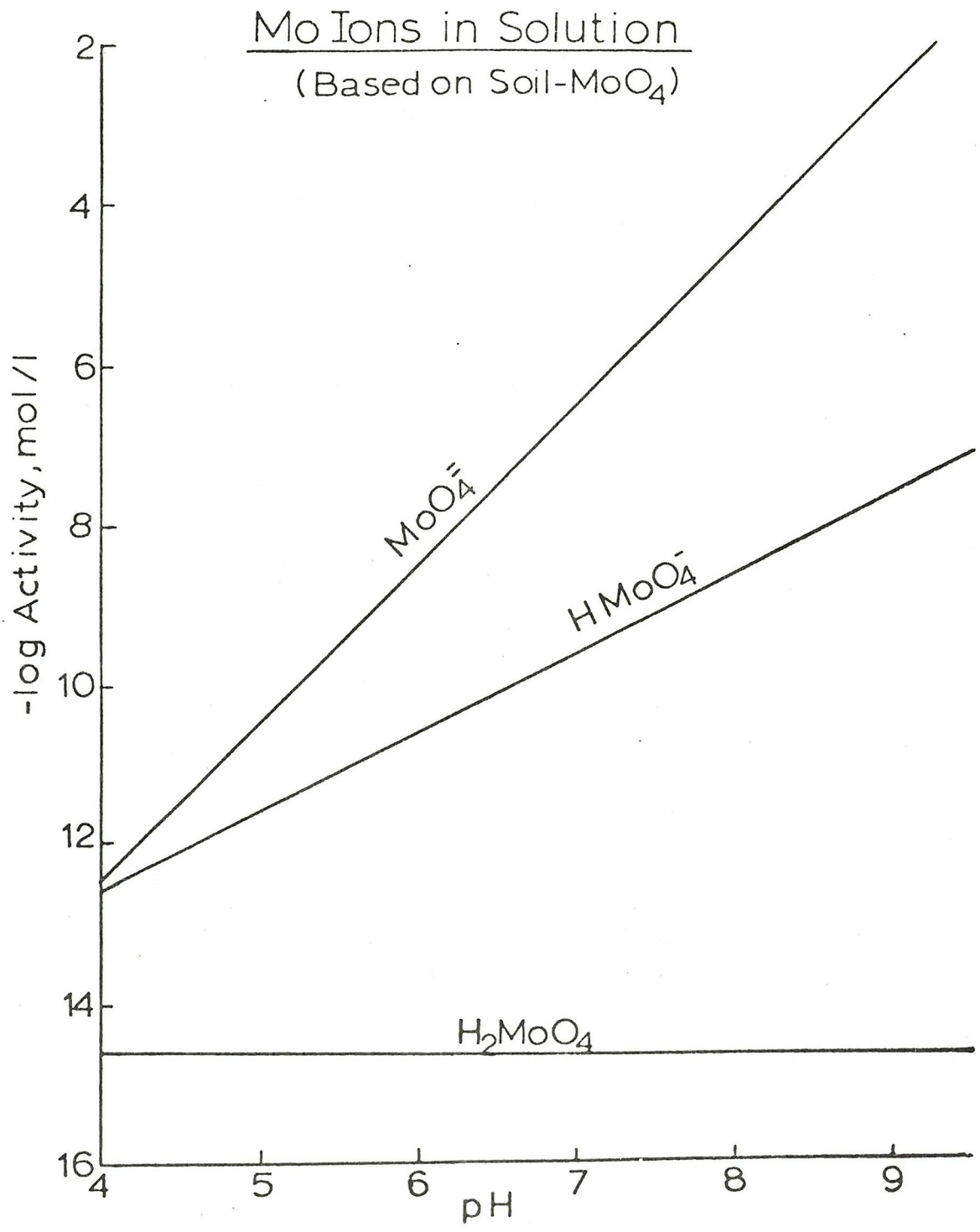


Fig. 4 —Soluble Mo(VI) species in equilibrium with soil Mo.

Table 1. Metal content of digested sewage sludges (ppm).

	U.S. Data			Canadian Prairie Cities			Soil Level
	Newer Suburban	Maximum Domestic	Maximum Industrial	Edmonton	Lethbridge	Winnipeg	
Zn	750	2500	50,000	1200	850	1950	100
Cu	250	1000	17,000	400	1200	265	30
Ni	25	200	8,000	160	70	80	40
Cd	5	25	3,400	23	7	10	1
Pb	-	1000	10,000	420	220	350	20
Hg	2	10	100	6	8	5	.04
Cr	50	1000	30,000	2000	240	870	27
B	4		680				
Mo	2		1,000				
As	0.5		30				

Compiled from Chaney and Giordano (1978), Zwarich and Mills (1970) and Dudas and Pawluk (1975).

Total dissolved solids in sewage effluent composition in Saskatchewan samples varies from 500 to 5,000 mg/litre (averages 1000 mg/l). Bole and Bell (1978) in a study of the land application of municipal sewage waste water in southern Alberta using a 15% leaching requirement and a 75% irrigation efficiency found that they needed to apply up to 152 cms of irrigation water per hectare of forage crops per year. This would mean an application of 7.5 to 75 metric tons of total dissolved solids per hectare depending on the concentration of the effluent. If the zinc content of the solid material in the effluent averaged 500 ppm (from sewage sludge data) then this means an application of 3.8 to 38 kg Zn/ha (average 7.6 kg). This is far in excess of plant needs.

Similarly, it can be calculated that a similar irrigation treatment of 152 cms/ha/annum would supply much more heavy metal or micronutrient than the forage plants require. What then happens to it in the soil?

This was the question asked of the University of Saskatchewan in 1972. First research efforts were centered on mercury as (a) there had been attention focussed on this element through reports of mercury

poisoning from fish, (b) by reports that fish from the South Saskatchewan River had high total mercury contents, (c) the City of Saskatoon had a new sewage plant and wanted to get rid of the sewage sludge, and (d) this meant that research funds became available from Canada Agriculture and the National Research Council to study the problem. The first task was to find a method of measuring mercury at nanogram levels (Hamm and Stewart, 1973) and to obtain information on background levels in Saskatchewan soils and major crops (Gracey and Stewart, 1974). Movement in soil and plant uptake of the three most common forms of mercury (mercuric chloride $HgCl_2$, methyl mercuric chloride MMC and phenyl mercuric acetate PMA) found in the environment were then researched in a series of laboratory, greenhouse and field experiments (Gracey and Stewart, 1974; Hogg et al., 1978a, b). Results indicated that both inorganic forms of applied mercury move to a small extent in the soil profile when subjected to effluent irrigation. Even in light textured soils of low organic matter, leaching of mercury into ground water systems is unlikely to occur. However, considerable accumulation (Tables 2 and 3) of mercury was found in plant-root systems but only small quantities were translocated to above ground plant parts.

Table 2—Dry matter yield and Hg concentration of bromegrass dry matter grown on Asquith and Oxbow soils under simulated fall conditions (42 days from third harvest) as detected by flameless atomic absorption analysis.

Treatment		Asquith		Oxbow	
Hg compound	Irrigation rate	Dry matter yield	Hg conc. FAA	Dry matter yield	Hg conc. FAA
	mm/season		ng/g DM		ng/g DM
$HgCl_2$	457	0.91 ± 0.21	242 ± 27	1.20 ± 0.35	119 ± 26
$HgCl_2$	686	1.23 ± 0.24	232 ± 16	1.41 ± 0.24	142 ± 41
PMA	457	0.85 ± 0.10	254 ± 16	1.59 ± 0.37	141 ± 41
PMA	686	1.23 ± 0.12	214 ± 13	1.51 ± 0.15	150 ± 28
MMC	457	1.12 ± 0.11	292 ± 31	1.82 ± 0.68	304 ± 12
MMC	686	1.05 ± 0.10	275 ± 40	1.64 ± 0.11	277 ± 43
Control	686	0.73 ± 0.22	122 ± 5	1.28 ± 0.19	96 ± 20
Treatment L.S.D. (0.05) = 0.26			44	N.S.†	50

† Not significant.

From Hogg et al. (1978b).

Table 3. Mercury concentrations of bromegrass stems and roots from the Asquith and Oxbow soil as detected by flameless atomic absorption (FAA).

Treatment		Mercury Concentration (µg/g DM)						
Mercury Compound	Irrigation Rate (mm/season)		0-10 cm					
		Stems	Main Roots	Fine Roots	10-20 cm	20-30 cm	30-40 cm	40-60 cm
				ASQUITH				
$HgCl_2$	457	0.74	26.89	43.22	4.29	0.65	0.18	0.19
$HgCl_2$	686	0.67	24.39	55.72	7.59	0.59	0.26	0.16
PMA	457	0.88	26.10	93.22	24.29	2.46	0.29	0.20
PMA	686	0.80	20.49	79.49	17.99	0.92	0.32	0.23
MMC	457	0.73	42.49	102.47	16.58	4.82	1.29	0.86
MMC	686	0.71	37.29	89.97	44.76	7.33	3.03	0.88
Control	686	0.095	0.11	0.08	0.08	0.07	0.05	0.06
				OXBOW				
$HgCl_2$	457	0.43	8.39	32.32	4.56	1.13	0.29	0.59
$HgCl_2$	686	0.39	14.59	27.21	2.23	1.09	0.44	0.56
PMA	457	0.60	14.79	35.69	5.67	2.36	1.09	0.62
PMA	686	0.72	17.28	27.72	8.25	1.70	0.49	0.30
MMC	457	0.59	10.29	36.58	9.98	0.63	0.70	1.06
MMC	686	0.44	18.09	59.11	11.75	3.75	0.66	1.43
Control	686	0.09	0.29	0.18	0.07	0.07	0.05	0.04

Not all the applied mercury was recovered in either the soil or plant material (Table 4). Careful analyses lead to the conclusion that this material was lost to the atmosphere. That quantity remaining in the soil appeared to be tightly held being neither removed by the plant roots

Table 4. Percentage of the total applied mercury recovered in soil and plants at the termination of the experiment.

Treatment		% recovery			
		Asquith		Oxbow	
Mercury compound	Irrigation rate (mm/season)	Plant material	Soil	Plant material	Soil
$HgCl_2$	457	1%	70%	1%	90%
$HgCl_2$	686	1%	71%	1%	85%
PMA	457	2%	74%	1%	87%
PMA	686	2%	76%	1%	89%
MMC	457	2%	78%	1%	79%
MMC	686	2%	82%	2%	75%

nor by subsequent extraction with either 0.5 N or 1.0 N HCl. It can therefore be stated that the hazard to animal health from the application of mercury to soil in sewage effluent is minimal due to the capacity of the soil to fix mercury in plant unavailable form and to the fact that mercury is not translocated easily within the plant.

Similar research on the uptake of native and applied lead (Karamanos et al., 1976) from soil showed that lead was rapidly immobilized in soils (especially soils with high organic matter content) resulting in a low concentration in the soil solution. Further, lead is subjected to a

barrier at the plant roots which limits further translocation into plant tops. Although marked differences were observed in the chemical extractability of added lead in the soils examined, these differences were not reflected in the lead concentration in the plant tops mainly due to the barrier to lead concentration at or in the roots (Tables 5 and 6).

Cadmium is the other heavy metal that may cause problems in the prairie environment. When people absorb cadmium it is accumulated in the kidney and liver. Major sources of cadmium in humans are thought to be food and smoking.

Field experiments generally show that plant Cd levels increase with sludge or waste water application. Translocation of cadmium within the plant may not be very efficient for instance corn growing on a sludge disposal farm in Ohio where the soil cadmium 2 to 50-70 ppm Cd. The corn

Table 5. Dry matter (g/pot) and concentration of total and applied lead (μg Pb/g DM) in bromegrass tops

	Asquith		Oxbow		Waitville		
	20 ppm	100 ppm	20 ppm	100 ppm	20 ppm	100 ppm	LSD
			1st harvest (0–90 days)				
Yield	0.84	0.99	2.52	2.32	2.61	2.78	0.27
Total Pb	4.2	8.0	3.7	8.9	3.7	9.0	0.8
Applied Pb	4.1	8.1	3.2	8.2	3.3	7.8	0.8
			2nd harvest (90–120 days)				
Effects of applied sulphur							
−S							
Yield	1.13	1.07	2.31	2.37	2.63	2.56	0.22
Total Pb	5.6	11.1	4.8	11.2	3.3	8.0	0.9
Applied Pb	5.6	10.2	4.8	8.7	2.9	7.4	1.0
+S							
Yield	1.49	1.37	2.60	3.10	3.02	3.03	0.22
Total Pb	3.8	10.2	4.4	10.2	3.5	7.6	0.9
Applied Pb	3.3	10.4	4.1	9.5	3.3	7.8	1.0
			3rd harvest (120–160 days)				
Effects of temperature and photoperiod							
−S							
Yield	1.05	0.80	1.89	2.08	2.41	2.47	0.22
Total Pb	4.8	12.6	5.2	9.1	3.0	9.5	0.9
Applied Pb	5.0	12.7	5.1	9.2	3.1	9.2	1.0
+S							
Yield	1.07	1.28	2.27	2.97	2.88	2.88	0.22
Total Pb	4.8	12.7	4.8	11.2	3.8	11.0	0.9
Applied Pb	4.0	11.3	3.9	10.0	2.9	10.0	1.0

From Karamanos et al. (1976).

Table 6. Dry matter yield (g/pot) and concentration of total and applied lead (μg Pb/g DM) in bromegrass roots

	Asquith		Oxbow		Waitville	
	20 ppm	100 ppm	20 ppm	100 ppm	20 ppm	100 ppm
			Main roots			
−S						
Yield	1.02	1.43	4.06	4.73	2.61	2.18
Total Pb	13.0	28.8	3.6	21.4	4.4	39.7
Applied Pb	11.8	25.5	3.1	22.0	3.7	30.2
+S						
Yield	1.28	1.40	4.55	5.04	2.97	2.88
Total Pb	11.1	35.0	6.5	23.0	4.7	44.4
Applied Pb	10.3	32.0	6.1	20.4	3.5	39.4
			Fine roots			
−S						
Yield	0.74	0.83	4.29	5.13	2.81	2.54
Total Pb	28.7	134.2	19.8	80.4	16.4	104.3
Applied Pb	24.2	123.3	18.5	75.4	12.2	78.0
+S						
Yield	2.20	1.98	4.65	5.13	3.30	3.30
Total Pb	32.5	172.2	24.7	102.0	26.2	132.0
Applied Pb	28.0	157.0	20.8	98.3	19.4	106.7
			Total roots			
−S						
Yield	1.76	2.26	8.35	9.86	5.42	4.72
Total Pb	19.6	67.5	11.9	52.1	10.2	74.5
Applied Pb	17.0	61.4	11.0	49.8	8.1	55.9
+S						
Yield	3.48	3.38	9.20	10.17	6.27	6.18
Total Pb	24.6	115.4	15.7	62.8	16.0	91.2
Applied Pb	21.5	105.2	13.4	59.7	11.9	75.3

From Karamanos et al. (1976).

leaves increased from 2.1 to 14 and 24 ppm Cd but the corn grain was increased only from 0.8 to 0.9 and 1.0 ppm Cd in the control, sludge treated and supernatant areas. In contrast to these results, work carried out in Agassiz, B.C. (John et al., 1972), found very high levels of cadmium in the edible portions of radish and lettuce grown in soil treated with 100 ppm Cd.

Changes in pH and organic matter levels through effluent irrigation tend to diminish increases in cadmium content in plants as does the joint application of zinc with cadmium. Increased zinc reduced cadmium uptake in dicotyledon plants but the results with monocotyledons are not clear.

Summary

Chaney and Giordano (1977) provided a general summary of observation on plant uptake of metals from sludge amended soils. "Zn, large increases: Mn, usually increased Cd, nearly always increased somewhat; Cu, increased a little with small additions and then generally reaches a plateau; Ni, increases somewhat; Pb, often decreased a little; Hg, only small changes; and Se, Mo, As, etc., to little data to make judgement at this time". Increases in Hg, Pb and Cd have to be monitored very closely because of their potential impact in the food chain. Also the major influences on metal uptake such as changes in pH, organic matter, available P must be carefully monitored to prevent deficiencies or toxicities of micronutrients occurring under sewage effluent irrigation.

Any municipality practising sewage effluent irrigation should monitor effluent, soil and plant product carefully. However, in the prairie environment there is unlikely to be any cause for alarm.

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Soil and Plant Response to Wastewater Irrigation: Nutrient Uptake and Plant Productivity[1]

J. B. Bole and V. O. Biederbeck[2]

Wastewater treatment must remove harmful constituents from the water before returning it to the biosystem. Our concept of harmful constituents has broadened from solid wastes and pathogenic organisms to include organic material and nutrients. Most treated wastewater is returned to a water body and the latter two fractions can lower the dissolved oxygen content of the water body and enhance the growth of aquatic macrophytes.

Most pollutants are natural resources out of place. By irrigating crops with the wastewater we can return these resources to the food chain and use both the nutrients and the water for food production while completely renovating any return flow.

This paper will present results from research studies conducted at Taber, Alberta, and Swift Current, Saskatchewan. Other papers in this proceedings present details of the respective municipal wastewater irrigation systems operating at the two locations.

Role of the Plants

Plants are an important component of a successful wastewater utilization system. The crop selected for irrigation should:-

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[1]Paper presented at the seminar on Effluent Irrigation under Prairie conditions. Regina, Saskatchewan, January 24-25, 1979.

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1) Take up high levels of nutrients so when the crop is harvested the nutrients are removed from the biosystem and returned to the food chain.

2) Transpire water at a high rate over a long growing season so as to minimize the area of land required for irrigation and the lagoon capacity required for winter storage.

3) Stabilize the soil to prevent erosion by wind or water.

4) Maintain soil structure to maintain or improve the water infiltration rate and permeability of the soil.

5) Provide food or fiber for society without transmitting any harmful pathogenic organisms or harmful levels of nutrients, or heavy metals into the food chain.

6) Tolerate the limited or excess moisture levels, salts, diseases, or other stresses specific to the system.

7) Provide a cash return to cover operating the system and perhaps a return on the capital investment.

Forage crops have been selected for most municipal and industrial wastewater utilization systems in Western Canada (Bole et al., 1976; Oldham, 1974) because they meet most or all of the above criteria. Because forages are not eaten directly by humans, the transfer of human diseases is unlikely.

Experimental Design

Taber.--Forage plots have been spray-irrigated with municipal wastewater from the town of Taber, Alberta, since 1972, at rates approximating (I_1) and

double (I_2) the seasonal evaporation minus precipitation deficit (about 50 cm). Commercial ammonium phosphate and ammonium nitrate fertilizers were applied at 0 and 56 kg/ha N and P each year. Two harvests are made annually.

The experimental design was a 2 x 2 factorial for effluent and fertilizer levels replicated four times. Two-meter-wide strips of alfalfa, reed canary grass, and smooth bromegrass were split on each whole plot. The design also included an uncropped control and two dryland grasses, Altai wild ryegrass and tall wheatgrass. These species were invaded by the irrigated forages and recently removed from the design.

The soil is a Brown Chernozemic Cavendish loamy sand with an infiltration rate of about 15 cm/hr. It is underlain (1 to 3m) by a relatively impermeable (CL-C) subsoil. Before the plots were established, the vegetation was a native Stipa-Bouteloua grassland of very low productivity.

The water was suitable for irrigation since it contained about 1,000 ppm salts and had an SAR of 1.7 to 3.4 (Table 1). The salts were largely Na, Ca, and Mg sulfates and bicarbonates. Most of the N was in the ammonium form.

Swift Current.--A 4-ha plot of alfalfa has been spray-irrigated with municipal wastewater since 1973. Sufficient irrigation water was applied to meet the evaporative demand of the crop.

Yield samples are taken from each of the four soil series. The orthic soil is the dominant series (more than 80%), thus representative orthic soils on adjacent sites are irrigated with Swift Current creek water or retained as a non-irrigated control.

Table 1. Mean chemical composition (ppm) of the municipal wastewater used to irrigate forages

Constitutent	Taber	Swift Current
Kjeldahl-N	17.2	17.4
NH_4-N	13.9 (8.6-23.9)*	9.2
NO_3-N	1.0 (0.1-3.0)	0.1
Total-P		7.2
PO_4-P	4.0 (2.9-5.8)	4.2
Na	152 (99-198)	328
Ca	86 (64-114)	106
Mg	55 (41-74)	134
K	31 (16-82)	26
SO_4	284 (15-500)	418
HCO_3	555 (354-1043)	707
Cl	57 (53-60)	162
Total salts	1066 (720-1261)	1625

*Range of annual mean levels.

The soil is a well drained Brown Chernozemic Birsay clay loam underlain by glacial till. The soil was previously in a 2-year wheat-fallow rotation. Roamer (cv.) alfalfa is harvested twice annually. Three cuts were made in 1975.

The Swift Current wastewater has a slightly lower quality for irrigation than that used at Taber since it contained an average of 1625 ppm total salts.

Yield Responses of Forages

A. Taber

In the initial year of the Taber study, there were no differences between the yields of the alfalfa, reed canary grass, or bromegrass (Table 2-A). Yields were increased by the high wastewater level as was noted again in 1973 (Table 2-B). Frequent equipment failure of the town's pumping system in the first few years of the study resulted in the plants suffering drought stress for 2-4 weeks despite the fact that the total annual water application, even at the low irrigation level, met or exceeded the net evapotranspiration.

Grass yields were similar to that of the legume in the first 2 years; however, in 1974, the yields of grasses receiving low levels of effluent and no fertilizer were greatly reduced, while those of the grasses receiving both the high irrigation rate and fertilizer exceeded the alfalfa yields (Table 2-C). It will be shown later that the grass yields are controlled by the N supply. In the initial two years, higher wastewater-N application and N mineralization on the newly broken soil supplied sufficient N for the grasses. However, in 1974, and in succeeding years, the alfalfa yields exceeded those of the grasses because of the reduced grass yield at the unfertilized, low wastewater treatment.

Table 2. Annual dry matter yield of the forage species at Taber as a function of wastewater and fertilizer levels

Irrigation (cm/year)	Fertilizer N-P ($Kg \cdot ha^{-1} year^{-1}$)	Alfalfa	Reed canary	Brome	Mean
		metric tons/ha			
A.			1972		
75	0- 0	5.45	7.31	6.70	6.49 c
	56-24	6.48	7.32	8.11	7.30 b
150	0- 0	9.46	8.65	8.32	8.81 a
	56-24	8.87	7.61	8.20	8.23 a
Mean		7.57 a*	7.72 a	7.83 a	7.71
B.			1973		
75	0- 0	6.96	6.29	6.75	6.67 c
	56-56	7.35	8.37	7.93	7.88 b
150	0- 0	9.67	8.79	9.97	9.48 a
	56-56	9.39	10.39	9.74	9.84 a
Mean		8.34 a	8.46 a	8.60 a	8.47
C.			1974		
50	0- 0	6.02	2.99	3.66	4.22 c
	56-56	8.09	6.91	6.96	7.32 b
100	0- 0	7.64	7.56	7.71	7.64 b
	56-56	7.33	9.13	8.81	8.42 a
Mean		7.72 a	6.65 b	6.78 b	6.90
D.			1975		
50	0- 0	16.30	6.62	6.81	9.91 c
	56-56	15.84	12.67	12.67	13.73 b
100	0- 0	14.03	12.40	13.82	13.42 b
	56-56	14.60	18.79	17.69	17.03 a
Mean		15.19 a	12.62 b	12.75 b	13.52
E.			1976		
47	0- 0	11.62	2.58	2.96	5.72 c
	56-56	13.38	6.27	5.68	8.44 b
94	0- 0	11.81	7.48	8.39	9.23 b
	56-56	12.52	9.98	9.95	10.82 a
Mean		12.33 a	6.58 b	6.75 b	8.55
F.			1977		
52	0- 0	9.40	3.24	3.69	5.44 c
	56-56	11.04	6.83	6.71	8.19 b
104	0- 0	11.88	7.09	6.73	8.57 b
	56-56	11.15	9.97	9.13	10.09 a
Mean		10.87 a	6.78 b	6.57 b	8.07
G.			6-year average		
58	0- 0	9.29	4.84	5.10	6.41 d
	56-51	10.36	8.06	8.01	8.81 c
116	0- 0	10.75	8.66	9.16	9.53 b
	56-51	10.64	10.98	10.59	10.74 a
		10.26 a	8.14 b	8.21 b	8.87

*Within a year, means in a row or column followed by by the same letter do not differ significantly at the 5% level by Duncan's multiple range test.

In 1975, yields were higher than in the other years of the study because May-August rainfall totalled 266 mm, while 1976 totalled 222 mm, and the other four years had from 128 to 141 mm (Table 2-E). Moisture sufficiency and above-average heat unit supply combined to maximize yield. The yield trends were similar to those of 1974. Grass yields were severely reduced at the unfertilized low wastewater treatment but exceeded the alfalfa yield with additional wastewater and fertilizer.

In 1976, alfalfa yields exceeded the grass yields at all treatments and were four times greater when the forages were irrigated at the net ET level, without fertilizer (Table 2-E). Similar results were obtained in 1977 (Table 2-F). An increasing problem of alfalfa winterkill at the high irrigation level has been noted in these two years; however, this is not reflected in the data since unaffected areas were sampled.

The mean yields over the six years of the Taber study show that the addition of NP fertilizer at both irrigation levels and, correspondingly, the application of excess wastewater with and without fertilizer have not affected alfalfa yield but have resulted in marked increases in the yields of both reed canary grass and bromegrass. Clearly, the N-fixing ability of the legume has given it a marked yield advantage over the grasses unless additional N is supplied by fertilizers or in the wastewater.

B. Swift Current

Annual alfalfa yields were similar on the four soil profiles, increasing slightly at the mid- and lower-slope, orthic and cumulic orthic

soil types of the catina (Table 3). On the orthic soils, wastewater has produced higher yields than creek water each year except 1974. The non-irrigated alfalfa was difficult to establish and yields have been about one-half those obtained with irrigation. Clearly, most of the alfalfa yield response to wastewater is due to the water rather than the dissolved nutrients.

It was anticipated that the soil-P reserves would be depleted on the creek water irrigated soil resulting in a differential yield advantage for wastewater irrigation. This may account in part for the slightly greater yields due to wastewater irrigation, especially since the yield differential has increased in 1976 and 1977.

Nitrogen Uptake by the Forages

A. Taber

In the initial year of the study, N application at all treatments, exceeded N uptake by the forages (Table 4-A). In 1973, however, N uptake exceeded application (Table 4-B). Since alfalfa yields did not differ from the grass yields, N applied in 1972 must have been stored over the winter and, combined with mineralization of organic-N, supplied sufficient N for maximum yields. The higher N uptake by the alfalfa is a reflection of the inherent higher protein content of the legume rather than a higher yield.

In 1974 and in successive years, N uptake by the forages was limited by the N supply (Table 4-C). N uptake by alfalfa greatly exceeded that of the grasses, especially at low wastewater levels. Wastewater-N gave a similar response to fertilizer-N. The I_1F_1

Table 3. Annual dry matter yield of alfalfa at Swift Current

Year	Wastewater irrigated				Creek water irrigated	Non-irrigated
	Orthic regosol	Cal-careous	Orthic	Cumulic orthic	Orthic	Orthic
1974	6.85	6.59	6.55	7.85	5.93	-
1975	7.07	7.72	8.81	9.29	9.17	-
1976	7.60	8.28	9.34	9.77	8.39	3.99
1977	10.08	9.31	11.26	10.64	9.37	4.75
Mean	7.90	7.98	8.99	9.39	8.22	4.37

Table 4. Uptake of N by the forage species at Taber as a function of wastewater and fertilizer N levels

Treatment	N applied	Forage: Alfalfa	Reed canary	Brome	Mean
		kg/ha			
A.		1972			
I_1F_0*	205	188	176	176	180 c
I_1F_1	261	217	198	229	215 b
I_2F_0	410	325	237	229	264 a
I_2F_1	466	281	241	253	258 a
Mean		253 a†	213 b	222 b	229
B.		1973			
I_1F_0	74	219	149	151	173 d
I_1F_1	130	206	221	200	209 c
I_2F_0	148	286	224	224	245 b
I_2F_1	204	287	294	274	285 a
Mean		249 a	222 b	212 b	228
C.		1974			
I_1F_0	52	184	59	60	101 c
I_1F_1	108	229	138	110	159 b
I_2F_0	104	205	141	121	156 b
I_2F_1	160	219	200	151	190 a
Mean		209 a	134 b	111 c	151
D.		1975			
I_1F_0	58	490	113	105	236 c
I_1F_1	114	474	216	206	299 b
I_2F_0	116	389	226	224	280 b
I_2F_1	172	446	352	331	376 a
Mean		450 a	227 b	217 b	298
E.		1976			
I_1F_0	66	329	49	55	144 c
I_1F_1	122	351	120	102	191 b
I_2F_0	132	316	143	148	202 b
I_2F_1	188	313	192	165	223 a
Mean		327 a	126 b	117 b	190
F.		1977			
I_1F_0	85	235	59	71	122 c
I_1F_1	141	283	135	121	180 b
I_2F_0	170	300	134	119	184 b
I_2F_1	226	273	188	143	202 a
Mean		273 a	129 b	114 b	172
G.		6-year average			
I_1F_0	90	274	101	103	159 c
I_1F_1	146	293	171	161	209 b
I_2F_0	180	304	184	178	222 b
I_2F_1	236	303	245	220	256 a
Mean		294 a	175 b	166 b	212

*I_1 and I_2 = irrigation at low and high levels (see Table 2); F_0 and F_1 = no fertilizer and N fertilizer at 56 kg/ha^{-1} year^{-1}.

†Within a year, means in a row or column followed by the same letter do not differ significantly at the 5% level by Duncan's multiple range test.

treatment supplied a similar level of N to that of the I_2F_0 treatment in both 1974 and 1975. The two treatments resulted in similar N uptake by and yields of each of the three forages in both years (Tables 2-C and 2-D). N uptake greatly exceeded N application in the abnormally moist year of 1975; thus N mineralization was still important in N supply.

N uptake by the grasses was dependent upon the N supply in both 1976 and 1977, while the N uptake by the alfalfa was unrelated to treatment (Tables 4-E and 4-F).

N uptake, even by the grasses, has exceeded N application over the six years of the study (Table 4-G). Any N losses by leaching or denitrification have been less than the N supply by mineralization of organic-N. The addition of 56 kg of fertilizer-N/ha annually resulted in the uptake of 70 and 58 kg/ha by the reed canary grass and bromegrass at the low irrigation rate, and 61 and 42 kg/ha at the high irrigation rate. Even at the high irrigation rate, additional N could be fully utilized.

B. Swift Current

The N budget over the first 5 years of the Swift Current study shows that considerably more N has been harvested in the forage than applied with the wastewater (Table 5). Creek water supplied insignificant levels of N. Uptake of N by the wastewater irrigated alfalfa exceeded that by the creek water irrigated alfalfa each year except 1975. The dryland alfalfa took up only 40% as much N as the irrigated treatments and the alfalfa contained an average of 2.79% of N compared to 3.11% for the wastewater irrigated treatment and 3.18% for the creek water irrigated.

Table 5. Nitrogen budget - Swift Current

Year	Wastewater			Water			Dryland	
	Added*	Harvested**	Soil analysis†	Added	Harvested	Soil analysis	Harvested	Soil analysis
	kg/ha							
1973	25	-	194	1.4	-	80	-	-
1974	38	205	231	3.7	193	169	-	-
1975	54	293	203	4.9	296	135	-	212
1976	99	308	192	10.2	289	113	118	154
1977	141	314	281	10.1	266	115	125	139

*Total Kjeldahl nitrogen in irrigation water.

**Sum of two harvests (three in 1975)--orthic soil type.

†NO_3-N plus NH_4-N (0-180 cm) in the orthic soil type after final harvest (October 6-21).

The amount of N obtained by the alfalfa from mineralization of organic-N or fixation of atmospheric nitrogen by the associated microorganisms can be estimated by subtracting N additions from the N uptake and adding the depletion of soil-N. Wastewater irrigated treatments acquired an average of 213 kg N/ha by fixation or from mineralization while creek water irrigated treatments averaged 263 kg/ha and dryland alfalfa 158 kg/ha per year. The reduced dinitrogen fixation on the wastewater irrigated plots probably reflects a feedback control by the added wastewater-NH_4-N rather than any adverse effects of the wastewater on the organisms. It is somewhat surprising that these high levels of N were fixed from atmospheric sources with 192 to 281 kg/ha inorganic-N in the rooting zone of the alfalfa (Table 5). Nitrate is known to retard nodule development (Munns, 1968) and both NO_3-N and NH_4-N cause the inhibition of dinitrogen fixation by nodulated legumes (Eady and Postgate, 1974). Since the N is distributed throughout the rooting zone, the N level in close proximity to the nodules may be too low to adversely affect fixation.

Detailed soil sampling at the Swift Current site has been conducted to determine the rate of N transformations throughout the growing season. The NO_3-N and NH_4-N levels in the surface 15 cm in 1975 are shown as an example (Fig. 1). Since the wastewater-N was applied in the NH_4 form immediate increases in NH_4-N are evident at each irrigation. Mineralization of the NH_4-N to NO_3-N resulted in an increase in NO_3-N between irrigations.

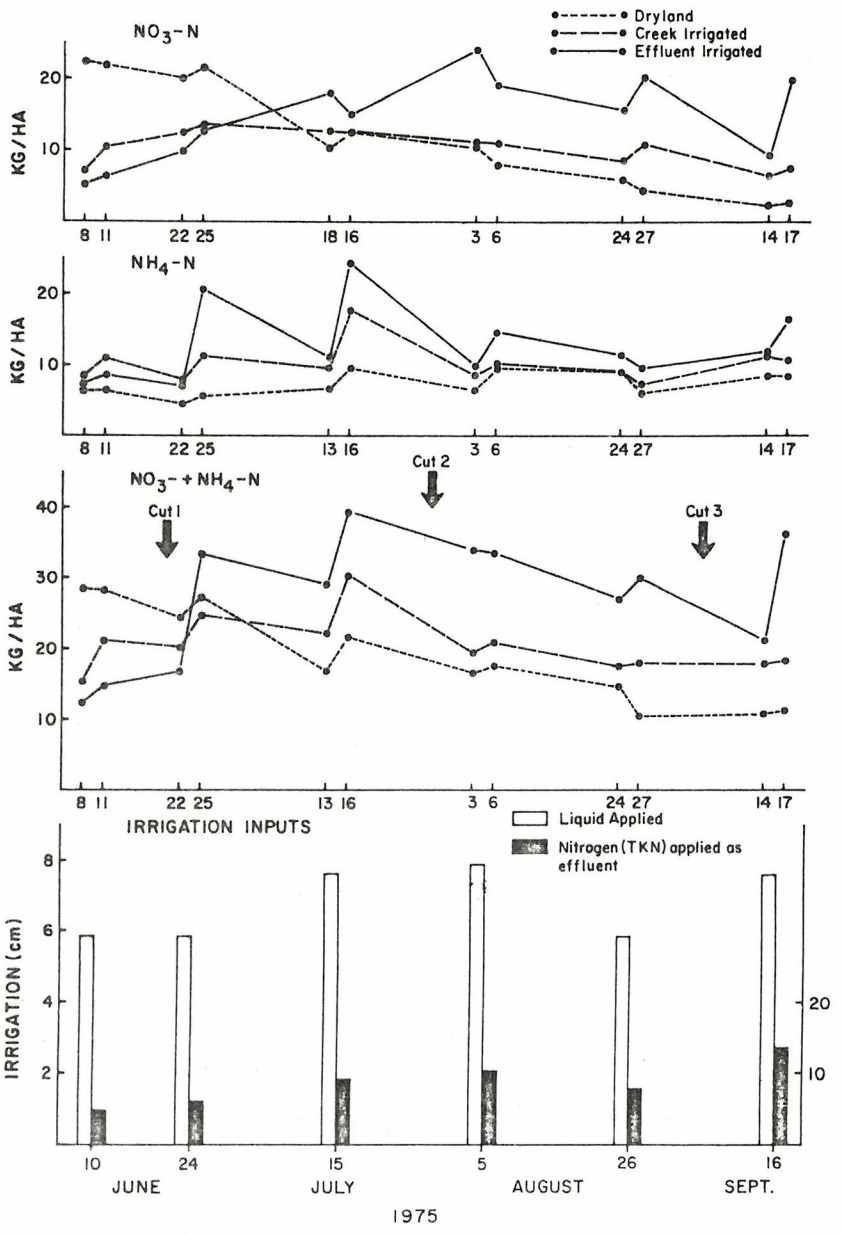


Fig. 1. Plant available-N in dryland, creek water, and wastewater irrigated surface soil (0-15 cm) during the third year of irri gation at Swift Current.

Phosphate Balance

A. Taber

Total P application varied from 107 to 406 kg/ha in the first 4 years of the Taber study, while P uptake by the grasses varied from 98 to 181 kg/ha (Table 6). The increased P uptake was largely due to the increased yield at the I_2F_1 treatments since the average P content of the two grass species only increased from 0.35 to 0.39% with the increase in P application. The excess application did not result in "luxury consumption" of P.

Despite the apparent agreement between P application and P uptake, P has built up in the surface 30 cm of the I_1F_0 treatment. This probably results from the application of organically bound-P and from P mineralization. P has leached to the 60-90 cm depth with the I_2F_1 treatment; but no P has been observed in the groundwater. The apparent agreement between the total increase in available P and the P unaccounted for in plant uptake is probably an artifact since a portion of the increased soil-P must exist in a form non-extractable with $NaHCO_3$.

B. Swift Current

The P level of the surface 30 cm of soil irrigated with wastewater at Swift Current remained relatively constant until 1977 when P application exceeded uptake (Table 7). The P supply has approximated the P requirement of the alfalfa. The $NaHCO_3$ extractable-P level has been depleted from 33 to 19 kg/ha by the creek water irrigated alfalfa. In the initial two years of the Swift Current study the P content of the alfalfa irrigated with water was similar to that irrigated with

Table 6. Level of $NaHCO_3$ extractable P at depth as a function of P application and P uptake by the two grass species in the initial 4 years of the Taber study

Depth (cm)	Available P (kg/ha)		
	Original	I_1F_0	I_2F_1
0- 15	10	63	102
15- 30	7	15	94
30- 60	7	7	48
60- 90	5	6	13
90-120	4	2	5
120-150	2	1	2
Total	35	94	264
P applied (kg/ha)		107	406
P uptake (kg/ha)		98	181
Difference		9	225

Table 7. Phosphorus budget - Swift Current

Year	Wastewater			Water			Dryland	
	Added*	Harvested**	Soil analysis†	Added	Harvested	Soil analysis	Harvested	Soil analysis
1973	18	-	30	.1	-	33	-	-
1974	25	15	26	.8	13	29	-	-
1975	40	21	21	1.5	24	22	-	28
1976	20	26	25	.1	22	18	8	40
1977	40	26	46	.8	18	19	8	35

*Total P in irrigation water.

**Sum of two harvests (three in 1975)--orthic soil.

†$NaHCO_3$ extractable-P (0-30 cm) in the orthic type soil after final harvest (October 6-21).

wastewater. However, the second cut of wastewater irrigated alfalfa in 1976 contained 0.326% P while the water irrigated alfalfa contained 0.292%. In 1977, comparative levels for the first cut were 0.235 and 0.196% P, and for the second cut were 0.228 and 0.185%. It is thus suggested that the P supply in the creek water irrigated treatments has been depleted to an even greater extent than evident in Table 7.

Other Nutrients

Potassium (K) is a macronutrient required by crops in amounts similar to those of N. In the Taber studies, an average of 160 and 320 kg K/ha have been applied at the I_1 and I_2 irrigation levels. The wastewater at Swift Current has applied from 58 to 154 kg/ha (Table 8). Although uptake by the alfalfa far exceeded this level of application, most prairie soils, including those studied, contain large reserves of K and the wastewater-K will not have affected yields. No depletion of the soil reserves at Swift Current is evident (Table 8). On other soils this K could be a valuable constituent of the wastewater.

Sulphur is present in the wastewater in the sulfate (SO_4-S) form. Levels of uptake by plants approximate those of P while 50 to 100 times as much S is applied. Fertilizer S is not required on wastewater irrigated land. Although the wastewater-S is a valuable nutrient, the sulphates can contribute to the buildup of salts in the profile

Ca and Mg application (300-500 and 100-200 kg/ha, respectively) has exceeded plant uptake by a factor of about five. Although these cations are available to plants they are more important in counteracting the adverse effect of Na in the water on soil structure and permeability.

Table 8. Potassium budget - Swift Current

Year	Wastewater		Water		Dryland
	Added	Soil analysis *	Added	Soil analysis	Soil analysis
1973	58	2489	11	2478	-
1974	80	3978	26	3136	-
1975	95	4151	47	3450	3354
1976	89	3774	39	3370	4087
1977	154	3711	45	3200	3185

*$NaHCO_3$ extractable-K (0-180 cm) in the orthic soil type after final harvest.

Wastewater normally contains minimal levels of micronutrients. Analysis of the forage irrigated with wastewater at Taber has shown no buildup or reduction in the Fe, Mn, Zn, or Cu content (Bole and Bell, 1978).

Heavy metal buildup, although a concern with sewage sludge utilization, is not normally a problem with wastewater irrigation. Municipal sewage is low in these cations and the treatment process removes most metals. Metals have not been detected in the Taber wastewater at measurable levels (Hg > 0.005, Pb > 0.005, Cd > 0.002 ppm). The metal content of industrial wastewater should be determined prior to its use for irrigation. Boron can be toxic to plants at levels as low as 1.0 ppm in irrigation water, although forages can tolerate slightly higher levels.

Conclusions Related to Management of Wastewater Irrigation Systems

Excellent yields of alfalfa can be obtained when wastewater suitable for irrigation is applied at rates approximating the seasonal evaporation minus precipitation deficit. Higher rates of application would reduce the productivity per unit of water applied and would result in management problems unless subsurface drainage was provided. The high yields and high levels of N fixation can be achieved for at least 6 years providing that stands are maintained. Little or no advantage can be anticipated from breaking a high yielding stand.

Winterkilling of alfalfa can be a serious problem if the forage is irrigated too late in the fall. Other research at both Lethbridge and Swift Current has shown winterkilling to be enhanced by cutting during September.

If winterkilling of alfalfa is a severe problem or if a site is selected where inadequate drainage may cause temporary flooding in low areas in the spring, grass may be a more suitable forage. Bromegrass and reed canary grass have performed well but required supplementary N fertilizater to achieve optimum yields.

In most areas of the Canadian prairies, municipal wastewater will supply sufficient P, K, S, Ca, Mg, and micronutrients to supplement that supplied by the soil.

Any wastewater utilization system is site specific and should not be contemplated without adequate characterization of the wastewater and soil. Problems should not arise as long as maximum productivity and human safety are considered more important than waste disposal.

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LAND SOIL AND EFFLUENT PREREQUISITES

by

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FOR PRESENTATION TO

EFFLUENT IRRIGATION UNDER PRAIRIE CONDITIONS
TECHNOLOGY TRANSFER SEMINAR

Regina, Sask.

January 24-25-1979

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LAND, SOIL AND EFFLUENT PREREQUISITES

Introduction

The purpose of this paper is to describe the soil and water characteristics important to successful application of waste water to land. Factors will be dealt with in the same order that would be appropriate to a specific situation. Criteria given are generally applicable but specific site conditions will often dictate adjustments to those values given herein.

Objectives

There are six main reasons for considering land treatment which may be present in varying degrees in any given waste water disposal project. These are:

(a) Zero Discharge. A situation where there is no water body or stream within reasonable distance which is adequate to receive and assimilate partially treated waste water.

(b) Difficult BOD and Suspended Solids Standards. The receiving water body is such that a relatively high degree of treatment is required to meet the required standards of Biological Oxygen Demand or Suspended Solids permitted in the water released.

(c) Toxic Wastes Removal. The wastes from industrial operations may contain sufficient toxic substances, especially in short

lethal slugs to upset the operation of conventional biological treatment units.

(d) Nutrient Removal. The receiving water body is such that nutrients present in the effluent (notably phosphorus) are causing or would cause unacceptable levels of algae growth.

(e) Economic Use. The waste water has a potential economic value in crop production resulting from its use.

(f) Water Recovery. Water is scarce enough that the relatively high quality water recoverable as ground water after land treatment has a significant value.

It is necessary to know the general objectives of the particular treatment being considered prior to defining the prerequisite land and water characteristics. In Western Canada there are few, if any, cases where water recovery would be a significant factor.

Type of Land Treatment

There are three basic processes of land treatment:

(a) Low rate or maximum water utilization, defined as application of water at a rate to supply crop and soil requirements,

(b) High rate or rapid infiltration defined as application of water at the highest rate that the soil and underlying geology or artificial drainage system will sustain, crop production being a secondary consideration, and

(c) overland flow, where water is applied at a rate greater than the infiltration rate of the soil and allowed to run off into a collection and disposal system. Crop production is a secondary consideration but a vegetative cover is generally maintained.

The choice and design of a treatment process is site specific and is determined mainly by soil permeability, waste water quality and the objectives of the project. The development of alternatives is iterative in nature requiring perhaps several cycles of site identification, site and process evaluation, refinement of site data and system requirements.

Emphasis in this presentation will be on the low rate process or more specifically irrigation for crop production.

Waste Water Quality

Land treatment of waste water is not generally sensitive to BOD and S.S. content of the waste water. Nutrient levels present in most waste water are beneficial to crop production. Bacteria and health aspects are discussed by others in this seminar and will not be dealt with herein.

The most critical aspect of water quality in land application of waste water is salt content. As one of the main objectives of waste water irrigation is the utilization of the water and

nutrients for crop production, it is essential that the soil system is capable of sustaining a reasonable level of productivity. The main requirement is, therefore, an irrigable soil and a waste water that will not eventually render the soil unproductive.

The first step in project feasibility assessment should be the evaluation of the waste water salts. The salinity, as measured by electrial conductivity (E.C.) and the sodium adsorption ratio (SAR) of the effluent, are most important, as these two parameters govern the life and efficiency of the system. SAR is a measure of the amount of sodium present in relation to calcium and magnesium.

High salinity effluent could result from a saline raw water supply, an industry which discharges a highly saline waste water or excessive evaporation and resultant salt concentration in a lagoon. Waste water with a high SAR value could result from a sodic water supply, an industry using sodium, or extensive use of water softeners.

Although limits for E.C. and SAR vary to some extent, dependent on soils and crops, it is usually considered advisable not to use water with E.C. and SAR values exceeding 2 mmhos/cm and 9 respectively.

Sandy soils tend to be more forgiving of the higher salt levels in the water than clay soils. Most irrigation textbooks contain a water quality rating chart prepared some years ago by the U.S. Salinity Laboratory which details the above relationship.

Leaching Requirement

A very important, but often ignored, aspect of irrigation is the fact that irrigation water, and particularly waste water, contains relatively large amounts of salts compared to rain water. These soluble salts will accumulate and reduce growth if not removed. The only method of removal is to flush, or leach, these salts through the root zone. There are several equations to determine the leaching requirements; in all cases the leaching requirement increases as the salinity of the irrigation water increases. The relative leaching requirement is dependent on the sacrifice in yield one is prepared to accept. In general terms, the leaching requirement may be 5 to 20 percent of the moisture deficit.

Soil Permeability

Soil permeability or the rate at which water can move through the soil is the main characteristic that determines its suitability for irrigation. The leaching requirement referred to above dictates that not only the root zone soils but also the

subsurface soil be permeable or "drainable".

The ideal soil would be a medium texture (sand loam to clay loam) with no seriously restrictive layers of impermeable clay or bedrock in a position to inhibit drainage of the soil profile. Since most prairie soils are underlain by relatively impermeable material the assurance of adequate drainage is one of the major aspects of site selection and/or development. There are numerous permutations of soil profiles, land slopes, natural and artificial drainage combinations which can occur or be developed provided the main ingredient, several feet of permeable soil, is present.

Most provincial governments have established criteria for rating irrigable land and should be consulted when contemplating development.

A formula using standard laboratory determinations which has proven to be fairly reliable is: Saturation Percentage X SAR $\leq$ 300; usually indicates a soil with adequate permeability for most irrigation and drainage requirements.

In complex situations and particularly in large systems where virtually irreversible decisions are involved the operation and monitoring of a pilot project to confirm the project's physical feasibility is recommended.

Geology and Ground water

The leach water from irrigation referred to above will be quite saline and may at times of excess moisture contain nitrates in significant amounts. In general, it is unlikely to have a significant detrimental effect on ground water or surface water of the area, but this aspect should be considered and monitored.

In cases where highly permeable soils exist and a rapid infiltration process is contemplated a positive knowledge of ground water geology and flows along with present and anticipated uses is necessary. Nitrogen loading resulting from the high application rates will likely be far in excess of crop requirements and nitrate contamination of the gound water could result.

Land Availability

Securing suitable land for long-term waste water irrigation is probably the most complex part of initiating a project. The amount and type of land and the land tenure are interdependent with the objectives of the project and the type of process anticipated. Factors such as distance and elevation from the water source, special drainage requirements and potential irrigation methods can have a significant bearing on the economics and management complexity of the project.

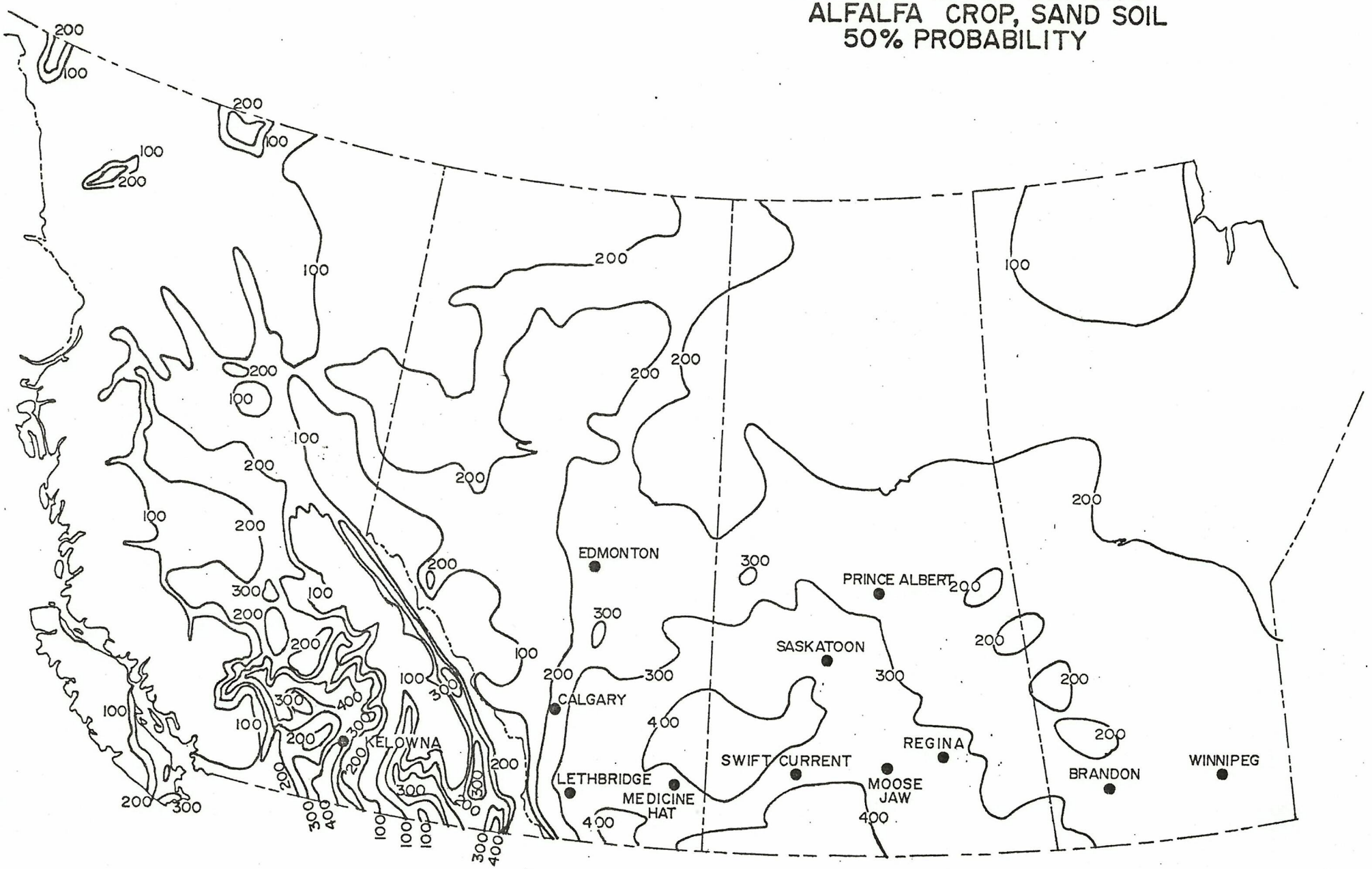
The amount of land required for maximum water utilization will vary with amount and quality of waste water, buffer zone requirements, climate, soil and cropping but will generally range between 70 and 100 acres (28-40 ha) per 1,000 population for municipal effluent.

If rapid infiltration is contemplated, land area requirements are dependent on permeability or hydraulic loading capacity of the site soil, water quality and length of operating season. Area requirements would generally amount to about one-third that of the maximum utilization process, or 20 to 30 acres (8-12 ha) per 1,000 population.

The probable seasonal moisture deficit for an alfalfa crop on a sandy soil is shown in Figure No. 1 for the four western provinces. Moisture deficits for cereal crops would amount to about two-thirds that of alfalfa. These deficits, adjusted for storage and irrigation losses, the leaching requirement and any anticipated crops with different water requirements should form the basis for calculating irrigable area requirements under maximum utilization.

Variations in seasonal rainfall will give variations in moisture deficits in the order of $\pm$ 30 percent in a given season. This problem should be addressed and at least tentative management

SEASONAL WATER DEFICITS*
ALFALFA CROP, SAND SOIL
50% PROBABILITY



* ADAPTED FROM MAP I AGROCLIMATIC MAPS FOR CANADA

techniques developed at the planning stages.

In Figure 2, the upper part of the graph shows a typical crop use pattern and the lower part represents water which might be applied in excess of crop needs either in a rapid infiltration process or in a wet year when supply exceeds demand. The maximum value of this excess application is determined mainly by the subsurface drainage capabilities of the site.

Buffer zone requirements will vary according to adjacent land use, wind speed and wind direction records but should be in excess of 200 feet (60 m).

With rapid infiltration system outright land ownership by the effluent disposal agency is desirable.

With low rate irrigation systems a variety of ownership patterns for land and equipment are possible. Where municipal effluent is delivered to private land owners it is important that the municipality, the land owners and the provincial water quality control authority agree to the operating arrangements. For example, what will be the method of disposal of excess waste water during years of high rainfall? Who will be responsible for any required drainage installation costs? What obligations does the municipality assume in providing technical assistance and equipment to farmers? The larger and more complex the system,

the more important it is to have realistic estimates of capital and operating costs and benefits on which to base agreements.

Storage Requirements

Irrigation is possible in about six months of each year with about 55 percent of the moisture demand coming in July and August. This means that if all the water is to be used for irrigation, storage for at least one half the yearly flow has to be provided. Storage in addition to this would be desirable to provide some degree of flexibility.

Many municipalities such as Swift Current already have sufficient lagoon storage capacity. For others fortunate enough to be able to permit continuous outflow to date such as Moose Jaw, the storage requirement can be a major component.

The objectives of the project have a significant bearing on the storage requirement. If some winter discharge is permissible and the main objective is crop production, storage would be considered only if it were warranted by the demand for waste water.

Figure 3 illustrates typical seasonal reservoir fluctuations.

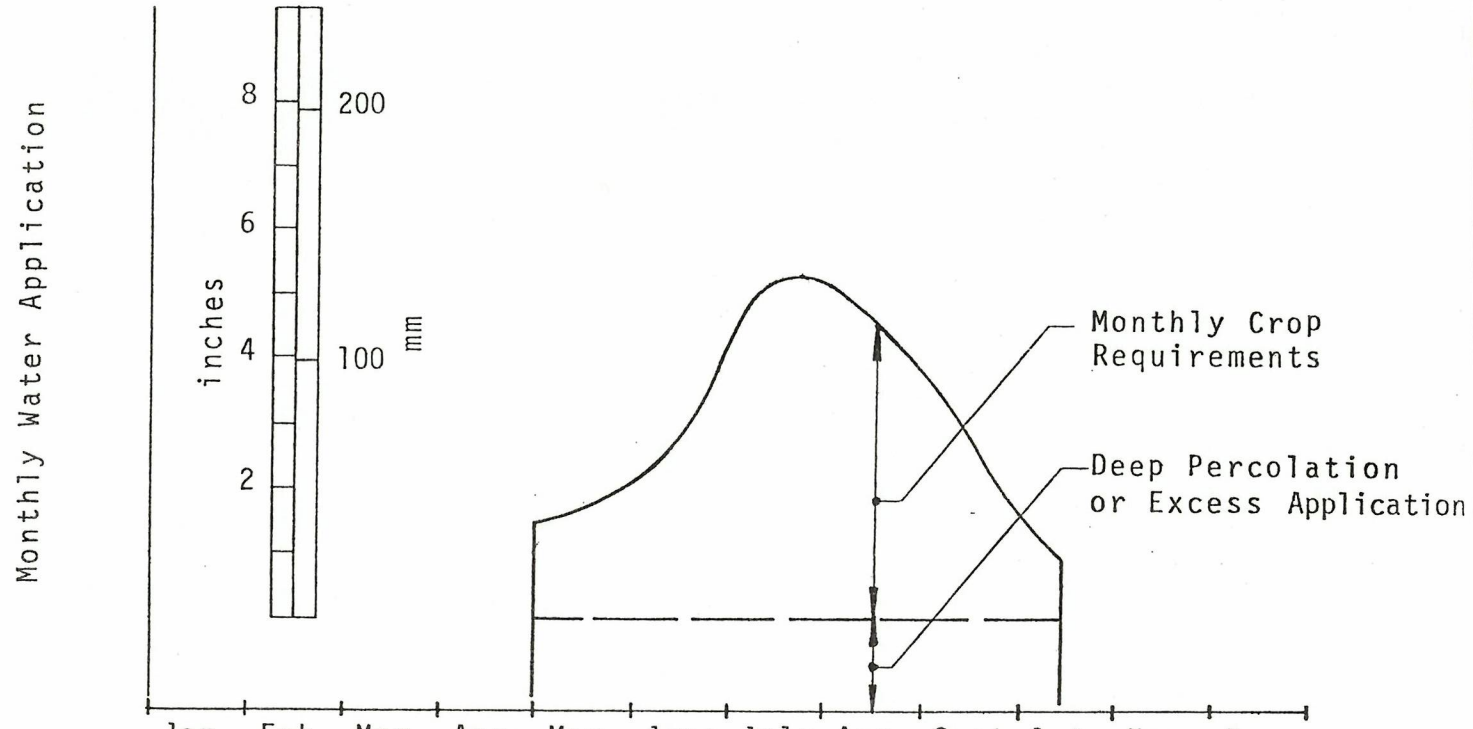


FIGURE 2 - Graph of Typical Crop Water Requirements and Application

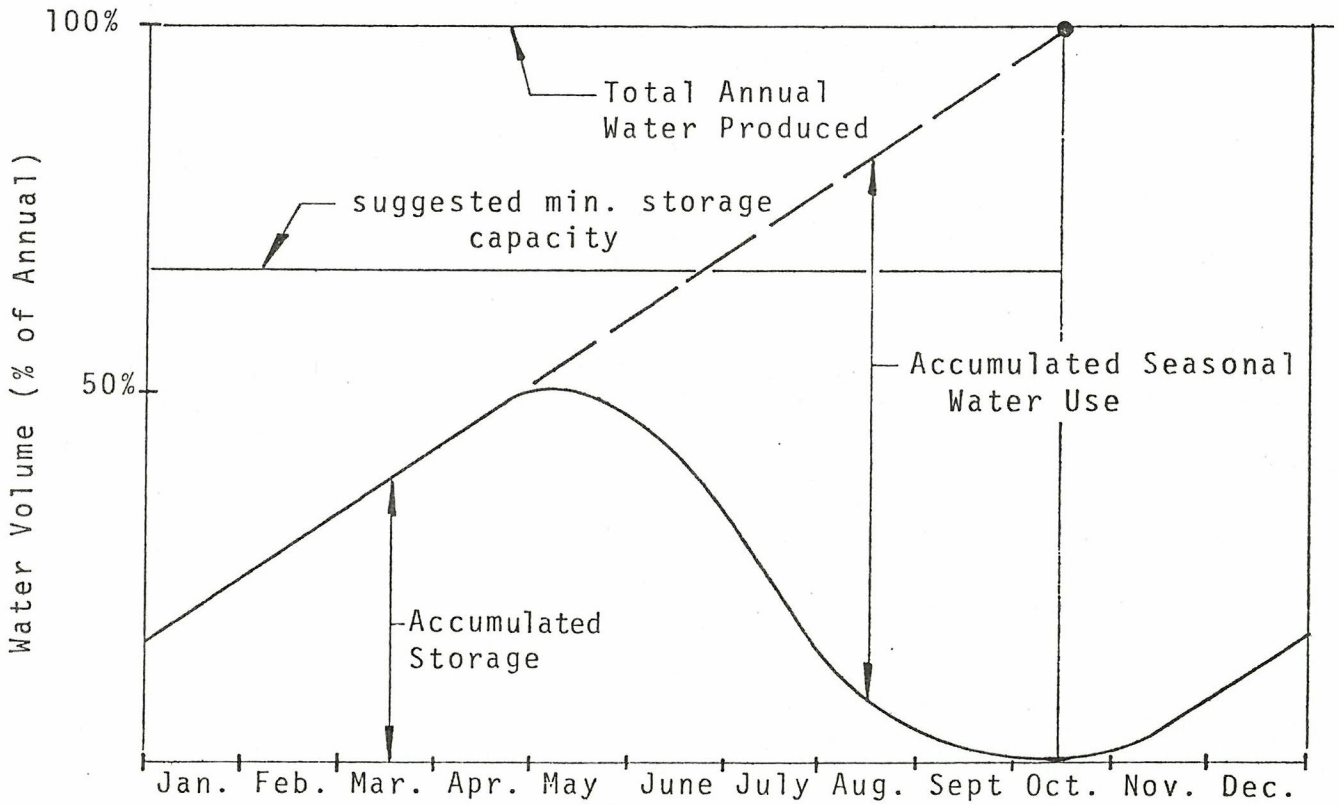


FIGURE 3 - Graph of Typical Seasonal Water Storage and Use

Topography and Irrigation Methods

Land which is smooth enough to be farmable can generally be considered irrigable provided it meets other criteria such as texture and drainability. Selection and design of irrigation methods are site specific but the development of mechanical-move sprinkler equipment over the past two decades has meant that topography is no longer the major constraint to irrigation that it once was.

While some of the most economical irrigation developments are open gravity or gated pipe and furrow systems on soil and topography ideally suited to the particular system, the contraint of distance and the extra degree of control of water application and drainage required with waste water system will usually dictate site selection on factors other than topography suited to a particular irrigation system.

Other factors being equal, however, a smooth topography with a continuous general slope of about one-percent is an asset to almost any irrigation development.

Irrigation system design is beyond the scope of this presentation but a few of the pertinent factors in choice of systems are:

(a) soil water holding capacity and the resultant frequency of water application required,

(b) soil infiltration rate,

(c) the degree of water control required in relation to sub-surface drainage capacity,

(d) height of crops to be grown,

(e) suitability of system to site topography,

(f) capital and operating costs,

(g) management and labor requirements in relation to availability.

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DESIGN CONSIDERATIONS IN EFFLUENT IRRIGATION

GROUNDWATER AND SURFACE WATER IMPACTS

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INTRODUCTION

This paper provides a general discussions from the design viewpoint of the effects on the local groundwater regimes of land application of treated wastewater. The paper is restricted to the conditions typical of the Canadian Prairies where the climatic conditions pose severe constraints on methods of effluent irrigation. It is important that experience with irrigation systems in other climatic zones of North America is not applied directly to Western Canadian conditions without appropriate modifications.

Following a brief discussion of waste treatment alternatives three basic methods of land application of wastewaters are considered,

- slow rate crop irrigation
- high rate crop irrigation
- rapid infiltration a) with water recovery
  b) without water recovery.

Each method is examined and the predicted impacts on the groundwater quality and hydrology are discussed.

In considering impacts on groundwater as compared with surface water the differences of the relatively large volumes and slow movements in groundwater as compared with smaller volumes, rapid mixing and higher

rates of movements in surface watercourses should be kept in mind. Similarly "spills" of partially treated effluent to surface watercourses will give rise to slugs of pollution which move off in a short time, whereas in groundwater the dilution may be greater, but the effects will be longer in time.

Waste Treatment Alternatives

A land treatment system is composed of three to five components:

- Waste Treatment
- Transmission and Storage
- Land Application
- Water reclamation) If Applicable
- Disposal of reclaimed water)

Each component will affect and must be compatible with, the other components and the system must be viewed as a whole to optimize the complete system.

Waste treatment falls into two main types, mechanical treatment plants, or lagoon treatment. Under Western Canadian conditions it is impractical to utilize crop irrigation in the Winter due to icing problems causing potential damage to perennial crops, and to surface run-off from melting ice in the Spring. It is therefore necessary to provide Winter storage, usually in the order of 6 to 7 months. These large storage lagoons have the potential for being used as part of the waste treatment component, thereby fitting in with a lagoon treatment type of waste treatment.

For example, at Swift Current the raw sewage is treated in two primary aerobic lagoons, and one secondary lagoon. These lagoons also

serve to provide Winter storage and are then progressively lowered by use for irrigation during the growing season.

It is possible that the requirement for Winter storage could be greatly reduced or eliminated with a rapid infiltration system of land treatment, as discussed below. Rapid infiltration system require a high quality effluent and for these reasons would appear to fit in well with a mechanical treatment plant.

Other combinations of wastewater treatment and land treatment alternatives are of course possible, the important point being to view and optimize the entire system.

LAND TREATMENT ALTERNATIVES

The characteristics of the methods of land application are detailed in Table 1. Other land application methods, such as overland flow and wetlands use, have not been widely used in Western Canada, and are not considered in this paper.

TABLE 1

COMPARISON OF LAND TREATMENT PROCESSES

FEATURE	CROP IRRIGATION		RAPID INFILTRATION	
	SLOW RATE	HIGH RATE	NO RECOVERY	WATER RECOVERY
Application	Sprinkler or Surface	Usually Sprinkler	Basins	Basins
Annual Application Rate metres (feet)	0.3 to 1.0 (1 to 3)	1.0 to 6.0 (3 to 20)	6.0 to 150 (20 to 500)	6.0 to 150 (20 to 500)
Vegetation	Required	Required	Not required	Not required
Disposition of wastewater	Mainly evapotranspiration	Evapotranspiration and percolation	Mainly percolation	Percolation, then disposal to watercourse or re-use
Soil permeability	Slow to moderate	Moderate to rapid	Rapid	Rapid
Minimum depth to groundwater	1.0 metre (3 feet)	1.0 metre (3 feet)	3 metres (10 feet)	3 metres (10 feet)
Winter use	Storage required	Storage required	Possible	Possible
Operating System	Taber, Alberta	Muskegon, Mich.	Whitter Narrows, Cal. (10)	Phoenix, Arizona (7)(9)

Slow Rate Irrigation

The objective with slow rate irrigation is to dispose of the majority of the sewage by plant uptake and thence evapotranspiration and crop harvesting. Sufficient excess moisture is applied to leach the salts from the root zone. Thus only 10 to 20% of the applied water and its pollutants are transmitted to the groundwater. Careful attention is paid to retaining the land in good condition so that its primary function of production of food and feed for humans and livestock is maintained.

High Rate Irrigation

With high rate crop irrigation considerably higher rates of loading are utilized, while still maintaining a suitable environment for crop growth. The quantities of water and pollutants passing down to the groundwater table are greatly increased.

Rapid Infiltration

Lastly, with rapid infiltration, no attempt is made to grow crops and indeed the infiltration basins are usually disked to prevent this. Thus the majority of the applied waste flow and a significant proportion of its contaminants pass down to the groundwater table, unless they are intercepted and removed by underdrains or wells as renovated water.

Rapid infiltration schemes have not found much application in Western Canada. Such schemes have two main purposes, either to recharge a depleted groundwater or to remove nutrient and other contaminants, with the effluent water being recaptured by underdrains or wells and then discharged to a surface watercourse.

The first application, that of groundwater recharge, is not normally applicable to Western Canada. Such schemes are usually in areas

adjacent to the ocean where there may be salt water intrusion or in aquifers which have heavy water withdrawals and tend to be overpumped.

The second case, however, where effluent is recaptured following contaminant removal, could have applications in larger schemes where land requirements for slow rate crop irrigation become large and difficult to manage.

Prerequisites for rapid infiltration are a good quality secondary effluent and areas with high permeability.

A pilot plant utilizing a rapid infiltration basin following a mechanical secondary treatment plant has been in operation since 1976 at Boulder, Colorado.[1] Boulder, north west of Denver, 1,655 m (5430 ft) above sea level, has low humidity and a growing season from May 9 to October 8, comparable with the Prairies. It was found that continuous operation of the infiltration basin was possible through the Winter. As the water infiltrated into the ground under the ice, the ice eventually collapsed and broke up, to be refloated on the next recharge of the basin. Winter operation did, however, reduce significantly the nitrogen removal in the ground.

IMPACTS ON GROUNDWATER

Hydraulic Loading

The amount of effluent reaching the groundwater will vary widely depending upon the method of land treatment used. For slow rate crop irrigation the annual hydraulic loading percolating to the groundwater may vary from 0.1 to 0.3 metre, for high rate crop irrigation 0.3 to 5 metres and for rapid infiltration up to 150 metres. Obviously the impacts and the design analyses necessary will vary for these different cases.

Sufficient information must be obtained before a slow rate crop irrigation scheme can be designed. This information includes: profiles of existing groundwater surface, approximate areal extent of the aquifer, and areas of groundwater discharge. Water quality and utilization should also be evaluated.

For high rate crop irrigation and for rapid infiltration it will be necessary to carry out a more detailed analysis to determine the effects on the groundwater. The added volume will cause a local rising of the water table under the application site, forming a "mound". This is the converse of the drawdown cone formed in an aquifer as a result of pumping a well. The calculations of the size and height of this mound are complex and require detailed and rigorous analysis.(6) Considerable testing will be required, including determinations of vertical and lateral permeability of the acquifer.

The essential object of these investigations is to ensure that the groundwater at its normal maximum seasonal level, together with the imposed "mound", does not reach the soil layer. It is essential that the groundwater does not saturate the soil layer, thus causing the soil to lose its aerobic properties to fulfill its functions of adsorbing or inactivating the contaminants in the sewage.

Water Quality Impacts

Groundwater resources are important for domestic and agricultural uses and it is important that the quality criteria be maintained to permit the continued beneficial use. If an aquifer is being used, or has the potential for a beneficial use, then the application of a treated wastewater can only be considered if the design will ensure that quality standards can be maintained. For example, potential groundwater

contamination may rule out the use of rapid infiltration systems, yet allow the use of a slow rate crop system which has a lower potential for contaminant transmission to the aquifer.

In cases where an aquifer has only limited present or future use the impact on the groundwater may be mitigated by agreements with the users, whereby they are provided at no cost with an alternative water supply, thus permitting the estimated impact on the groundwater to proceed.

The contaminants of greatest concern in the design of an irrigation system can be grouped under seven main headings,

- nitrogen compounds
- phosphates
- dissolved salts
- heavy metals
- biocides
- bacteria
- viruses

Nitrogen Compounds

The nitrogen in the sewage effluent will be largely in the form of ammonia, with some organic nitrogen and nitrate nitrogen.

While the nitrogen in the sewage effluent has considerable benefit to crop yields as a fertilizer, it also has potential to contaminate the groundwater as it tends to percolate through the soil with the leachate. Nitrogen loading may, therefore, often be the limiting contaminant which sets the maximum loading of effluent which may be applied. This applies mainly to high rate crop irrigation and rapid infiltration.

A complex series of interactions take place within the soil, leading to nitrification of the ammonia to nitrate and some denitrification near the soil surface, resulting in the release of free nitrogen to the atmosphere. The nitrate nitrogen will percolate through the soil with the leachate and could reach the groundwater.

The calculated nitrogen loading to the groundwater will vary with the type of land treatment, being smallest with slow rate crop irrigation and highest with rapid infiltration. The U.S. EPA[5] recommends a maximum percolate nitrogen concentration of 10 mg/litre unless a complete hydrogeological analysis sets other limits. The Saskatchewan objective for drinking water[3] is 9 mg/litre as N (40 mg/l as NO_3). Limits for nitrates are based on ingestion in potable water potentially causing infantile methaemoglobinemia.

A typical analysis for a nitrogen balance is set out in Table 2.

TABLE 2

	Slow Rate Crop Irrigation	Rapid Infiltration
Wastewater loading hydraulic metres/year	1.6	100
Nitrogen concentration in effluent mg/l	25	25
Nitrogen loading kgs/ha	400	25,000
Crop Uptake kgs/ha	300	0
Denitrification kgs/ha	40	10,000*
Nitrogen to Groundwater kg/ha	60	15,000
Percolate metres/year	1.0	100
Nitrogen in Percolate mg/l	6	15

* Based on 40% removal by denitrification and ammonium sorption in the soil

In slow rate crop irrigation schemes the crop uptake may equal or even exceed the applied nitrogen loading.

Nitrogen removals in the soil layer are reported at various levels in the literature, generally being higher in Summer and lower in Winter. Phoenix, Arizona[7][9] reported average annual removals of 30% for a rapid infiltration system with alternate wetting and drying. Denitrification at the soil surface will generally be in the range of 15 to 25%.

Phosphates

A large number of studies have shown that phosphates are largely adsorbed into the soil structure and do not percolate down into the groundwter. However, for rapid infiltration systems where the soils are necessarily of coarser texture and loading rates much higher, it is probable that some phosphates may be leached to the groundwater. The resultant effect on the groundwater chemistry should thus be calculated for all rapid infiltration systems but is not usually of importance to slow or high rate crop irrigation. Experience with a rapid infiltration system at Phoenix, Arizona[7] showed phosphates concentrations of 0.1 to 3 mg/l (as PO_4) depending on the distance of travel through the coarse soil. Estimated levels of phosphorus are not normally significant in groundwater.

Dissolved Salts

Increases in salinity in the soil layer can be a problem with irrigation systems using water, and are enhanced in sewage effluent applications due to the total dissolved solids in the effluent. There are many areas of solonetzic soils in Western Canada and the problems of saline soils and crop growth is discussed in other papers in this seminar.

Usually there will be little removal of salts by the soil layer, indeed with low rate crop irrigation systems additional effluent may have to be added to leach the salts into the groundwater.

In general groundwaters in Western Canada are already high in total dissolved solids as evidenced by the fact that while the Canadian Drinking Water Standards call for an objective of less than 500 mg/l of TDS, with 1,000 as the acceptable limit, the Saskatchewan objectives asre 1,500 mg/l.

Heavy Metals

It is important to evaluate heavy metal concentrations in irrigation wastewaters due to the toxicity of metals to organisms. Toxic effects, both acute and chronic, are dependent on the levels of concentration and ecology of the organism. Synergistic effects are important. Problems are normally restricted to the soil layer and the plants growing in the soil layer. Percolation to the groundwater will generally be negligible[14] except where the soil is very coarse textured and contains little clay or organic matter. This might occur in the case of a rapid infiltration system.

Heavy metals are normally concentrated in the sludges produced in the waste treatment processes and levels in the liquid effluent are much lower. Thus the application of sludges to land presents a greater hazard and a possiblity of contamination than does effluent irrigation.

In general, heavy metals should not present a problem to the treatment system other than that of potential crop toxicity. Should there be any evidence that heavy metals will exceed toxic limits in sewage then further investigations should be made of this parameter.

Biocides

Biocides should normally be present in sewage effluents only in minute concentrations, and these should be adsorbed in the soil.

At a previous Technology Transfer Seminar it was stated "There is probably more danger regarding water pollution from exotic organics, such as pesticides, that are applied separately from the irrigation water than there is from organics contained in the irrigation water".(8)

Bacteria and Viruses

A major concern for wastewater disposal to land has been the potential health hazards by transmission of bacteria or viruses. Definite possibilities of disease transmission by land disposal exist. They can be minimized and controlled by good design, management and operation but these factors should not be lightly dismissed. There have been enough examples,(2)(13) some fairly recent, of disease outbreaks from this source. In most cases these can be attributed to a contravention of good practice in one or more aspects, such as irrigation on crops eaten raw, irrigation of raw sewage or sludge, etc.

The sewage treatment part of the system will greatly reduce the number of bacteria and viruses in the effluent, and the use of storage lagoons provides a further reduction of bacteria.

The environment at the soil/air interface is hostile to the survival of bacteria and viruses and they exhibit a rapid die-off in the presence of sunlight. However, under moist conditions and in the absence of sunlight, (eg. in folds and crevices in plants) bacteria may survive for days or even weeks.

Within the soil structure itself, bacteria may survive for periods varying from a few hours to several months and, in some cases

reported, even years depending on the type of organism, the soil, its moisture content, etc. Under continuously moist conditions the survival of bacteria is enhanced but die-off increases with intermittent wetting and drying. Survival also increases at low soil temperatures. While some researchers have found that viruses are largely adsorbed within the soil layer it appears that they may survive for long periods of time, up to three months, and may be eluted by subsequent applications of effluent,[11] percolating down to the groundwater table.

Bacterial and viral survival in the groundwater may be quite long, as the environment there is less hostile. They may persist under these moist conditions, in the absence of sunlight, for many months. They do not diffuse but move slowly with the groundwater itself. Good design should ensure that the majority of bacteria and viruses are removed in the treatment process and further reduced within the soil layer. Reduction in numbers beyond this stage will be small, and it is therefore important to select a land application site away from groundwater areas which are used, or may be used, for potable water.

Good management to avoid ponding and saturation of the soil layer on a continuous basis should further reduce the hazard. Under proper conditions as outlined, bacterial and viral contamination of the groundwater should be low. None the less perimeter wells should be monitored to ensure that potential problems are identified and remedial measures taken.

DESIGN AND MONITORING REQUIREMENTS

The groundwater component of the concept design will require the following stages.

Stage 1 Assemble all existing data regarding the groundwater from records of existing wells and any other sources. This should include:

- depth to the water table;
- quality of the groundwater;
- present uses;
- information regarding surface discharge of groundwater.

Stage 2 Make a preliminary estimate of the impact of the percolate water on the groundwater quality and determine its significance. From this the need and extent of further investigations can be determined.

Stage 3 Carry out the field investigation as determined from Stage 2.

Stage 4 Assemble the data from the investigative programme (Stage 3) and calculate loadings and impacts from the proposed scheme in terms hydrogeologic and contaminant loading.

Stage 5 Make any necessary changes to the other steps of the concept design, including sewage treatment requirements, and the loading for the land application, to reduce the impacts to an acceptable level.

In considering the effects on the groundwater it is important to remember that in many cases the impacts take place slowly and over a long period of time as compared with discharges to surface watercourses. Samples taken from observation wells will usually represent long term averages. Daily changes are not significant but seasonal variations may be important, although they may be displaced in time depending on the rate of travel.

Monitoring wells should be established around the downstream perimeter of the land application site and their depth should be carefully

selected to ensure that the samples collected represent the groundwater flow from the site. Samples taken in the shallower monitoring wells will usually have a much more rapid response to the effects of the groundwater contamination than deeper wells to which the travel time is longer.

The location of the sampling wells needs careful analysis. Based on the plan view in Figure 1, wells 2, 3, 4 and 5 should all be valid monitoring wells, with well 1 acting as a control. However, the elevation shows that well 2, if cased, and well 5 would give erroneous results.

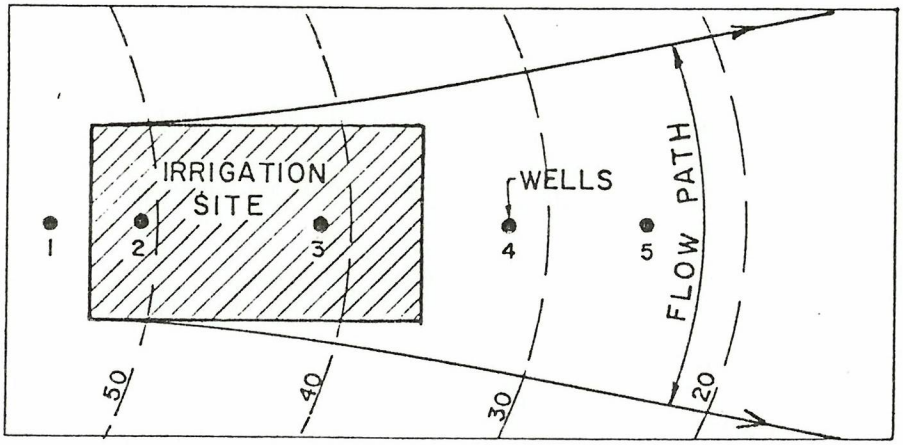
In addition to the perimeter wells some monitoring wells should be established upstream of the land treatment site. These will record long term changes in the groundwater to compare with the quality being monitored around the perimeter of the site. Long term records should be kept of the water levels and quality in all the monitoring wells. Table 3 attached, reproduced from the EPA Manual,[12] shows a recommended monitoring programme for a large low rate crop irrigation scheme. In some cases, additional parameters may be critical and require monitoring.

Examples of monitoring programmes at Swift Current and Taber will be discussed in later papers.

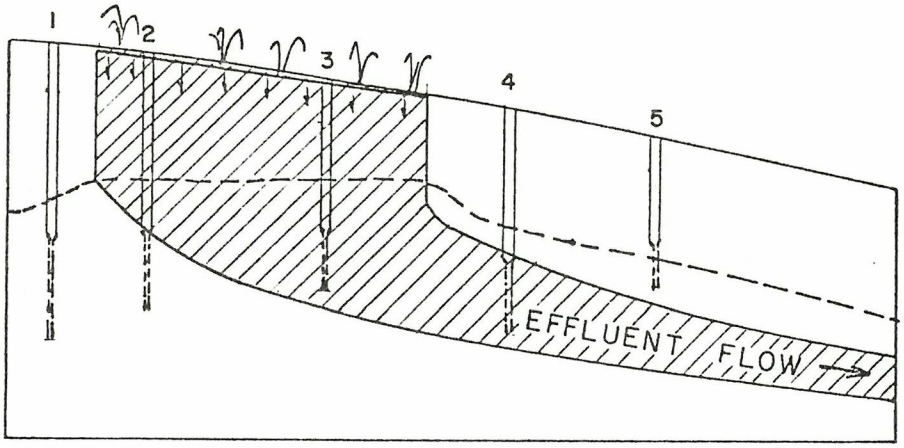
SUMMARY

The foregoing sets out some of the design considerations and impacts pertaining to the groundwater at a land treatment site.

An analysis should be made for each parameter discussed to determine the degree of treatment required before land application, and the maximum loading rate at the land treatment site. The limiting



PLAN VIEW



ELEVATION

Figure 1

TABLE 3

EXAMPLE MONITORING PROGRAM FOR
A LARGE SLOW RATE SYSTEM

Parameter	Frequency of analysis					
				Groundwater		
	Applied wastewater	Soil	Plants	Onsite wells	Perimeter wells	Background wells
Flow	C	..	..	..	..	..
BOD or TOC	W	..	..	Q	Q	Q
COD	W	..	..	Q	Q	Q
Suspended solids	W	..	..	..	..	..
Nitrogen, total	W	2A	A	Q	Q	Q
Nitrogen, nitrate	..	..	..	Q	Q	Q
Phosphorus, total	M	2A	A	Q	Q	Q
Coliforms, total	W	..	..	Q	Q	Q
pH	D	Q	..	Q	Q	Q
Total dissolved solids	M	..	..	Q	Q	Q
Alkalinity	M	..	..	Q	Q	Q
SAR	M	Q	..	Q	Q	Q
Static water level	..	..	..	M	M	M

Note: C = Continuously
D = Daily
Q = Quarterly
W = Weekly
2A = Two samples per year
A = Annually
M = Monthly

a. Wastewater applied and groundwater should be tested initially and periodically thereafter, as appropriate, for heavy metals, trace organics, or other constituents of environmental concern.

parameter can then be determined and, if necessary, investigated in more detail, or the design of the system modified.

The impacts are normally greatest for rapid infiltration systems and nitrogen compounds will often be the limiting parameter. The importance of other criteria depend upon the site hydrogeology, and the characteristics and use of the groundwater.

The significance of the inevitable deterioration of the groundwater should be included in a benefit-cost analysis of all alternative methods of wastewater disposal.

With all types of land treatment, the main objective is to provide additional treatment and disposal of wastewater effluents. To the municipality, crop production and sale is a by-product or secondary objective of the scheme; hopefully the two objectives can be mutually benefical. No scheme should cause long term, irreversible damage to large areas of productive land.

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SWIFT CURRENT EFFLUENT IRRIGATION PROJECT

D. G. Green
Research Scientist (Agriculture Canada)
and Irrigation Farmer

We use the City of Swift Current Effluent Project as the water source on our privately-owned irrigation farm. This effluent, provided under pressure by the City, is used to irrigate 225 acres of hay and pasture. Prior to joining the effluent project we irrigated 80 acres using wheel rolls and water from the Swift Current Creek.

In 1973-74 the City conducted a preliminary study on the feasibility of using effluent for spray irrigation. The City planned to purchase sufficient land and machinery to operate the project, and to provide the labor for managing the equipment. This study showed that the project was uneconomical for the City to manage, and City Council turned down spray irrigation as an alternative for effluent disposal.

At this time I was an employee of Agriculture Canada experimenting with corn silage production using effluent as the water source. In the evenings and on weekends I grew irrigated alfalfa-brome hay, about one kilometer north of the lagoon system. The effluent looked "good" to me and in discussing its potential we discovered that four farms were interested in helping to solve the City's disposal problem. All four farms were in the irrigation business in 1974. Vic Rempel, whom you will meet in a few minutes, obtained permission to "experiment" with effluent and started his project in 1974. All four farmers read and discussed effluent irrigation, and we became more positive with time in our appraisal of its potential.

After considerable debate, meetings, and time, the City and the four farms (the "Effluent Society") agreed to proceed with the project. We have

a legal agreement between both parties; a copy is here today. The City's engineering consultants who had worked with us throughout the negotiations then drew a final plan and the project was constructed (On-Line June 1978).

George Beck will cover the City's involvement later.

The PFRA and SDA were very helpful to the farmers in designing equipment, testing soils for suitability, etc. Results from the Swift Current Research Station by Drs. Biederbeck, Jame and others were also encouraging. The Water Rights Branch of the Province have extended our licenses five years, while we run a long-term evaluation of the project. We could not risk losing our Swift Current Creek Water Rights Licenses, at least until we knew the system was viable. The engineering services provided by government agencies were good; an agronomist versed in effluent irrigation, potential crops, machinery, etc., is needed to save time and money when designing future effluent projects.

As a group, we look forward to a successful year of irrigation in 1979.

SEMINAR ON EFFLUENT IRRIGATION UNDER PRAIRIE CONDITIONS

V. Rempel
Irrigation Farmer

Sewage effluent to the irrigation farmer is the water that is in the sewage lagoon. We use this water the same way as we use creek or irrigation canal water. In summer the effluent becomes clear and doesn't smell too bad. Effluent that lies in an unused pipeline smells, particularly in warm weather. In early spring (May), the effluent is cloudy and has a stronger odour.

We use effluent to replace creek water in our irrigation program. The City has enough effluent for disposal to water more than 800 acres (four farms). This effluent is supplied by the City pumping system. The four farms use about all kinds of irrigation equipment available to distribute the water. There are wheel rolls, centre pivots, big guns and hand move systems.

Alfalfa is the major crop grown by the Swift Current farmers. Rapeseed, wheat, oats, barley and pasture have been grown. Cattle have been pastured on grass while the sprinklers are running with no visible problems.

Yields? I've grown alfalfa for four years using sewage effluent. Alfalfa has averaged 4 to 4½ tons/acre. In 1978 rapeseed yielded 30 bushels/acre; we only started irrigating in July, so this is a low irrigation yield. Oats yielded 100 bushels/acre.

Irrigating with effluent hasn't caused any more problems than creek water. Nozzle plugging isn't a problem but the City has a clean intake system.

CITY OF SWIFT CURRENT

A SUMMARY OF THE DEVELOPMENT OF SEWAGE SPRAY IRRIGATION AT THE CITY OF SWIFT CURRENT

GEORGE BECK - JANUARY 1979

As far back as 1969, seeds of thought regarding sewage disposal by irrigation were being planted in Swift Current. The Swift Current Creek runs through the City and meanders 30 miles or more north to the Saskatchewan River. In the spring and again in the fall, the City discharged their lagoons into the Creek. Each discharging period lasted for ten days to three weeks. Livestock farmers, sportsmen, environmentalists and just concerned citizens, twice each year renewed their objections to the City's discharge of effluent to the Creek.

During this same period, Taber, Alberta was initiating studies into the aspects of sewage irrigation. The City became more and more interested in the Taber project. In 1972, an alderman, the City Commissioner and two scientists from the Department of Agriculture Research Station located at Swift Current, travelled to Taber for a first-hand look at the proceedings. Later on, Mr. Dave Graveland, from the Alberta Department of the Environment, was invited to Swift Current, to open discussions on the topic of "Recycling Municipal Sewage Through Agricultural Crops." In attendance were people from the Research Station, the City, the Provincial Government and others. Mr. Graveland had been involved with the Taber project from the ground up and afforded the Swift Current group a good deal of encouragement.

In 1969, the Water Resources Commission wrote to the City stating that the existing sewage treatment facilities were becoming inadequate in terms of capacity and requested the City to upgrade the lagoons.

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The City commissioned consulting Engineers, Reid, Crowther and Partners Ltd. to do a study and report on the various methods of handling our sewage. For their report, Reid, Crowther needed to know the strength of our sewage. Once every two weeks, for several months that year we gathered sewage samples and sent them off to Edmonton for analysis.

When Reid, Crowther and Partners submitted their "Interim Report on Extension to Sewage Treatment Facilities" in August of 1970, we were still left in a state of indecision. A tertiary treatment plant would cost in the neighbourhood of ($3,000,000.00) three million dollars. This was out of our reach. Alternatively we could enlarge our aerobic lagoon system, but we would probably have to chlorinate the effluent. This was still only secondary treatment with poor quality effluent in the spring discharge. A third method would be to construct small inexpensive ponds and install aeration equipment which would considerably improve the quality of the effluent. Rather than discharge twice annually though, if we could get permission to discharge continuously, we could eliminate the necessity of buying land and constructing an additional large scale storage pond. At this time however, the Water Resources Commission did not have a definite policy regarding intermittent or continuous discharge. Not until 1973 did the Pollution Control Branch of the Department of the Environment give us their decision on intermittent versus continuous discharge and it was against continuous discharge.

In the meantime the prospect of disposal by irrigation was edging its way up to the forefront. The City had concluded arrangements with the Research Station to do an experimental pilot project on sewage spray irrigation. From the outset, the Research Station, under the directorship of Mr. Art Guitard; and a score of the station's research people, were interested and co-operative and helped the City immeasurably. So it was that in June 1973, a 15 acre plot was seeded to Roamer alfalfa and the Pilot Project got underway. It is still going today.

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In March of 1973, the Department of Environment had officially sanctioned sewage spray irrigation as a possibly viable alternative to disposal by discharge to the Swift Current Creek.

Vic Rempel, who farmed south-east of the lagoons, had been irrigating 60 acres of alfalfa from the P.F.R.A. canal. He was interested in trying effluent if the City would supply him with 1,200 feet of pipe to reach his wheel-roll sprinkler. The City agreed and in the spring of 1975 Vic started irrigating his 60 acres with water from the lagoons.

As time and events progressed, indications more and more favoured spray irrigation. In the fall of 1976, construction was completed of a third lagoon cell, 64 acres in size. With the other two existing cells of 67 and 80 acres, there was adequate storage to accommodate an irrigation system.

At this time the Department of the Environment required that if the City went to irrigation, they would have to own the land to be irrigated to ensure City control. Land became hard to get at reasonable prices and for awhile it looked like the irrigation concept could be abandoned. Fortunately, within short distances of the lagoons, farmers who were irrigating out of the Creek had been following, with interest, the developments of the past few years. Four of the farmers, Messrs. Dave Green, Vic Rempel, Earl McMurtry and Wes Westrom approached the City as a group interested in using the effluent. After many discussions and meetings, a formal Agreement was drawn up between the group of farmers and the City. In essence the Agreement obligated the City to provide the sewage to the farmers at the quantity and pressure they required. In return the farmers would take all the City's sewage. Of major importance regarding the Agreement was that it satisfied the control requirements the Department of the Environment thought essential to the City.

The stage was now set for the grande finale. Reid, Crowther & Partners were hired to design and supervise construction of the pumphouses, pipe lines, etc. Working from the fall of 1977, to the summer of 1978, the

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system was completed and put into full scale operation near the end of June 1978.

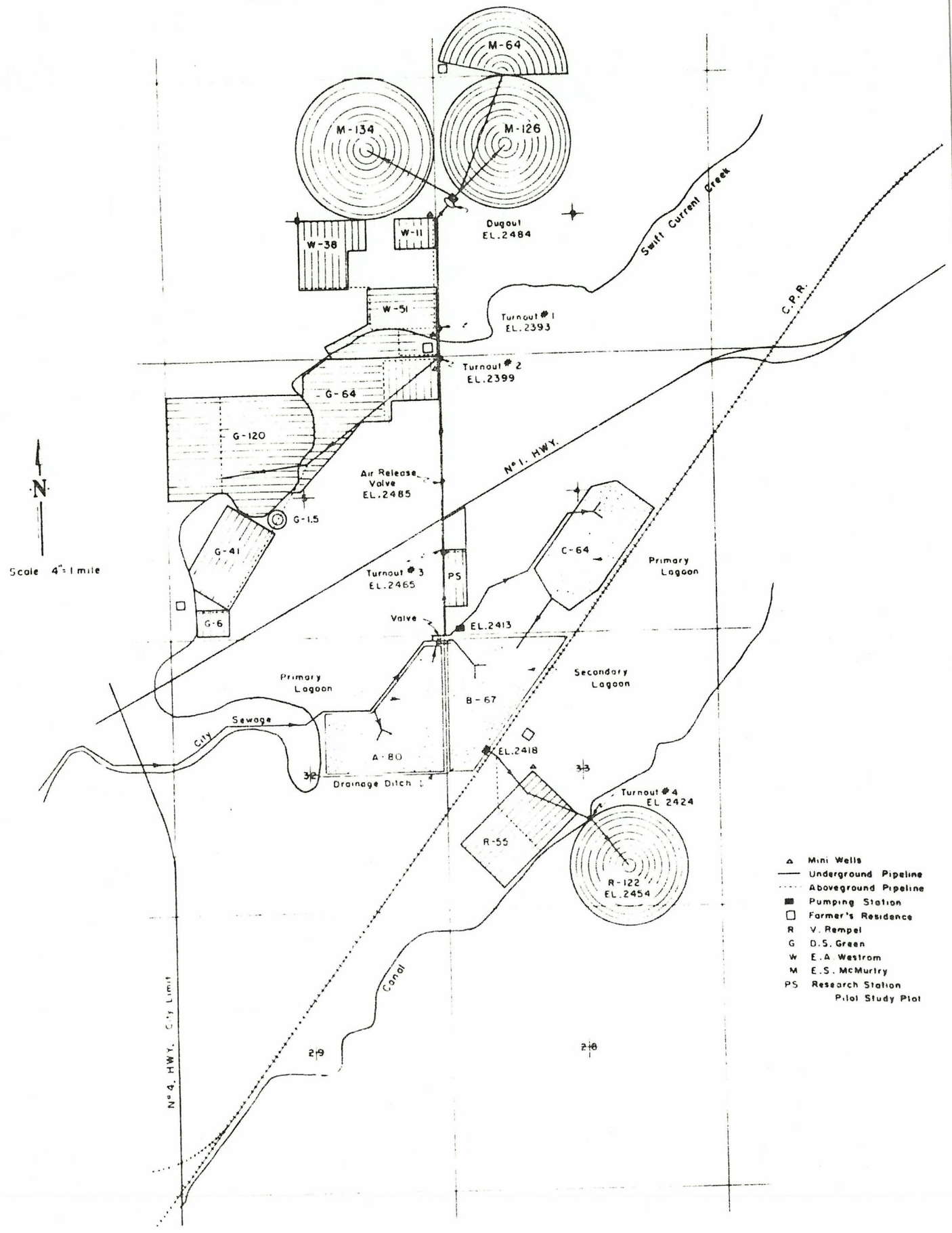
The combined capital costs of the new lagoon cell and the pumphouses, pipelines, etc. was approximately ($1,000,000.00) one million dollars. The lagoon cell was about $350,000.00 and other facilities about $650,000.00.

The City is eligible for grants on the $350,000.00 of 1/6 through Central Mortgage & Housing Corporation (C.M.H.C.) and 10% (secondary treatment facility) under the Water Pollution Control Assistance Act.

On the $650,000.00, grants eligible are 1/6 C.M.H.C. and 15% (tertiary treatment facilities) under the Water Pollution Control Assistance Act.

The basic system consists of about 210 acres of lagoon area. Pumphouses are located at the south and north sides of the storage cell. Pipe lines run south about 3,000 feet and north 6,000 feet. Diameters of these pressure pipe lines range from 6" to 16". The capacity of the total system is about 6,000 imperial gallons per minute and maximum pressures of 160 p.s.i. can be reached at the pumphouses.

Swift Current Effluent Irrigation Project



TERTIARY SEWAGE TREATMENT

EFFLUENT IRRIGATION ALTERNATIVE

CITY OF MOOSE JAW

The City of Moose Jaw presently utilizes aerated lagoons for sewage treatment. This form of treatment provides a good secondary treatment, however nutrients particularly phosphorous, create problems downstream of the City's Lagoons because of their potential to support algae and weed growths.

In the "Report of the Qu'Appelle Basin Study Board" of 1972, it was estimated that under average conditions, the effluent from Regina and Moose Jaw contributes 57% and 13% respectively of the phosphorous entering the Qu'Appelle River System.

A major recommendation of this Report was:

> "It is recommended that the Cities of Regina and Moose Jaw be required to provide a higher level of waste treatment that includes the removal of phosphorous and algae."

This was not the first formal report written on the Qu'Appelle Lakes. One of the more earlier reports was one written by Captain Hinde. In his report in 1858, he described the Qu'Appelle Lakes as a chain of four emerald green lakes covered with a vegetable-like green scum which extended down for several feet. In other words, these lakes were covered with algae long before there was any settlement at "Pile of Bones or Moose Jaw." It is noted, that although the Cities of Moose Jaw and Regina contribute heavily to the phosphorous loading of the stream, the considerable sums of money being required to be expended to solve this contributing nutrient load should certainly not be considered as a solution to the eutrophication of these water bodies.

Since 1972, after the "Qu'Appelle Basin Study Report" was printed, the City of Moose Jaw along with Regina did realize that they would be called upon to expend considerable number of dollars for further sewage treatment of a tertiary nature.

I do not think it is required to elaborate on the advantages of utilizing this 'nutrient enriched water' to the benefit of the agricultural industry rather than applying tons of more chemicals to this water and then dumping it back into the river and losing this valuable resource.

The Province of Saskatchewan through the Department of Environment, who realizing the potential of utilizing secondary sewage effluent for irrigation purposes, commissioned two studies to be undertaken. These were:

1) Moose Jaw Effluent Irrigation Study by W.A. Meneley, P.Eng., Geology Division, Saskatchewan Research Council.

2) The Use of Sewage Effluent for Irrigation - Growth Chamber Studies and Modelling by E. de Jong of the Saskatchewan Institute of Pedology, University of Saskatchewan, Saskatoon Campus.

In April, 1974, the Saskatchewan Research Council was commissioned by Environment Saskatchewan, to determine the consequences of Effluent Irrigation on the Hydro and Geological Environment of the proposed site near Baildon. This particular site is approximately 6 miles straight south of the Lagoons of the City of Moose Jaw. The study included evaluation of existing information, test drilling to define the geological environment, installation of piezometers and observation wells to determine the direction of groundwater flow and the field permeability and collection of soil and water samples to determine the antecedent soil and water chemistry.

The results obtained indicate that the hydrogeological environment is suitable for effluent irrigation.

In the Report submitted to the Saskatchewan Department of the Environment by Mr. E. de Jong, on the "Use of Sewage Effluent for Irrigation"

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three growth chamber experiments were conducted to investigate the use of sewage effluent for irrigation.

These three experiments lead to a number of conclusions:

1) The soluble salt content of the effluent is high and more water must be applied than is used by the crop to ensure leaching of these salts and maintenance of soil productivity.

2) If the buildup of salts is prevented, effluent irrigation increases crop yields and has no detrimental effects on crop or soil quality.

3) Effluent irrigation provides a practical way of utilizing the nutrients and water in the effluent. Effluent irrigation provided more N and P than needed by the crop, but at some future date, fertilization with K may be necessary.

4) Effluent irrigation increased plant available P and B in the soil, but had no effect on plant available N, Zn, or Hg.

   Very high rates of denitrification occur under effluent irrigation.

5) The greatest potential for drainage exist in early spring or late fall and is least during the growing season. The possibilities for drainage and losses of plant nutrients (N, P and K) are especially large during the year the crop is established.

6) Leaching losses of NO_3-N were small when an actively growing crop was present, however, they seemed to increase as the seasons progressed. After the first season, leaching losses of P were minimal.

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7) Cl moved relatively unimpeded through the soil, but all the other elements were affected by such processes as dissolution (e.g. of gypsum), exchange and absorption. Structure did not appear to affect the movement of the ions, neither did temperature have a measurable affect except for the passage of various forms of N.

8) On the soil horizons tested, P was absorbed most strongly on Asquith B and C horizons and least on the Asquith A horizon, the Oxbow A horizon was intermediate. As time progressed more P started to leach through and ultimately P must be expected in the drainage water. There was an indication that leaching of P could be higher in spring and fall than in mid-season.

9) Infiltration problems can arise under continuous application of effluent and/or poor aeration.

The results of growth chamber studies cannot be transferred directly to the field due to environmental differences. Based on the results of this study, the following recommendations are made:

1) The findings of this study should be verified under field conditions by carefully monitoring the results of sewage effluent irrigation under actual operating conditions for annual changes in soluble salts and available nutrients (in particular NO_3-N) in the soil. If available nutrients build up to high levels, it might be necessary to stop effluent irrigation for a year or more until the supplies have been used by the crop. Occasional monitoring for potentially toxic levels of plant available heavy metals and B is recommended, the frequency of this monitoring depends on the quality of sewage. Measurements of the amount and quality of the drainage water that recharges to the groundwater are advisable.

2) Effluent irrigation rates should be based primarily on the need to maintain a proper salt balance in the soil, but consideration should also be given to maximum crop utilization of the plant nutrients in the effluent to ensure that as few nutrients as possible leach through the soil profile. Effluent should not be applied or applied sparingly, during the year the grass is seeded.

3) The model should be verified under field conditions with particular attention being directed toward over-winter snow accumulation and runoff of both snowmelt water and rain.

4) Studies aimed to increase the understanding of the N-cycle under effluent irrigation conditions would be desirable.

Further to these Reports, being review and with the co-operation of the "Qu-Appelle Implementation Office" the firm Underwood McLellan Ltd. was commissioned by the City of Moose Jaw to undertake a Study of the Advanced Wastewater Treatment and Disposal for the City comparing capital costs and operating costs of various disposal alternatives.

The Provincial Department of the Environment has advised the City of Moose Jaw to reduce its wastewater phosphorous discharged to less than 1 milligram per litre from the present level of approximately 6.6.

The City recognized there were several approaches that could be used to achieve this end and in co-operation with the Department of the Environment, had identified that there were two apparent ways of achieving the requirement. One would be chemically treating the wastewater for the removal of phosphorous in a physical-chemical plant and the second was by utilization of a nutrient rich wastewater in an irrigation scheme.

This Report was to determine the feasibility of utilizing effluent irrigation as an alternate to the physical-chemical treatment.

The Report pointed out that the least total cost alternative for the City was to be the irrigation alternatives. Although these entailed additional grants from senior governments in the order of one to two million dollars, the potential saving of several hundred thousand dollars per year in operating cost is very evident.

The physical-chemical plant as reviewed, would meet the present effluent regulation. However, in the event of more stringent regulations, additional phases would be required adding to the cost discrepancy between these two alternatives.

The Report recommended that the City give serious consideration to the implementation of the irrigation method of wastewater disposal, which involves the construction of a reservoir, pipelines, pumping facilities and the purchase of sprinkler equipment.

City Council of the City of Moose Jaw, after reviewing the Report as submitted by Underwood McLelland, adopted in principle, the utilization of this nutrient enriched water for irrigation purposes.

Once again, through the co-operation of the Qu'Appelle Implementation Office, Underwood McLellan were commissioned to meet with the farmers in the Baildon area to ascertain if, in fact, there was enough interest and land available which was irrigable.

This Study is still continuing and the total results have yet to be reported to the City of Moose Jaw, however, indications are that the farmers are more than interested in participating in this joint venture, however, there may be some difficulties in finding enough area for irrigation to satisfy the future needs of potential growth of the City.

As was noted in the foregoing, the City's main objective is to:

1) Comply with the request of the Department of the Environment and reduce the level of phosphorus of approximately 6.6 to 1 milligram per litre or less.

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2) Recognizing the valuable resource which is present in this nutrient enriched water to utilize this in co-operation with nearby farmers to increase the productivity of what may be termed marginal agricultural land to benefit both the farmers in the area and the governments of the Province of Saskatchewan and the City of Moose Jaw. A 5-000 acre area several miles south of the City of Moose Jaw has been tentatively identified as suitable for effluent irrigation of several similar crops.

It was suggested that an annual effluent application rate of 20 inches per year is suitable for effluent disposal and crop use in this area. Approximately twenty-four hundred and four thousand acres of net irrigation area are required for 1978 and two thousand projected wastewater flows. The area farmers appear receptive to the idea of partaking in an irrigation scheme.

Four alternative land-ownership-operation arrangements are discussed in respect to the irrigation scheme. These include private, private with City owned sprinklers, City owned and leased and City owned and operated. The cost of the irrigation alternatives range from 5 million to 7 million dollars for immediate future requirements. Further staged expansion of the alternatives would involve the expenditure of an additional one to two million dollars over the next 20 years.

The projected annual cost assuming total grant eligibility ranges from $390,000 per year to $214,000 in the immediate future. The most apparent alternative for the City to consider in respect to costs and implementation is suggested as being between alternative 2 and 3 where the City would construct and operate the head works, purchase the sprinklers and negotiate with the private farmers for effluent utilization.

Physical chemical treatment with lime chemical precipitation has been suggested as the most appropriate form of treatment of the alternatives considered for algae and phosphorous removal.

Chemical recovery was found unfeasible, therefore, it was proposed that the precipitated phosphorous and chemical sludge generated in the process be de-watered and truck hauled to a disposal site approximately 15 miles south of Moose Jaw.

The irrigation and physical chemical treatment would remove 95% plus and 90% of the nutrients respectively with the exception of nitrogen. The present regulations do not require the removal of nitrogen.

In the event of more stringent effluent controls, the physical chemical plant alternative would have to be supplemented with additional treatment stages.

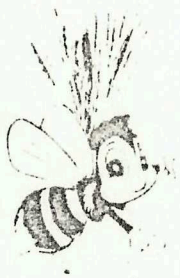
The estimated capital and annual operating cost of the lime physical chemical alternative is 3.2 million dollars and $450,000 per year respectively. In assessing the respective operating cost for a period in the future when the variable operating costs double, the irrigation alternative showed a decided cost advantage over physical chemical alternative.

The environmental impact of the irrigation has been identified as farming and employment opportunities. Negative aspects include the disruption of local wildlife habitat and the drainage of the leachate from the site tile drain into the Moose Jaw River. The drainage water would be similar to groundwater and is not anticipated to create problems in the drainage course. The physical chemical alternative would discharge its wastewater at the present location.

A.J. SCHWINGHAMER, P. Eng.,
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CITY OF MOOSE JAW

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Mr. Chairman

As a Baildon district dryland farmer, I note from your agenda, that I am the only participant in this seminar who is at present, not actively into irrigation like Mr. Rempel, but who is also not actively associated with effluent irrigation through an educational, governmental or commercial connection.

I am something like the effluent you are discussing - a raw product at this stage that has to be processed in one fashion or another.

To those of you who have been associated with past projects, my remarks could be a repetition of farm views and concerns. To those who may be looking at farm effluent systems for the future, a farmer viewpoint at this time might mirror concerns you will be faced with in your future building of like systems.

I would like to divide my comments into two sections. Firstly from a farm viewpoint what to me could be called "Potential Positive Aspects of Effluent Irrigation" as they directly relate to the farm level.

Secondly - "Some Farm Concerns Prior to Irrigation."

Put together they could be called "good news" and "bad news."

Firstly, the "good news."

1) More Varience in Selection of Crops:

In a province noted for a one shot economy (wheat), where we have continuing cycles of surpluses and quotas, the ability to produce cash crops is an appealing alternative.

2) Assurance of Moisture Supplies:

"If we had only had another rain" is probably the most oft repeated remark you hear at harvest time. The Baildon area has rain patterns that seem to consistently "go round" to the clay areas to the east. If farmers of our area had their choice of one more ingredient to produce better crops, water at the right time would be Number One.

3) Ability to Continuous Crop:

We are approaching a time when the advocates of "zero till", the pressures of land prices and the maximization of income per acre, are going to make continuous cropping more and more attractive. Soil moisture remains the key to this "switch over", especially in light land areas.

4) Prevention of Soil Drifting:

Our Baildon area was an area drastically hit by the Dirty Thirties. We still have areas of unreclaimed land considered too "touchy" to tangle with for fear of them taking off and spreading to areas which have been brought back to production through a good deal of patience and hard work. Trash farming, forage crops and tree rows have all been used in this area to combat soil drifting. Moisture when you need it is one of the best weapons to have in the fight to beat soil drifting.

5) Increase in Land Valuation:

This is an aspect I hesitate to mention because of our cost sharing negotiations with the City of Moose Jaw and Mr. Schwinghamer in particular. However even the briefest comparison of irrigated land values versus dryland would point out the obvious estate values of irrigated land.

These are just some of the advantages which could accrue to the farm level. You no doubt could point out many more.

Secondly, concerns:

1) Health of the Land:

There isn't a farmer who "loves his land" who doesn't want to pass it on to the next generation in better shape than when he started. This isn't only a sentimental concern, it's also a monetary one. Well kept land produces more dollars.

Under normal operations carried on over a number of years, the farmer knows it will be his decisions, his assessment, his building which will eventually determine the health of his land and the health of his pocketbook.

You will appreciate the reluctance of farmers accustomed to this pattern of self-assessing over many years to suddenly commit their farm practice, economic welfare and the future health of their land to the assessment of any "outside expert."

Needless to say if a project assessment were wrong, for example, salt accumulation, it is the farmer's future income that suffers, not the "outside expert's."

This can lead to a "bird in the hand is worth two in the bush" attitude by farmers. I mention it to show the reluctance to any swift and dramatic change which might affect the health of the land.

2) Time Frames for Participation, Education and Finance:

The meeting here will appreciate the desire of each level of participant, be it environmental, government or urban city to make sure that every aspect relating to their particular concerns be adequately discussed, explored, assessed, financed and okayed before putting on the rubber stamp of approval.

From a farm standpoint may I say we wouldn't want it any other way. Any "sin of omission" here might cost us dearly in the future.

However I would like to point out to this seminar that it is only when all of these august bodies have completed their decisions, that we as farmers can commence ours.

Our participation in a project this size is substantial for each individual farmer.

It isn't something you could commit a corner of land to and write it off as another experiment if it failed.

Education wise, it is a complete new concept with minimum time to become accustomed to. No time to "feel" your way in.

Finance wise, you are committing your whole future with no guarantees. In fact, I doubt if any of the participating agencies who have had to approve steps along the way, would want to guarantee any farmer's financial return, even to past performance.

Therefore, I would recommend that at least as much time be given to the farmers to consider their participation with its many decisions, as say each of the other participating bodies have had to date.

3) Management the Key:

Most of you have heard the story of the three persons, one of them a farmer, who each won a million dollars in Loto Canada. The first said he would now be able to travel all over the world - a lifelong ambition. The second said he could now retire and indulge in his many hobbies. The farmer when asked, hesitated, then said he would probably just keep on farming till it was all gone.

While farming probably isn't that much of a losing proposition, there are times when return on investment isn't that great. Farmers usually have to pick and choose when and where to put their time, money and effort. For example, a time to go into cattle and a time to go out. These decisions and timing are crucial management evaluations.

So the final concern that I submit today is that the timing and extent of entry into these types of projects will probably not be a luxury that cities and towns can afford to participating farmers. For many it will, of necessity, be a now or never proposition.

The key to a successful survival in a new specialized type of farming, one that employs considerable amounts of capital and labor, will be adequate management.

I believe that while farmers are always used to making management decisions, usually based on past experience, at this time they have a real concern that they face a fast timetable to equip themselves to the specialization of irrigation and in particular effluent irrigation.

If you can go broke under ordinary farming, the additional variables under specialized irrigation make management more acute.

My recommendation would be for a continuing program of direction to be made available to farmers entering into these types of programs.

Many of these programs are presently available; for example, information on cropping procedures and water management techniques.

Some additional services that I believe will be needed are:

a) Legal advice both for Water Users Groups and for individual farmers. For example, the greater use of capital requirements will necessitate incorporation in many cases.

b) Farm records analysis for individuals during the start up phase of the projects.

c) Clarification and, if at all possible, consolidation of grant and loan agencies for one-stop financing.

The success or failure for farmers of a decision to enter into these types of projects will be made during the very first years of the switch from dryland to irrigation farming.

They offer an exciting challenge.

Thank you for the opportunity to bring these thoughts to this seminar.

Don Swenson

OPERATION & MAINTENANCE OF IRRIGATION EQUIPMENT

SEMINAR ON EFFLUENT IRRIGATION
UNDER PRAIRIE CONDITIONS

Presented by: CENTRAL IRRIGATION CO. LTD. - January, 1979

OPERATION AND MAINTENANCE OF IRRIGATION EQUIPMENT

THE SUPPLIER OF IRRIGATION EQUIPMENT SHOULD DEMONSTRATE THE STEPS INVOLVED IN START-UP, SHUT DOWN, PRE-SEASON AND OFF-SEASON CARE. BETTER KNOWLEDGE IS GAINED IN THESE AREAS ON PRACTICAL EXPERIENCE.

PUMPS

In most cases where surface water is being used, a Centrifugal pump is usually installed. These pumps require priming whether it be done with a hand primer, exhaust, or by manifold. In some cases where a well is the source of water, or the volume of water and the total dynamic head are too great for the capabilities of a centrifugal pump, a vertical turbine pump is used. These pumps are self-priming and installation is somewhat more costly.

POWER PLANTS

Throughout Saskatchewan, diesel engines are the most common source of power. Three phase power is the second source of power, but the availability is restricted in our rural areas. Liquid propane gas has proven to be too high in cost while natural gas hook-ups are not convenient. Since a diesel is the most common source of power, regular maintenance is required as there is on any other farm tractor: - Oil changes
Coolant level checks
Fuel service

... 2

All internal combustion engines that are sitting stationary should be equipped with safety gauges to protect against faults of:

- Oil pressure drops
- Temperature rise
- Loss of pump pressure

In any of the above cases the engine will automatically shut down.

ELECTRIC MOTORS

Maintenance on electric motors is limited; lubrication of bearings and rodent protection are the main concerns. An oil check is required when a vertical turbine pump is used. When either an electric vertical turbine or centrifugal is used, a foundation is required for support and in most cases a pump house is built for protection of wiring, panels and the electric motor in the case of a centrifugal installation. Usually the cost of installing electrically driven pumps (including power supply, panelling, etc.) is equally as high as a diesel operated system.

PIPE LINES

Aluminum Surface Lines:

- Most commonly used with hand line or side roll irrigation.
- Pipes are connected with a quick coupling usually in the style of a hook or band-lock clamp.
- In off-season periods, the tubing should be stocked and gaskets removed and stored in a dry place.
- Aluminum tubing must be free of water due to freezing.

Buried Plastic Lines:

- Buried PVC lines should be buried approximately 3' and the joints left open on installation for pressure testing.
- If possible, buried pipe of any type should be layed to grade to conveniently pump out or drain the water in the off-season. If this is not possible, pump out valves must be placed in all low spots for drainage. This is done to protect against freezing.

... 3

- Air relief vents should be installed at high points and at the end of lines to prevent collapsing of the pipe and to remove air pockets that reduce the capacity of the line. If there were to be a sudden shut down of the pump, there could be a reversal of water movement creating a vacuum, therefore possibly the collapsing action taking place.
- Buried lines must be backfilled and anchored to prevent splitting and buckling due to line surges.

OPERATION AND MAINTENANCE OF A LATERAL WHEEL MOVE

Operation:

- A main line is layed down the middle of the field with the wheel lines at right angles to the main line. (Main lines usually have a valve every 60'.)
- When a system of two wheel lines is installed, one wheel line is positioned at the far end of the main line and the other line at the valve closest to the pump; therefore, the pump is not required to push the full gallonage any further than the middle point of the main line where the laterals will meet and pass each other. This procedure requires less power than running the two lines together at the far end.
- Wheel lines are most commonly moved by a hydraulic mover situated in the middle of the lateral line. The user walks down to the mover, starts a small horse power air-cooled engine and moves the hydraulic lever into gear. The mover uses the pipe on wheels as an axle, moving the system in either a forward or reverse action.
- The wheel line is moved 60' to the next valve where a simple hook up is made and the water turned back on.
- Before the lines are moved, a period of 8 to 10 minutes is required to drain the lines. (Self-draining).
- Lines over the standard ¼ mile length require pressure

... 4

regulators at each sprinkler head over the ¼ mile. Pressure regulators are installed on the sprinkler heads closest to the mainlines where the higher pressure exists.

- A wheel line is operated from 40-45 P.S.I. and uses anywhere from 200-400 G.P.M.

Maintenance:

- Throughout the season, the only maintenance required on a wheel line system is to grease the hydraulic mover once or twice and check the level of the hydraulic oil.
- In off-season use, the line should be braced at three to four places along the wheel line on both sides of the mover due to winds; pipes should be split every four or five joints due to contraction movement in cold weather and the hydraulic drive engine should be stored.

CENTRE PIVOTS

Operation: Visual Presentation.

Maintenance:

- Greasing all drive joints at each tower with water resistant grease. This should be done monthly when in use.
- Grease the pivot point monthly when in use, using water resistant grease.
- Check electrical cables for wear seasonally.
- Check wheel drives for oil.
- Wheel drive oil should be drained completely in the fall and then refilled to recommended capacity.
- Check for structural abnormalities.
- Check security of all electrical panels and outlets.
- Check tire inflation.
- Check alignment mechanisms for freedom of movement.
- In the off-season, make sure all water has drained from the system and that the flush valve on the end boom is open and drained.

COSTS OF IRRIGATION EQUIPMENT

CENTRE PIVOT:

Centre Pivot Machine	$35,000.00
Pipe Line	5,500.00
Power (By portable generator)	6,500.00
Pumping Unit - Electric (Approx 100 h.p.)	3,500.00
Diesel	10,000.00

(Electric price does not include the price of panel or service)

* Per Acre Cost Using Diesel Power: Approximately $425.00
Electric : Approximately $350.00

The initial cost of either the diesel operated pump and pivot, or electric operated pump and pivot, is usually closer in price because of the cost of the power supply installation and panelling, etc. The per acre cost of electric power mentioned above does not include the additional supplies.

WHEEL MOVE:

Lateral Wheel Moves (2)	$11,000.00
Main Line (½ Mile)	9,500.00
Pump: Electric - (50 h.p.)	2,200.00
Diesel	9,000.00

Per Acre Cost Using Electric Power: $150.00
Diesel Power: $180.00

Per Acre Cost Using Four Wheel Lines: Electric Power: $210.00
Diesel Power: $255.00

* As mentioned in the Centre Pivot pricing, the electric per acre costs do not include power supply, panelling, etc.

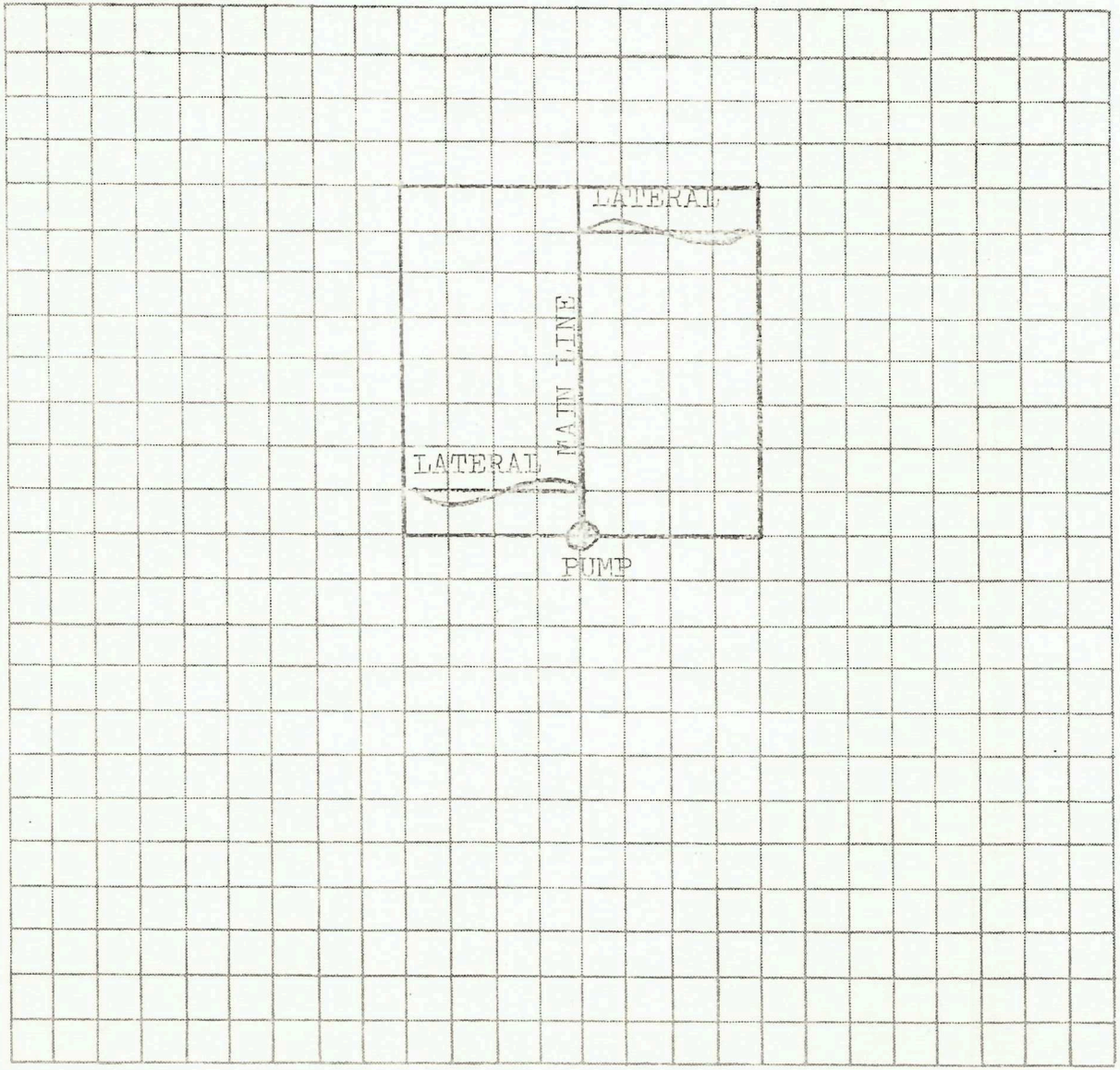
Central Irrigation Company Ltd.

SWIFT CURRENT, SASK. S9H 3X5 - OUTLOOK, SASK. S0L 2N0

PHONE (306) 867-8700 - 867-8800

SPRINKLER SYSTEM LAYOUT & ENGINEERING DATA

For
Address
Location



Scale: in. to ft.

No. of Acres	160
Type of Soil	SANDY
Suction Lift	10
Lift Beyond Pump	20
Friction Supply Line	
Friction Suction Line	
Friction Main Line	31.41
Friction Lateral Line	15.50
Other	18.09
Pressure 45PSI	104.00
Total Head in Ft.	199.00
Total Head in Lbs.	86.16
No. Ft. Water Spreads	104
Nozzle Size	7/32 x 1/8
Gal. per Min. per Head	12.5
No. Heads	64
Gal. per Min.	12.5
In. per Hour	.48
No. In. will be Applied	3.84
No. moves per Day	3
No. Lateral Moves	
No. days to cover Plot	14
No. Hrs. per Day	24
Approx Eff. of	
Net Water on Ground	
Size of Pump	4 x 3
R.P.M. of Motor or Engine	1825
R.P.M. of pump	1825
Make and No. of Pump	
Type of Power	
H.P. of Motor	
Diam. of Impellar	
Eff. of Pump	78%
B.H.P. Required	54
Length of Main	2640
Size of Main	7 - 6
Length of Lateral	1320
Size of Lateral	5
Spacing	40 x 60

BY _____

DATE _____ 19____

Central Irrigation Company Ltd.

SWIFT CURRENT, SASK. S9H 3X5 - OUTLOOK, SASK. S0L 2N0

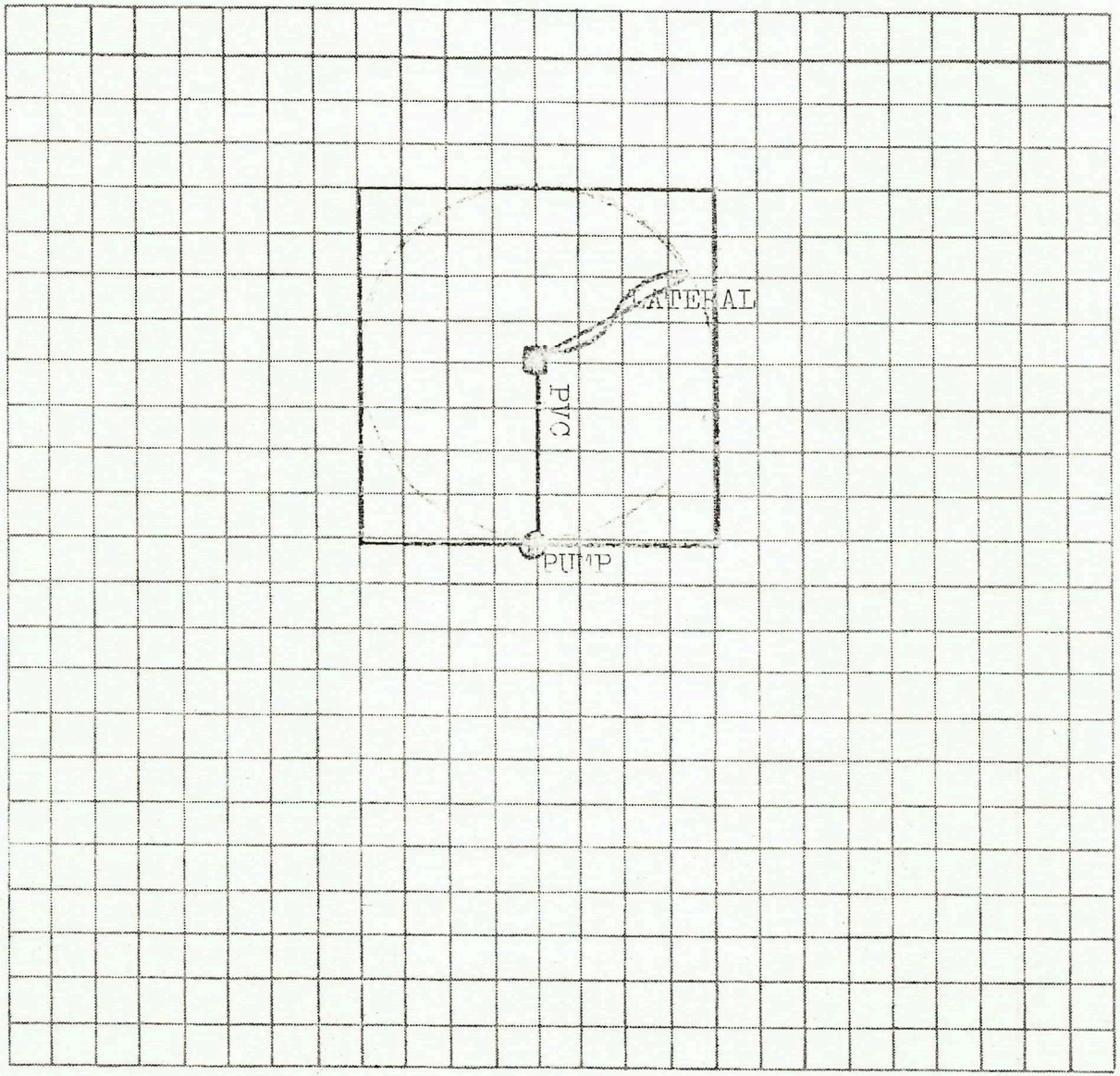
PHONE (306) 867-8700 - 867-8800

SPRINKLER SYSTEM LAYOUT & ENGINEERING DATA

For

Address

Location



Scale: in. to ft.

No. of Acres	130
Type of Soil	SANDY
Suction Lift	10
Lift Beyond Pump	20
Friction Supply Line	18.2
Friction Suction Line	–
Friction Main Line	–
Friction Lateral Line	–
Other	19.84
Pressure	150.15
Total Head in Ft.	218.19
Total Head in Lbs.	94.47
No. Ft. Water Spreads	VARIOUS
Nozzle Size	
Gal. per Min. per Head	VARIOUS
No. Heads	
Gal. per Min.	1000
In. per Hour	VARIOUS
No. In. will be Applied	
No. moves per Day	VARIOUS
No. Lateral Moves	–
No. days to cover Plot	VARIOUS
No. Hrs. per Day	"
Approx Eff. of	"
Net Water on Ground	"
Size of Pump	4 x 5
R.P.M. of Motor or Engine	1700
R.P.M. of pump	1700
Make and No. of Pump	
Type of Power	
H.P. of Motor	
Diam. of Impellar	
Eff. of Pump	
B.H.P. Required	85
Length of Main	1320
Size of Main	8
Length of Lateral	
Size of Lateral	
Spacing	

BY

DATE 19

CASE HISTORY OF THE TABER, ALBERTA WASTEWATER IRRIGATION PROJECT

Introduction

During the late 1960's it became apparent that the water quality of the Oldman River was rapidly deteriorating, particularly during the winter months when the discharge of the river may drop to a low of 400 cfs (11.3 m^3/s). Therefore various cities, towns and industries were required to reduce their pollution loads to the river. The town of Taber, with a population of about 5,000 and various food processing industries, was required to substantially reduce its pollution load. Various methods of wastewater treatment were considered and wastewater irrigation was selected for detailed feasibility studies in 1969.

The two major industries located in Taber were a potato dehydrating plant and a vegetable canning plant. The dehydrating plant used the lye-peeling process which rendered the effluent from the plant unsuitable for irrigation due to the high sodium concentration. However, when its wastewater was diluted with other wastewater, reduction of the sodium concentration to acceptable levels was obtained.

The combined domestic and industrial flows averaged 0.5 million gallons (1890 m^3) per day on an annual basis with peaks of 0.8 million gallons (3030 m^3) per day on a monthly basis.

The effluent from the sanitary sewage system now flows by gravity to a syphon under the Oldman River, then discharges to open storage on the north side of the river approximately three miles

(4.8 km) from the town. Metering is provided by a Parshall flume at the syphon.

One year after start-up of the system, the potato dehydrating plant ceased operation but two other small food processing plants eventually moved into Taber.

Preliminary Studies

Considerable government land was available for purchase by the Town, and Alberta Department of the Environment conducted a soil investigation for irrigability. This included drilling, logging and sample analysis to a depth of up to 12 meters. The amount of land required for the irrigation scheme was determined by taking into account the volume and quality of effluent available, the consumptive use of the crop, the mean annual precipitation and its distribution over the growing season. On this basis it was estimated that a four hundred acre (162 ha) area would be sufficient and a suitable portion of land (Chaplin loamy sand underlain by sand and gravel) was selected for effluent irrigation at a rate of 18 inches (45 cm) per year. The soils were non-saline, non-sodic with a water table at a depth of approximately 13 to 16 feet (4 to 5 m) from the surface. The land was vegetated with native grass, fairly characteristic of the short grass prairie. The mean total precipitation is 38 inches, (96 cm) 65% of which is received during the growing season.

Research and testing work was conducted in the field, laboratory and greenhouse. The laboratory work consisted of passing the lagoon-treated effluent through eight feet (2.5 m) of soil obtained

from the site and collecting the percolating solution at different depths of the soil column. Analysis was conducted on the soil and effluent before application and also on the percolating solution and the soil after the application of 120 inches (300 cm) of effluent.

Table 1

Effluent characteristics

pH	-	6.5	NH_3-N	-	20 mg/L
EC	-	2.2 mmhos/cm	HO_3-N	-	0.5 mg/L
SAR	-	6.0	P	-	7 mg/L
COD	-	1000 mg/L	Cl	-	50 mg/L

The results showed that 150 cm of this soil was effective in removing 90 percent of the calcium, 60 percent of the magnesium and practically all of the ammonium, phosphorus and BOD. Nitrates resulting from the oxidation of ammonium appeared to move freely through the soil. It was felt that some of the calcium and magnesium was precipitated out as carbonates. The effluent did increase the salinity and the sodium content of the soil to some extent but well within acceptable limits. Total nitrogen and phosphorus in the soil were increased considerably by the effluent application.

Application of the effluent to the soil in permeability tubes showed a distinct reduction in permeability during continuous innundation. The permeability was restored after a rest period of a few days.

A test plot of land was established adjacent to a temporary lagoon and a weekly application of about 15 cm was made to a soil

similar to that in the selected field. Analyses of soil samples taken inside and outside of the irrigated area indicated an increase in soluble salts, including sodium, similar to that found in the laboratory columns. Soil analyses of the same sites that were undertaken several months after effluent application ceased, showed a significant reduction of salinity problems due to natural leaching. No symptom of toxicity was noted in the native vegetation.

Barley grown in a greenhouse yielded 44 percent more dry matter when watered with the effluent than with tap water.

Design and Installation

The planning and design of the project was done by the Town of Taber, Reid Crowthers and Partners, and Alberta Environment. Due to cold weather during winter months and the high BOD loading of the sewage, which could not be discharged to the river, storage facilities with a volume of 400 acre feet (500,000 m^3) were constructed using earth embankments in a natural depression. The main storage unit is preceded by two small anaerobic settling basins each of which has a capacity of two days average flow.

A single pumping unit with a capacity of 1,000 gallons (0.4 m^3) per minute against a discharge pressure of 100 psi (4800 Pa) was installed to pump effluent through 5,000 feet (1500 m) of 18-inch (45 cm pipe and 5,000 feet (1500 m) of surface 12-inch (30 cm) pipe to the irrigation area. Four five-inch (13 cm) laterals, each 1,300 feet (400 m) long, with nozzles at 40 foot (12 m) spacings were used for spraying. Lateral connections were provided every 180 feet (54 m)

along the 12-inch (30 cm) lateral. Nozzle pressures were recorded at 55 to 70 psi (2460 to 3360 Pa) depending on the number of nozzles used for spraying.

Application of the effluent was at the rate of 0.5 inches (1.2 cm) gross per hour, with the duration of application controlled by the movement of the wheel-mounted laterals.

Groundwater observation wells and soil monitoring sites were established by Alberta Environment well in advance of actual irrigation in order to measure changes in groundwater and soils due to the application of effluent. Routine analyses of soils and groundwater samples include conductivity (EC), pH, Ca, Mg, Na, Cl^-, HCO_3^-, $CO_3^=$, Total P, NO_3-N, NH_4^-N and Total N. It was also planned to determine "heavy metals" in soils after the system has been operated for 5 years.

Operation and observations

Storage of effluent began in December 1970 and irrigation was initiated in July 1971 on the native sod. An attempt to establish grass and alfalfa by seeding directly into the sod in the fall of 1971 was not successful although reasonably good germination did result. Competition by the native species was probably responsible for the mortality of the domestic species as the native grasses (primarily spear grass), although inferior in quality, responded to irrigation with the effluent with rapid and dense growth.

Subsequent to this experience on half of the 320 acres

(128 ha) was cultivated and seeded to alfalfa on a two-year schedule. A diamgram of the system is shown in Figure 1.

The wastewater flow has increased from 0.5 million gallons per day (1890 m^3) in 1970 to 0.62 million gallons (2360 m^3) in 1978. Insufficent storage and land for irrigation has necessitated some release to the Oldman River during the past few winters. These releases are well within the allowable permitted loadings. Engineering studies are currently in progress with respect to up-grading the system. A number of treatment alternatives are being investigated.

Wastewater chemistry

The chemical characterization of a wastewater is of vital importance to the feasibility evaluation of a wastewater irrigation project, as these characteristics dictate the effect the wastewater will have on the soil. The wastewater chemistry is also necessary to determine the annual application with respect to the limiting loading factor, i.e. hydraulic, nitrogen, etc. The chemical characteristics of this actual effluent at Taber appear in Table 1.

Table 1 Some characteristics of Taber wastewater at pump site (mean of 40 samples)

Parameter	Value
pH	8.0
Electrical conductivity	1.3 mS/cm
Sodium adsorption ratio	3.0
Chloride	55 mg/L
Bicarbonate	300 mg/L
Sulfate	400 mg/L
Total nitrogen	17 mg/L
Total phosphorus	5 mg/L
Potassium	15 mg/L

The Taber wastewater is considered suitable for irrigation and the limiting factor is dependant on the amount of wastewater that can be used by plants, plus a small amount required for leaching.

Groundwater depths and chemistry

The data from three groundwater observation wells have been selected for discussion. Observation well #5 (Figure 1) is located one-half mile (0.8 km) down slope from the irrigated field and in a draw leading from the field to the Oldman River in the probable direction of groundwater flow. Data obtained from this well (Figure 11) have shown a slight rise in the water table and an increase in chloride to about one me/L. Nitrate-nitrogen levels generally have been below

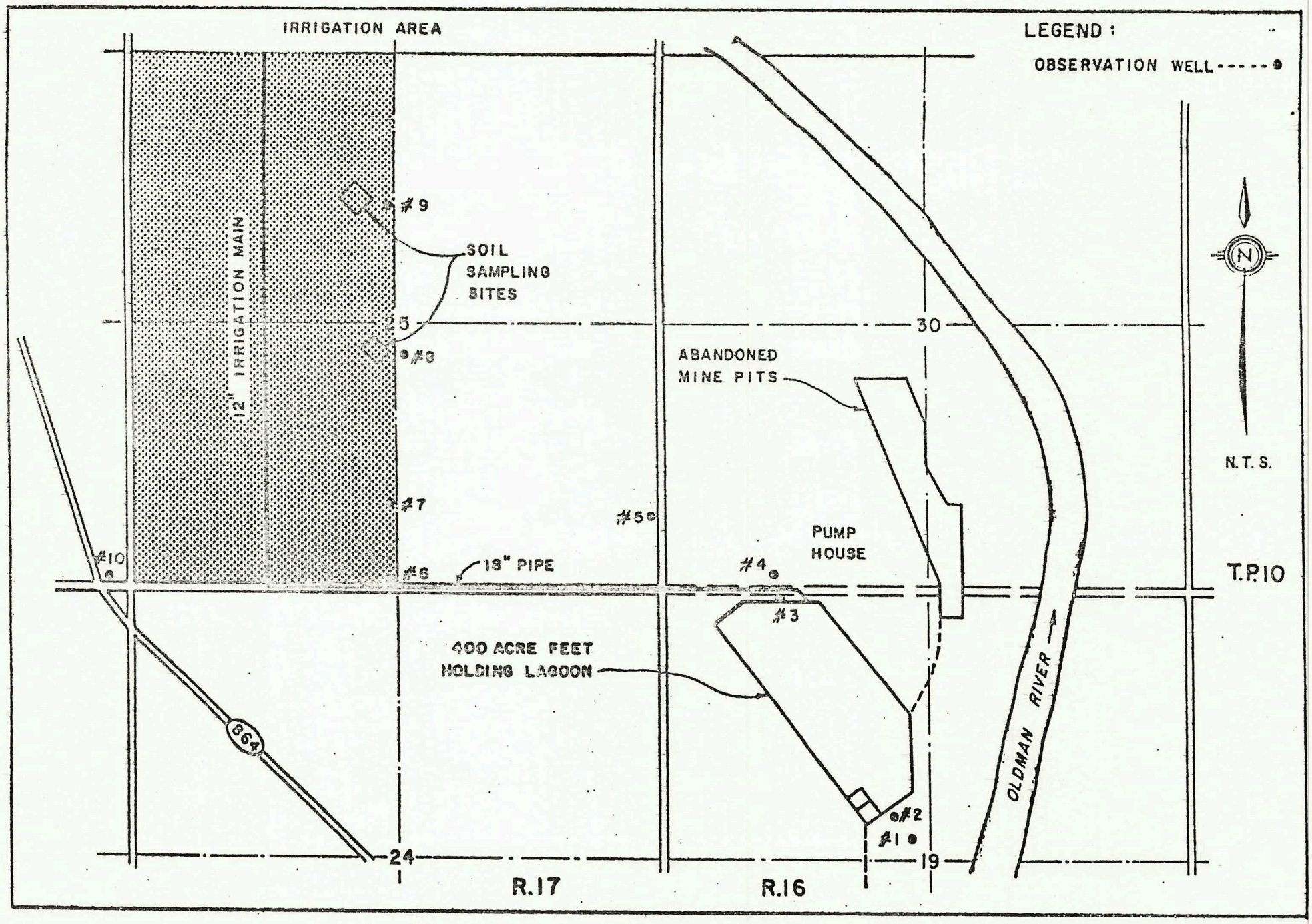


Fig. I Taber Project Layout

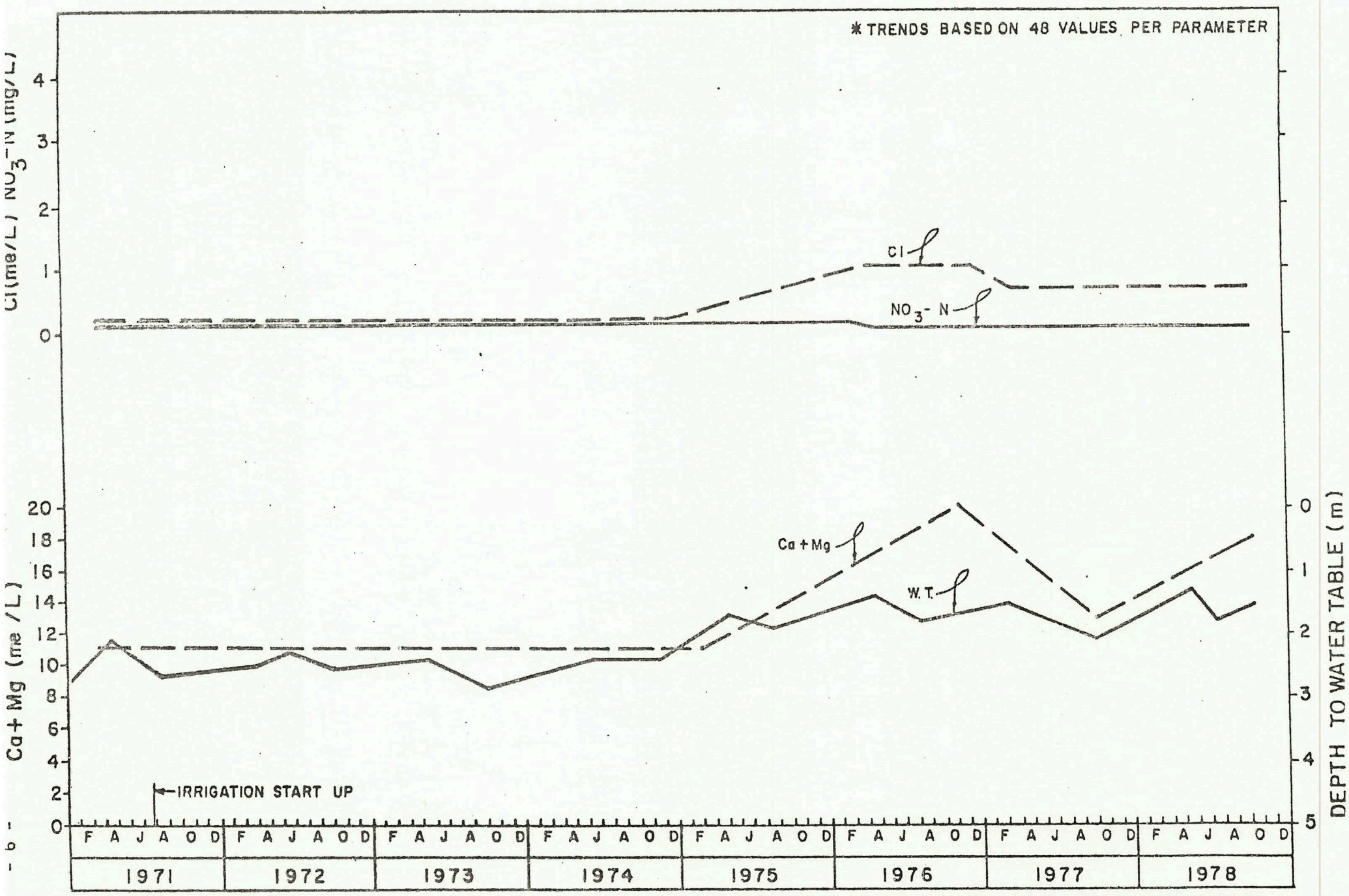


Fig. II - Concentrations Of Cl, NO_3-N And Ca + Mg In Ground Water, And Depth To The Water Table At Well # 5 *

DEC. 1978

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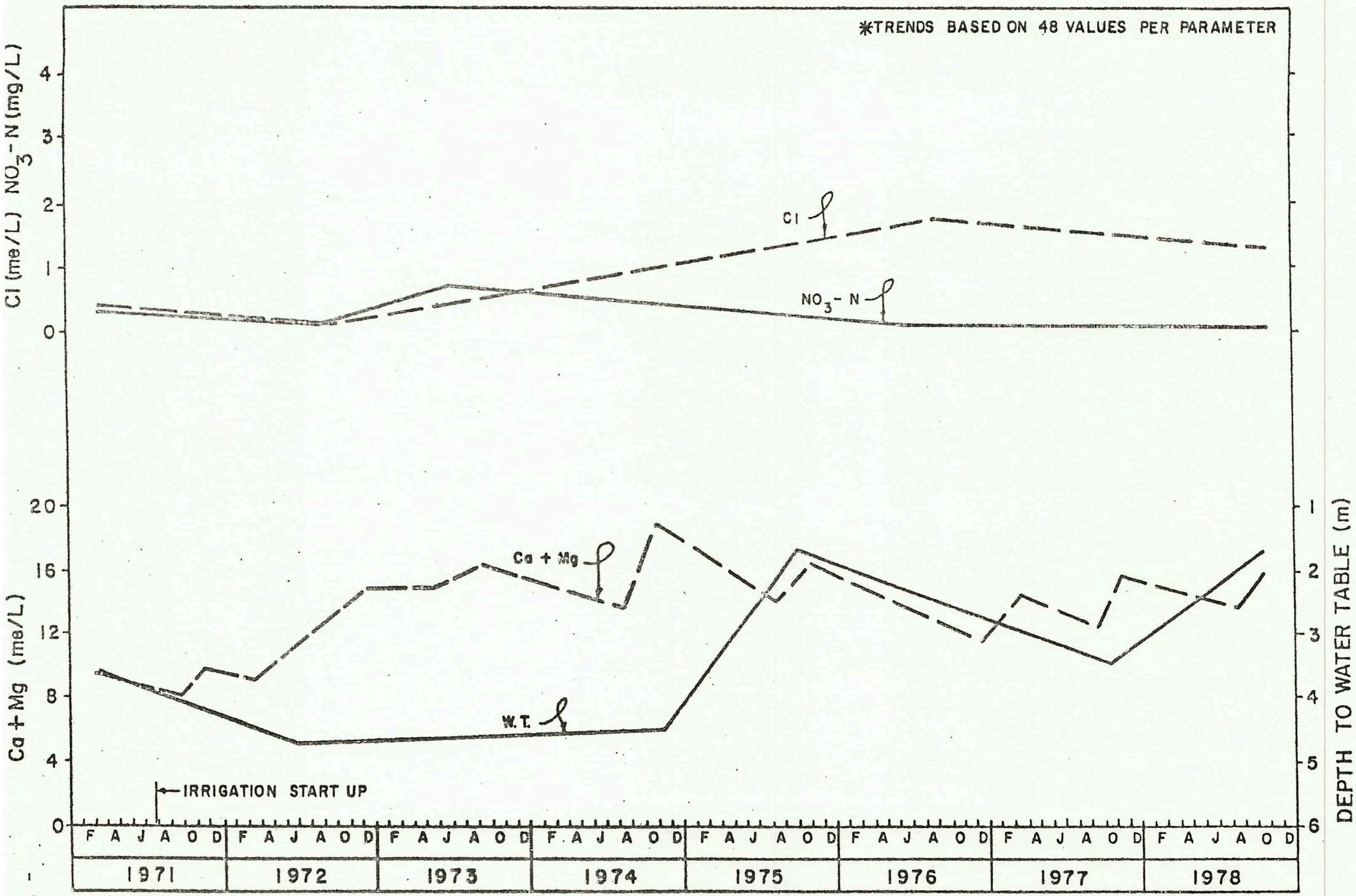


Fig. III- Concentrations Of Cl, NO_3-N And Ca + Mg In Ground Water, And Depth To The Water Table At Well #7 *

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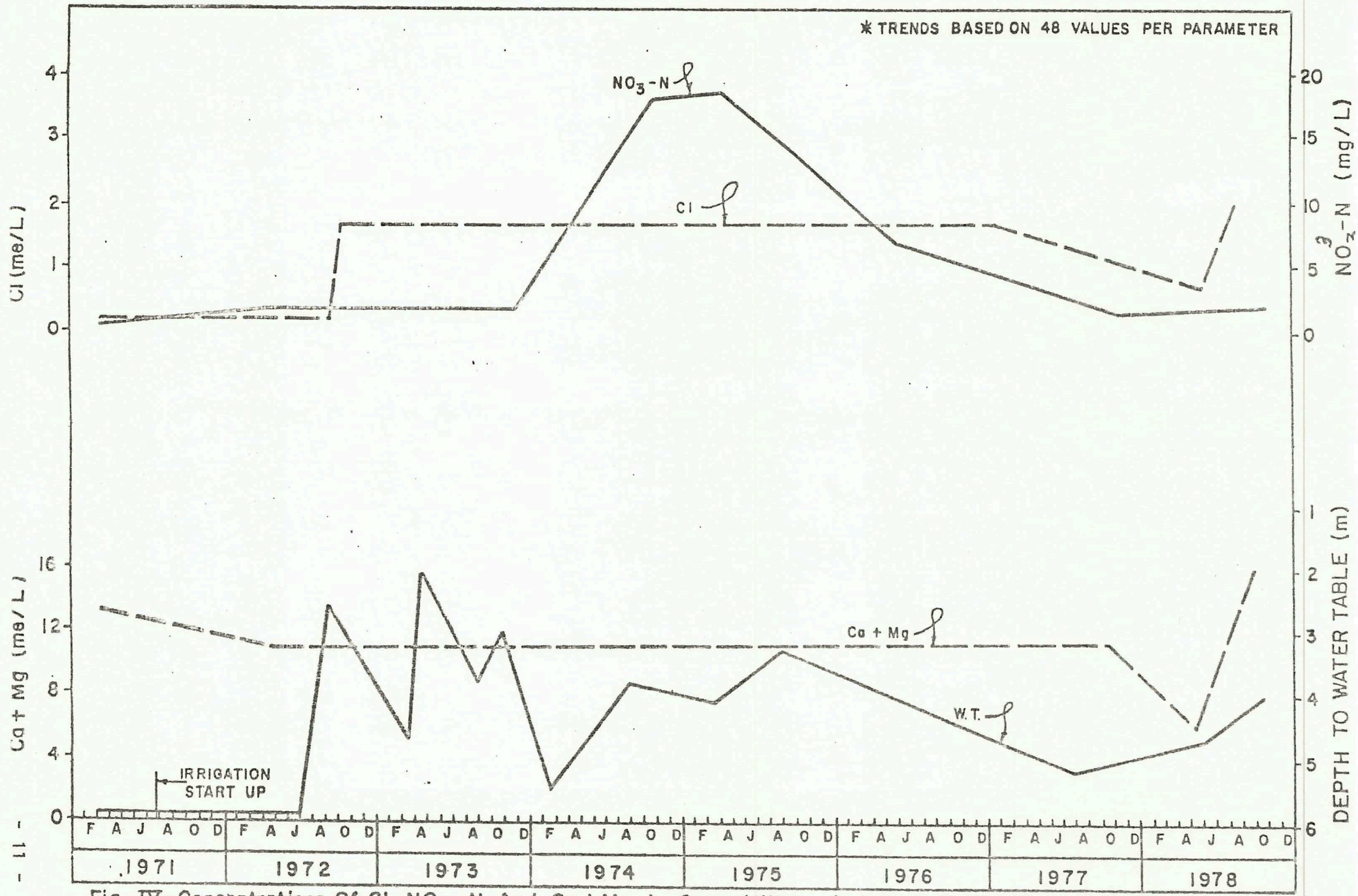


Fig. IV - Concentrations Of Cl, NO_3-N And Ca + Mg In Ground Water, And Depth To The Water Table At Well #9 *

DEC. 1978

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0.1 mg/L, while hardness has increased by approximately 20%. Well #7 is immediately adjacent to a slight depression in which water will pond if irrigation or precipitation is excessive. The water table (Figure 111) has risen from a dpeth of 13 feet (4 m) to approximately nine feet (3 m) over the eight years of irrigation. The chloride and calcium plus magnesium concentration have also increased during this period. Well #9 is located at a higher elevation immediately adjacent to the irrigated field where surface drainage is good. The water table at this site, originally at a depth of 20 feet (6 m) before irrigation, has fluctuated between seven feet (2 m) and 17 feet (5 m) over the past eight years. Chloride concentrations have increased by approximately one me/L, while calcium plus manganese has remained reasonably stable. Nitrate-nitrogen levels in this well have fluctuated, reaching a high of 18 mg/L in 1974 and 1975, and then receeding to levels just slightly above those measured prior to irrigation.

The increase in chloride and hardness concentration was forecast at the outset of the project. It should be pointed out that this increase was measurable in this area because the original groundwater quality was good initially and that it would not be measurable in areas with poor quality groundwater.

Multiple tube sampling wells were installed in the saturated zone to determine if a horizontal strata of grossly contaminated water was present. Analyses of the samples showed no significant differences between samples taken at two foot (0.6 m) differences in elevation.

Soil chemistry

Chemical differences between the non-cultivated soils and the wastewater irrigated soils could be due to the effect of cultivation, or irrigation, or the addition of wastewater constituents. One can only speculate on the relative importance of each of the three possible causes of the changes.

Chemical analyses of soils (Table 2) indicate that there are highly significant differences in several parameters between irrigated and non-irrigated soils. Many of these differences, namely nitrate-nitrogen, available phosphorus, sodium adsorption ratio, extractable sodium and electrical conductivities are directly attributable to wastewater addition. Considering the nature of the soil, particularily texture, drainability and the composition of the wastewater (Table 1) these differences are not surprising, and for the most part were predicted in the planning stage of the project. The present values of electrical conductivity and sodium adsorption ratio are well below critical levels, and will not increase with time. It should be pointed out that the soils in this area are extremely non-saline, non-sodic and therefore only small additions of salts are required to result in significant increases.

Increases in available phosphorus occurred at greater depths than had been anticipated. One possible explanation of this is that part of the wastewater phosphorus is in the particulate form, and may move downwards through larger pores in these coarse-textured soils. In addition, some of the dissolved phosphorus may be in organic form and may be more mobile than orthophosphorus.

Table 2 Comparison of several characteristics of soils irrigated annually with wastewater for eight (8) years with those from an adjacent non-cultivated, non-irrigated area

(mean of 12 samples)

Cultivated Practice	Soil Depth	pH	Elect. Cond.	Carbonates as $CaCO_3$	NH_4OAc Extractable				NO_3-N	NH_4F Extractable	SAR
					Ca	Mg	Na	K		P	
	cm		mS/cm	%	me/100 gm				µg/gm		
Irrigated	0-5	7.3***	0.89***	0.11	7.5	3.3***	0.6***	0.64*	8.0***	26.4***	2.5***
	5-10	7.3	0.96***	0.37	9.1	3.1***	0.5	0.51	2.5***	10.0**	2.4***
	10-15		1.07***						2.2**	5.8***	2.7***
	15-30		0.74**						1.7**	5.6*	2.6***
	30-45		0.82***						0.9	3.6	2.4***
	45-60		0.88***						0.8	1.7	2.5***
Non-irrigated and Non-cultivated	0-5	6.7	0.43	0.28	12.2***	1.8	0.3	0.49	0.3	9.1	0.1
	5-10	7.3	0.37	1.58	17.8**	1.8	0.4	0.35	0.5	4.2	0.2
	10-15		0.34						0.4	2.6	0.2
	15-30		0.26						0.3	3.9	0.2
	30-45		0.34						0.5	3.5	0.2
	45-60		0.34						0.7	2.3	0.3

* Significantly higher at the 95% level

** Significantly higher at the 99% level

*** Significantly higher at the 99.9% level

Table 2 continued

Cultural Practice	Soil Depth	Total Nitrogen	Clay	Silt	DTPA Extractable Fe	Cu	Zn	Pb	Mn	Ni	Cd
	cm	%			µg/gm						
Irrigated	0-5	0.13	10	15	10.8	0.46	0.96	0.43	4.1	0.26	<0.2
	5-10	0.09			9.6	0.36	0.37	0.35	4.4	0.28	<0.2
	10-15				9.6	0.35	0.45*	0.40	4.4	0.31	<0.2
	15-30				7.9	0.31	0.28	0.35	3.9	0.36	<0.2
	30-45				8.6	0.46	0.38	0.28	3.2	0.45	<0.2
	45-60				7.7	0.46	0.25	0.30	2.6	0.55	<0.2
Non-irrigated and Non-cultivated	0-5	0.14	12*	20**	16.2*	0.41	1.01	0.68*	8.5***	0.61***	<0.2
	5-10	0.10			10.7	0.41	0.35	0.38	7.2***	0.68***	<0.2
	10-15				11.1	0.40	0.22	0.41	6.0	0.71***	<0.2
	15-30				10.7*	0.45	0.22	0.40	5.1	0.83***	<0.2
	30-45				8.8	0.45	0.19	0.43	4.8**	0.83	<0.2
	45-60				8.1	0.40	0.19	0.46	3.9	0.68	<0.2

* Significantly higher at the 95% level

** Significantly higher at the 99% level

*** Significantly higher at the 99.9% level

Non-irrigated soils have significantly higher clay, silt and total extractable cations in the surface (0 - 5 cm) samples than irrigated soils. This strongly suggests that some fine soil particles have been moved downward in the irrigated soils. Extractable magnesium contents, however, are significantly higher in the irrigated soils (0 - 5 and 5 - 10 cm depth). This may be due, in part, to the differences in calcium to magnesium ratios of the wastewater and the soil. Furthermore, dolomite was probably brought to the surface by cultivation of the irrigated area. Subsequent dissolution of the dolomite may have contributed to the increase of magnesium on the exchange complex, and an increase in pH.

In most instances, no significant difference exists in levels of DTPA-extractable metals between the irrigated and non-irrigated soils.

Where significant differences do occur (usually in the 0 - 5 and 5 - 10 cm depth), the non-irrigated samples contained the higher amounts. The differences, which do occur, cannot be accounted for by net removal from the system of the harvested portion of the crop (data not presented). One possible explanation does exist in that some metals tend to concentrate in the roots of most plant species, and as the biomass of alfalfa roots probably far exceeds the root biomass of the native grass, relatively large amounts of metals may be bound in the root mass. One other partial explanation, particularily for the 0 - 5 cm depth, is that the lower pH in the non-irrigated soils resulted in greater extraction of some of the metals.

Annual costs and returns

The Town of Taber has generally supplied annual irrigation

operating costs and revenues received from product sales for the years 1976 and 1977. Costs do not include those incurred to control odour in the lagoon as these costs would be independent of the final fate of the effluent.

1976

Wages	$12,000
Materials	1,000 app
Power	4,300
Total annual variable cost	17,300
Revenue received*	$24,900
Net return	7,600

* 1385 tons of alfalfa or (4.3 tons/acre or 11 tonnes/ha)

1977

Wages	$ 9,700
Matarials	300
Power	5,330
Total annual variable cost	15,330
Revenue received*	$26,000
Net return excluding fixed costs	10,670

* 1300 tons of alfalfa (4.1 tons/acre or 10.2 tonnes/ha)

The net return was more than offset by the purchase of an organic compound, which was added to the raw sewage for odour control, most of which emanates from the lagoon.

Conclusion

1. The project has been effective in the maintenance of Oldman River water quality.
2. Odours from the lagoon have been a problem in some years.
3. Irrigation has resulted in a slight rise in the water table.
4. Irrigation has resulted in a significant increase in salinity, adsorbed sodium, nitrogen, potassium and phosphorus in the soil.
5. Chloride and hardness levels have increased in the groundwater due to wastewater irrigation.
6. The irrigated soils contain significantly less DPTA extractable iron, lead, manganese and nickel than does the non-irrigated, non-cultivated soils.
7. Financial returns of wastewater irrigation at Taber has more than compensated for the operation costs of the irrigation system.

This paper simply relates what has happened at one particular location, and the results cannot be transcribed to all other areas. Each project must be evaluated separately.

D.N. Graveland,
Technical Development Branch,
Earth Sciences Division,
Alberta Environment,
Lethbridge, Alberta.

December, 1978.

EFFLUENT IRRIGATION DEVELOPMENT

SEWAGE LAGOON - TOWN OF BALGONIE, SASKATCHEWAN

Prepared By: W. E. Randall
Irrigation Engineer
Conservation and Land Improvement Branch
Saskatchewan Department of Agriculture

In the Province of Saskatchewan there are in excess of four hundred municipal lagoon systems in operation. It is estimated that beneficial usage of the effluent, as a supply of water for agricultural crops, would be possible in over three hundred cases. In addition, it is estimated that about one hundred urban centres are faced with serious disposal problems, ranging from vocal complaints to pending law suits. Effluent irrigation can be utilized to solve the disposal problems in many, if not most, of these cases. Development of an effluent irrigation project can be viewed by the urban centre as a method for drainage of the lagoon for which the Town of Eatonia is an example or viewed by a local farmer as an available source of water for increased crop production for which the Town of Balgonie is an example. The following provides a brief history of the Balgonie development with pertinant comparisons to other developments not totally initiated by the farmer.

The irrigation development located at Balgonie is situated on the SE 1/4 33-17-17-2 and incorporates the irrigation of 52.5 acres by the wheel move method. A drawing depicting the irrigation development is presented in Figure 1. The development is owned and operated by Donsdale Farms Co., a partnership in the business of dairy farming and comprised of Messrs Geoffrey Miles, Dale Keith and Donald glen Strudwick. Due to the farming operations carried out by Donsdale Farms Co., a need existed for good quality feed and consequently, the Balgonie sewage lagoon was viewed as a source of water for the production of alfalfa forage.

The project was initiated by Donsdale Farms Co. by submission of an Application for Investigation to the Conservation and Land Improvement Branch of the Saskatchewan Department of Agriculture under the policy for irrigation development on indidivudal farms. This policy was set up to assist individual farmers, partnerships, co-operatives and corporations in development of

irrigation projects and provides engineering and technical assistance for such development, as well as limited financial assistance. In addition, the policy provides assistance to small urban centres for disposal of sewage lagoon effluent by irrigation methods. The application was received in May, 1975 and during the summer of that year, investigations were carried out to determine the physical potential for development and to enable a design and cost estimate to be prepared. At the time that the application was acknowledged, the Water Pollution Control Branch of the Saskatchewan Department of the Environment was made aware of the interest for development. The investigation included an inspection of the area, evaluation of the soil suitability and effluent quality, estimation of the available annual effluent volume and engineering surveys.

Samples of the effluent were obtained and analysis by the Soil Testing Laboratory at the University of Saskatchewan in Saskatoon indicated a range of from 900 ppm to 1400 ppm of total dissolved solids. Soil samples were obtained and evaluated by O. P. Bristol (Soils Specialist for the Conservation and Land Improvement Branch). Analysis of the samples, as provided by the Soil Testing Laboratory, are presented in Table 1. Mr. Bristol reported the soil as belonging to the Weyburn Association. They are dominantly chernozemic dark brown soils developed on medium textured calcareous glacial till. Surface textures are dominantly loams with an estimated basic infiltration rate of 0.35 to 0.4 inches per hour. Bristol rated the soils of the area as good for irrigation and placed them in Group II under the classification system for irrigation.

Determination of the amount of effluent that may be available for irrigation usage and hence, the acreage that should be developed is generally a matter of the best guess since effluent discharges are generally not metered by small urban centres. The project sizing, to be effective as a

means for effluent disposal, must be sufficient to utilize all the available effluent. In addition, the economics of development on a per acre basis, are usually more favourable as the project becomes larger. However, the area developed must take into account the crop grown and subsequent water requirements. Development of too large an area for the available water supply will result in reduced yields with subsequent poor project economics, while development of too small an area will result in either continued disposal problems for the urban centre or the application of water in excess of what the crop can utilize and resultant increased operating costs. In general, a farmer will wish to restrict the amount of water applied to obtain a realistic balance between crop yields and operating expenditures. For example, alfalfa grown on the prairies will utilize an average net irrigation application of approximately 17 inches from optimum growth. Realistically, however, the amount of water a farmer will apply rarely exceeds a gross application of 17 or 18 inches which results in a net application of about 12 inches considering application efficiencies in the range of 70 to 75 percent. This is particularly true for sprinkler irrigation methods due to the operating costs involved. The above points to a potential problem in applying insufficient water to meet the leaching requirements inherent in irrigation and particularly required with effluent irrigation.

For the Balgonie development, three methods were utilized to estimate the volume of effluent. Considering a population of 600 and the discharge rate of effluent at 60 g.c.d. the annual volume was estimated at 13,000,000 imperial gallons or approximately 48 acre-feet. The two lagoon cells were estimated at holding seven million gallons and were, prior to the irrigation taking place, emptied by discharging into a natural run twice each year. The third method employed considered the domestic water consumption during the winter months for a two year period (averaged out at approxi-

mately 1,400,000 per month) and by applying a factor of 80% provided a volume 13,700,000 imperial gallons or 50 acre-feet. The three estimates were very close and for design purposes, it was felt that the project could be based on an available water supply in the order of 50 acre-feet. The acreage developed could range therefore from a low of 35 acres considering an 18 inch application to a high of 50 acres, considering a 12 inch application.

During the summer of 1975, engineering surveys were completed which enabled the project to be designed and a cost estimate prepared. The details of the design are shown in Figure 2. The design details and cost estimate were submitted to Donsdale Farms Co. for their consideration in November, 1975. The equipment suggested was capable of irrigating in the order of 60 acres by modifications to the length of main line. However, the cost estimate was based on irrigating approximately 50 acres. It was further explained that this would only provide in the order of 12 inches of water and yields would undoubtedly be better if the application was in the order of 18 inches and the development limited to around 35 acres. It should be noted, however, that the acreage could be reduced at any time by restricting the number of irrigation sets. Also, as the town grows in population, the available water will increase and the number of irrigations, and thus applied water can be increased accordingly. The material submitted to Donsdale Farms Co. provided an estimated cost of $15,000 excluding the Saskatchewan Power Corporation capital levy for providing power or approximately $290 per acre. In addition to the design details and cost estimate, Donsdale Farms Co. were informed that an agreement would be required with the Town of Balgonie for use of the effluent and that the Town of Balgonie would require a Certificate of Approval to Operate from the Department of the Environment. Further to the above, land control would be required for access to the pumpsite at the lagoon and for placement and operation of

the main line through the NW 34-17-17-2.

In the early spring of 1976, Donsdale Farms Co. contacted irrigation equpment dealers, obtained a private easement for access to the lagoon, and negotiated an agreement with the Town of Balgonie to allow for and ensure continued diversion of the sewage effluent for irrigation purposes. The equipment was purchased in May, 1976 and the equipment details are indicated on Figure 1. A "Certificate of Approval to Operate" was issued on February 17, 1977 to the Town of Balgonie under the authority of the Water Resources Management Act, 1972. The Certificate of Approval was issued by the Saskatchewan Department of the Environment in connection with the operation of the sanitary sewage works and included approval to operate the effluent irrigation project. The approval includes a requirement for the maintenance of certain records and submission of these records annually to the Department of the Environment for documentation. The records are to include: (a) period of irrigation; (b) volume of effluent used for irrigation; (c) area of land irrigated; (d) type of crop grown; (e) estimated crop yield. It must be pointed out at this time that the information submitted by Balgonie and the other towns and villages with effluent irrigation development is rather sketchy and incomplete. The Department of the Environment is endeavouring at this time to arrange for the collection of the data on a more consistent and complete basis.

In the spring of 1976, the area to be irrigated was seeded to alfalfa with an oats nurse crop. Irrigation was initiated in July, 1976. During 1977 and 1978, the area received four irrigations each year which emptied the lagoon by the fall of each year. The four irrigations applied 50 acre-feet in total or approximately 12 inches of water to each acre. This corresponds exceptionally well with the original estimates for the volume of effluent annually available. Yields have been exceedingly good amounting with two cuts each year, to seven tons/acre during 1977 and five and one-half

tons during 1978. The reduced yield in 1978 is attributed to an extreme hailstorm during the end of May which destroyed all growth up to that time. As a result of the high yields Donsdale Farms Co. are extremely pleased with the project development thus far.

To monitor the effect on the groundwater two water table wells were installed by the Conservation and Land Improvement Branch for annual sampling by the Department of the Environment, and to monitor any changes in the surface salts, two sites were selected for sampling every second year by the Conservation and Land Improvement Branch. The water table wells are indicated as W.T.W. #1 and W.T.W. #2 on Figure 1. The analysis of the samples are shown in Table 2. The soil sampling sites are indicated as S.S.S. #1 and S.S.S. #2 on Figure 1. The analysis of the samples are shown in Table 3. The depth to the water table is at approximately fourteen feet and has not increased. There would seem to be, however, a general increase in the total dissolved solids, particularly for Water Table Well No. 1. The significance of this increase has not been determined. In addition, due to the limited water application, it would be suspected that the change in the groundwater may not be attributal to the irrigation. The analysis of the soil samples taken in 1976 and 1978, as shown in Table 3, indicate a slight rise in the total salts as indicated by the electrical conductivity but more significantly a rise in the S.A.R. The rise indicates a sharp increase in sodium, although the readings are still within acceptable limits. The data is too limited at this time to properly assess and additional samples will be obtained during 1979 in the spring prior to irrigation in the late fall.

Effluent irrigation developments of this type are eligible for financial assistance under the Conservation and Land Improvement Branch Assistance Policy for Irrigation Development on Individual Farms. Currently, this policy provides financial assistance of one-third of the cost to a

maximum of $35 per acre for a maximum of 50 acres. This assistance is available for up to three members of a partnership, co-operative or corportion. Donsdale Farms Co. development amounted to a capital cost of $18,144.00 including the Saskatchewan Power Corporation capital levy and electrical hookup. Consequently, the development qualified for the maximum assistance of $35/acre for the 52.5 acres developed or a total of $1,837.50. It must be pointed out at this time that since the project was initiated and developed totally by the farmer, financial assistance was limited to that indicated above. Effluent irrigation projects at most other small urban centres are initiated by the urban centre and thus, the capital development costs are paid for by the village or town or shared between the village or town and the farmer in some manner. In these instances, since the village or town make the expenditures, additional financial assistance may be available through the Municipal Water Assistance Board amounting to one-third of the capital cost.

As indicated initially, effluent irrigation development may be initially promoted by an urban centre as a means of effluent disposal or initiated by an interested farmer as a source of water for irrigated agriculture. The Balgonie project was developed with the capital cost and operating costs being borne by the interested local farmer. The development at Eatonia, on the other hand, was initiated by the town as a means of solving their effluent disposal problem. Consequently, the capital cost was borne by the town. The operational costs are, by agreement with the farmer operating the project, borne by the farmer. The basic differences in the project initiation and development are, besides the eligibility for available financial assistance, reflected in the agreements between the urban centre and the operating farmer.

In the case of Balgonie, the intent of the agreement is to allow use of the effluent by the farmer and provide protection for continued usage.

The following clauses extracted from the actual agreement indicate this intent:

Now, therefore, this agreement witnesseth:

1. That the Town shall permit the diversion of water from the second cell of sewage lagoon by the applicant for irrigation purposes on the NE 33-17-17-W2 and no charge will be assessed the applicant for the said diversion.

2. That the quantity of water diverted and the rate of diversion will be dependent on the irrigation requirements of the applicant and shall not be restricted by the Town except by the physical capabilities of the Town's sewage lagoon and associated sewage works.

3. That the Town will not permit or enter into other agreements for the diversion of water from the sewage lagoon except by mutual agreement between the applicant and the Town.

4. That the Town shall permit the installation of a pump house, pumping plant and necessary accessories on land owned by the Town and adjacent to second cell of the sewage lagoon and shall allow free access by the applicant to such works as may be necessary for the construction, operation and maintenance procedures necessary for operation of the irrigation system.

10. That this agreement may be terminated by the applicant should the sewage effluent detrimentally affect the composition of the soil to be irrigated or for any cause whatsoever upon thirty days prior notice in writing to the Town.

11. That this agreement may be terminated by the Town upon one year prior notice in writing to the applicant in the event that the applicant without cause does not utilize the effluent throughout one irrigation season.

12. This agreement shall be effective from the date hereof to the 31st day of December, 1985 A.D., and shall thereafter continue in force and effect unless or until terminated by the Town upon one year prior notice in writing to the applicant. The agreement may be re-negotiated or amended at any time by mutual consent of the parties hereto.

In the case of Eatonia, Coronach and other towns and villages, the intent of the agreement is to ensure adequate and continued disposal of the effluent in a satisfactory manner. The following clauses extracted from the Coronach agreement indicate this intent:

Now, therefore, this agreement witnesseth:

1. That the Village will purchase the irrigation equipment necessary to enable irrigation on the NW 12-2-27-2 by the thirty-first day of May, A.D. 1980 in accordance with suggested specifications and requirements of the Conservation and Land Improvement Branch of the Saskatchewan Department of Agriculture and that such equipment will be shown on a drawing depicting the development to be prepared by the said Conservation and Land Improvement Branch and designated as drawing 50413-1 and that a detailed list of the equipment shall be made upon purchase and such list form an addendum to this agreement.

2. That the Village agrees to demise and lease to the Applicant the irrigation equipment indicated in Article 1 for a period of time from the date upon which said equipment is in place and in operation up to and including the thirty-first day of December, A.D. 1988. The Applicant shall have an option to renew this agreement for a further ten (10) years upon the same terms and conditions.

3. That both the village and the applicant agree that this agreement may be terminated in any year of the said agreement by giving written notice of intention to terminate to the other party. The said notice to be given at least three (3) months prior to the thirty-first day of December in any given year. Upon said notice being properly given, the agreement shall terminate on the thirty-first day of December in the said year. Should the agreement be terminated at the option of the applicant, then in that event, the village shall have an option to purchase the lands irrigated by the said equipment. The within parties further agree that in the event that the within parties cannot agree on the purchase price of the land, then the question of price shall be determined by an arbitrator agreed to by the within parties. Further, should the within parties fail to agree upon an arbitrator, then one shall be appointed by the courts.

4. That the village will not permit or enter into other agreements for the diversion of water from the sewage lagoon except by mutual agreement between the APPLICANT and the VILLAGE, provided that the applicant is fulfilling the terms of the agreement and making satisfactory disposal of the effluent.

5. That the applicant agrees to return the irrigation equipment free of expense in as good condition as received, reasonable wear and tear excepted.

6. That the applicant agrees to pay all costs, expenses and repairs incurred in the operation and maintenance of the irrigation equipment.

7. That both the village and the applicant agree that any replacement costs that cannot be reasonably considered as maintenance and repair shall be shared jointly by the within parties according to the hereinafter mentioned formula, that is to say:

   The village will be responsible to pay towards the cost of replacement a sum equal to one-fifteenth of the total replacement cost times the number of years that the said irrigation equipment has been in use on the above mentioned land.

   The applicant shall be responsible for the balance of the replacement cost.

   Provided, however, the village shall in no case be responsible for replacement costs caused by negligence or improper operation.

   The village shall carry sufficient insurance on the irrigation equipment to cover the replacement cost of the said equipment.

8. That ownership of and equity in the said irrigation equipment shall remain with the village and it shall be their decision as to when any part of the said equipment shall be replaced, however, in this determination, the rationale of this agreement shall be the primary consideration.

9. That the village shall permit the diversion of water from the second cell only of the sewage lagoon by the applicant for irrigation purposes on the NW 12-2-27-2.

10. That the applicant agrees to follow good irrigation practices throughout the irrigation season in the utilization of the lagoon effluent and irrigation equipment, such that the volume of effluent required to be discharged by the first day of November in each and every year during the currency of this agreement will be discharged.

11. That the applicant agrees to use the said irrigation equipment only to irrigate from the said sewage lagoon and shall not remove the equipment except to make repairs.

Both methods of development incorporate into the agreement certain general clauses applicable to both. The following clauses will be found in both agreements:

- That the applicant agrees to keep accurate records of his irrigation practices consisting of the hours of pumping, irrigation timing, and crop yields during each and every year and agrees to submit said records to the village at the conclusion of each irrigation season.

- That the village shall not be responsible for failure to provide water when prevented due to required maintenance or construction of the sewage treatment works or for alterations or when prevented as a result of floods, washouts, droughts, disasters, Acts of God, or for any other cause for which the village has no control.

- That the applicant shall hold the village harmless from all claims, losses and damages associated with or arising from the water diversion.

- That the applicant shall accept full responsibility for the quality of the water diverted and shall save the village harmless from all claims, losses or damages resulting therefrom.

- That both the applicant and the village agree that the operation of the irrigation system and the diversion of the sewage effluent shall be subject to any and all requirements issued under The Water Resource Management Act and/or The Department of the Environment Act and regulations thereto.

- That this agreement may be re-negotiated or amended at any time by mutual consent of the parties hereto.

- That this agreement may not be transferred or assigned by either of the parties hereto.

There are currently eight effluent irrigation projects operating throughout the province and investigations are proceeding and development pending at twelve additional sites. Technical assistance may be provided by the Conservation and Land Improvement Branch, Saskatchewan Department of Agriculture and Environment Saskatchewan, Water Pollution Control Branch, as financial and manpower resources are available. The technical assistance will include the following:

a) preliminary evaluation of the proposed irrigation site, including soil sampling, soil assays, effluent analyses, engineering surveys and recommendations on crop type, irrigation methods, and preliminary cost estimates;

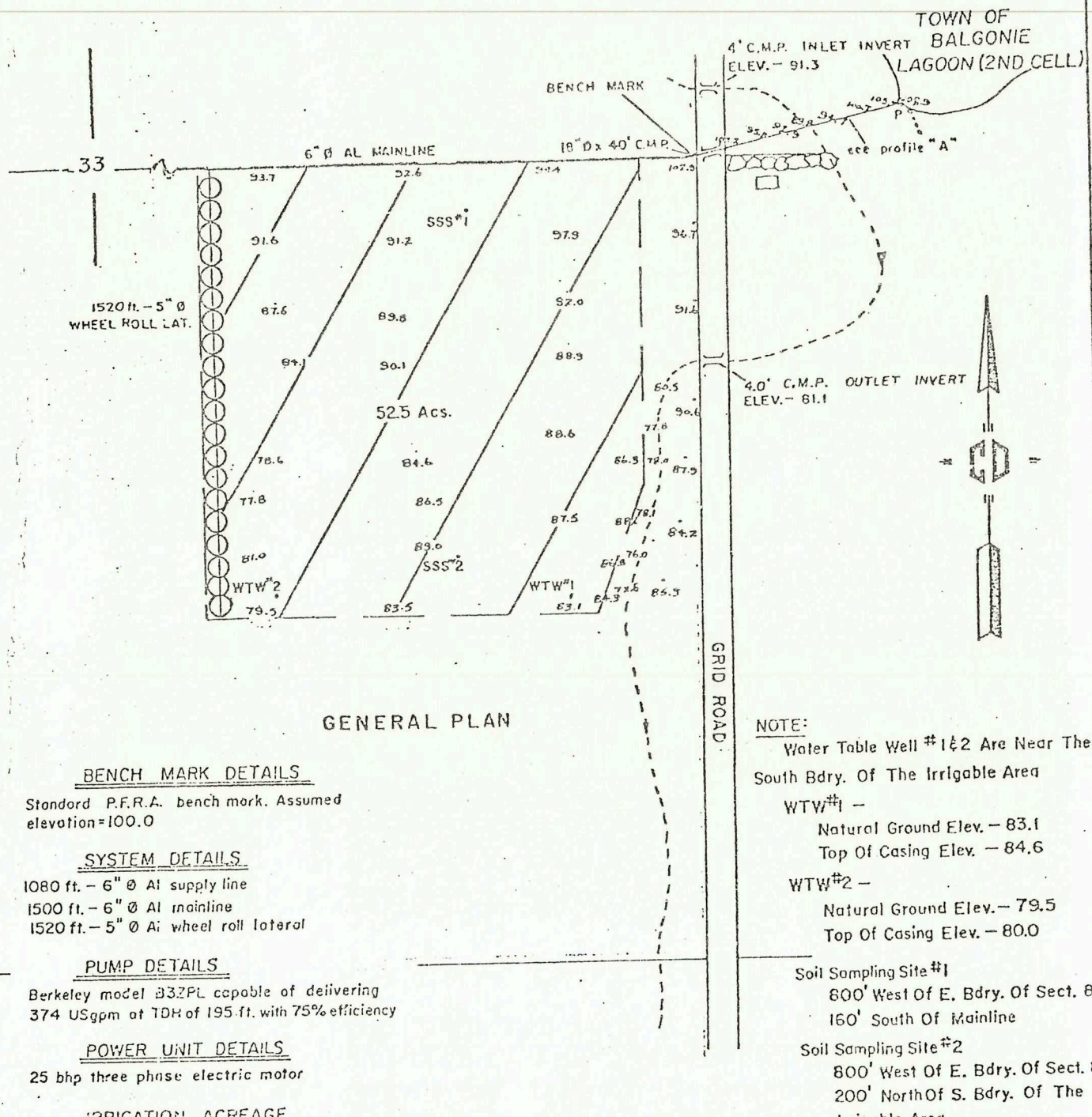
b) system design, cost estimates and operating recommendations;

c) monitor well installation; and

d) advice on collection of soil and monitor well water samples.

Initiation of a project and request for assistance by either the town or village and/or interested farmers, can be made by contacting either of the above agencies directly. Additional information on development requirements and assistance is provided in the "Sewage Effluent Irrigation Guidelines" prepared by Environment Saskatchewan.

FIGURE 1



GENERAL PLAN

BENCH MARK DETAILS

Standard P.F.R.A. bench mark. Assumed elevation = 100.0

SYSTEM DETAILS

1080 ft. – 6" Ø Al supply line
1500 ft. – 6" Ø Al mainline
1520 ft. – 5" Ø Al wheel roll lateral

PUMP DETAILS

Berkeley model B3ZPL capable of delivering 374 USgpm at TDH of 195 ft. with 75% efficiency

POWER UNIT DETAILS

25 bhp three phase electric motor

IRRIGATION ACREAGE

SE. 33 – 17 – 17 – W2M ..... 52.5 acres

OWNER & APPLICANT

Donsdale Farms

NOTE:

Water Table Well #1 & 2 Are Near The South Bdry. Of The Irrigable Area

WTW#1 –
Natural Ground Elev. – 83.1
Top Of Casing Elev. – 84.6

WTW#2 –
Natural Ground Elev. – 79.5
Top Of Casing Elev. – 80.0

Soil Sampling Site #1
800' West Of E. Bdry. Of Sect. 8
160' South Of Mainline

Soil Sampling Site #2
800' West Of E. Bdry. Of Sect. 8
200' North Of S. Bdry. Of The Irrigable Area

		CK'D
W.E.R.	W.E.R.	BY
Water Table Wells & Soil Sampling Sites Added	AS CONSTRUCTED DETAILS ADDED	REVISION
JULY 1976	FEB. 13/72	DATE
2	1	NO.

SASKATCHEWAN
DEPARTMENT OF AGRICULTURE
CONSERVATION AND DEVELOPMENT BRANCH

GENERAL PLAN
showing
INDIVIDUAL IRRIGATION PROJECT
of
DONSDALE FARM CO.
S.E.1/4 sec. 33 TWP. 17 RGE 17 W2 M

SCALE – as shown
SUBMITTED Bryan Ireland
RECOMMENDED
APPROVED W.C. Caudell
DATE: OCT. 14/75

DRAWN M.R.
TRACED
CHECKED
EXAMINED

50300 – 1

FIGURE 2

SPRINKLER EVALUATION

Date Oct. 1974

Applicant Donsdale Farms Co. File No: 50300

Area Land Location S.E. 33-17-17-2 Acres: 52.5

Source of Water Town of Balgonie Lagoon

DESIGN INFORMATION

Soil Texture Loam

Moisture Holding Capacity approx 2 In/Ft

Infiltration Rate 0.4 In/Hr.

Kind of Crop various

Working Root Depth 3-4 Ft.

Peak Use Rate 0.22 In/Day

Irrig. Interval Desired _____ Days

Minimum Water Req'D _____ Ins.

Sprinkler Spacing 40 x 60

Discharge / Sprinkler 10.1 G.P.M.

Application Rate $\frac{96.3 \times G.P.M.}{A}$ = $\frac{96.3 \times 10.1}{2400}$ = 0.4 In/Hr.

Time Per Set 7 1/2 Hrs.

Gross Water Applied 3.0 Ins.

Application Efficiency 75 %

Net Water Applied 2.25 Ins.

Irrig. Interval 10.23 Days

No. of Sets 25

No. of Laterals 1

Sets/Day 3

Acres Per Set 2.15

Acres Per Day 6.45

Operation Time/ Irrig. 8 1/3 Days

Relocation Time 1.9 Days

SYSTEM DESIGN

Lateral Lines

Length of Lateral Lines 5"ø - 1520 Ft. _____ Ft.

Sprinkler Nozzle, Size 3/16" x 1/8" G.P.M. 10.1 @ 45 P.S.I. Ave.

Allowable Pressure Loss in Line 20% of Ave. P.S.I. = 9 P.S.I.

Line	Size In.	Length Ft.	No. of Sprinklers	G.P.M./ Sprinkler	Capacity	Friction Loss P.S.I.	Elev. Dif.P.S.I.	Pressure Loss P.S.I.
	5	1520	38	10.1	384	6.6	-5	1.6

P.S.I. Req'd @ Inlet of Lateral = Ave. P.S.I. 45 + ½ Friction Loss 5 + Elev. Diff. -5 = 45 P.S.I.

Total System Capacity 384 G.P.M.

Main Line

Total Length of Main Line _____ Ft.

Selection of Main Line:

Pipe Size	Capacity G.P.M.	Length	Friction Loss/100'	Friction Loss	Elev. Diff.	Total Head Loss
6"	384	2600	1.25'	33	-10	25

Main Line Selected Size 6 "x _____ ': Size _____ " x _____ '

PUMP UNIT

Maximum Capacity Req'd 384 G.P.M.

Pressure Req'd @ Lateral 45 P.S.I. or 104 Ft.

Head Loss in Main Line _____ 25 Ft.

Static Lift _____ 5 Ft.

Miscellaneous Losses _____ 16 Ft.

Total Dynamic Head _____ 150 Ft.

Pump Efficiency 70 %

Horsepower Required $\frac{150 \times 384}{3,960 \times 0.7}$ = 21 B.H.P. Continuous

Designed By: B.I.

AC 501 Rev./Mar/70

TABLE 1

SOIL EVALUATION

HOLE NO.	DEPTH	TEXTURE	SAT.%	COND. mmhas/cm	pH	SOLUBLE SALTS/ppm Na^+	Ca^{++}	Mg^{++}	K^+	CL^-	$SO_4^=$	SAR
#1	0-8"	L	46	1.19	7.5	24	218	50	25	28		0.38
	8-20"	CL	44	1.36	7.2	30	157	108	12	8		0.45
	20-32"	CL	38	7.25	7.7	258	791	1024	33	8		1.47
#2	0-8"	L	48	0.87	7.2	9	138	42	26	16		0.17
	8-20"	CL	44	0.96	7.8	24	85	36	13	9		0.55
	20-36"	CL	46	1.38	8.1	95	80	101	22	16		1.67
#3	0-8"	L	48	1.17	7.0	16	158	82	35	36		0.26
	8-20"	CL	44	6.32	7.5	66	1448	524	39	11		0.38
	20-26"	CL	44	4.56	7.8	168	658	420	40	10		1.26
#4	0-8"	L	49	1.08	7.5	13	197	45	35	17		0.22
	8-18"	CL	51	0.70	7.7	17	110	40	11	7		0.35
	18-30"	CL	44	4.70	7.9	159	586	477	31	8		1.18

Note: Analysis by Soil Testing Laboratory - University of Saskatchewan.

TABLE 2

WATER TABLE MONITORING

	WATER TABLE WELL NO. 1					WATER TABLE WELL NO. 2				
)ATE	15/12/76	26/04/77	31/10/77	07/06/78	02/10/78	15/12/76	26/04/77	31/10/77	07/06/78	02/10/78
)H	7.7	7.7	7.5	7.3	7.3	7.5	7.6	7.2	7.2	7.3
;ICARBONATE mg/1	498	478	476	386	429	566	510	493	505	447
:ARBONATE mg/1										
:HLORIDE mg/1	28	22	94	166	138	190	194	216	190	284
;ULPHATE mg/1	480	405	1300	3000	2000	1450	1450	1600	1500	1800
.ALCIUM mg/1	139	16	318	424	360	252	170	411	392	448
MAGNESIUM mg/1	90	154	189	467	292	321	323	220	219	272
'OTASSIUM mg/1	11	8	13	12	11	17	13	15	11	12
.ODIUM mg/1	84	84	155	272	270	159	158	165	163	186
.ONDUCTIVITY umho/cm	1400	1300	2400	3700	3300	2500	3000	2800	2400	3200
.UM OF IONS (TDS) mg/1	1338	1171	2547	4766	3516	2970	2824	3123	2987	3454
'OTAL HARDNESS mg/1 as $CaCO_3$	720	672	1572	2980	2100	1950	1752	1932	1880	2240
'OTAL ALKALINITY mg/1 as $CaCO_3$	408	392	390	316	352	464	418	404	414	366

Note: - The samples were obtained by the Water Pollution Control Branch, Saskatchewan Department of the Environment.

- Analysis by Provincial Laboratories.

TABLE 3

SOIL MONITORING

SITE	DATE	DEPTH	TEXTURE	SAT.%	COND. mmhos/cm	pH	SOLUBLE SALTS/ppm Na^+	Ca^{++}	Mg^{++}	K^+	CL^-	$SO_4^=$	SAR
Soil Sampling Site #1	Aug. 1976	0-6"	L	44	1.3	6.6	18	205	70	27	27	80	0.3
		6-12"	CL	44	1.3	7.0	18	170	75	14	14	170	0.3
		12-24"	CL	42	1.0	7.5	34	80	70	14	17	57	0.7
		24-30"	CL	43	7.2	7.5	354	665	850	30	98	6700	2.1
	Dec. 1978	0-6"	L	48	1.6	7.2	134	100	70	18	41	310	2.5
		6-12"	CL	47	1.5	7.3	113	115	60	9	91	315	2.1
		12-24"	CL	46	1.5	7.6	75	75	60	11	100	335	1.6
Soil Sampling Site #2	Aug. 1976	0-6"	L	41	1.4	7.3	11	225	50	94	18	190	0.2
		6-12"	CL	45	1.3	7.6	14	140	50	140	20	85	0.3
		12-24"	CL	33	1.9	7.7	31	160	110	166	22	730	0.5
		24-36"	CL	32	6.7	7.7	255	690	800	122	56	6600	1.6
	Dec. 1978	0-6"	L	46	1.0	7.4	66	70	40	12	60	185	1.6
		6-12"	CL	50	1.5	7.2	90	125	80	10	128	330	1.5
		12-24"	CL	48	4.5	7.4	237	385	405	21	180	3600	2.0

Note: Analysis by Soil Testing Laboratory - University of Saskatchewan.

The Report pointed out that the least total cost alternative for the City was to be the irrigation alternatives. Although these entailed additional grants from senior governments in the order of one to two million dollars, the potential saving of several hundred thousand dollars per year in operating cost is very evident.

The physical-chemical plant as reviewed, would meet the present effluent regulation. However, in the event of more stringent regulations, additional phases would be required adding to the cost discrepancy between these two alternatives.

The Report recommended that the City give serious consideration to the implementation of the irrigation method of wastewater disposal, which involves the construction of a reservoir, pipelines, pumping facilities and the purchase of sprinkler equipment.

City Council of the City of Moose Jaw, after reviewing the Report as submitted by Underwood McLelland, adopted in principle, the utilization of this nutrient enriched water for irrigation purposes.

Once again, through the co-operation of the Qu'Appelle Implementation Office, Underwood McLellan were commissioned to meet with the farmers in the Baildon area to ascertain if, in fact, there was enough interest and land available which was irrigable.

This Study is still continuing and the total results have yet to be reported to the City of Moose Jaw, however, indications are that the farmers are more than interested in participating in this joint venture, however, there may be some difficulties in finding enough area for irrigation to satisfy the future needs of potential growth of the City.

As was noted in the foregoing, the City's main objective is to:

1) Comply with the request of the Department of the Environment and reduce the level of phosphorus of approximately 6.6 to 1 milligram per litre or less.

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2) Recognizing the valuable resource which is present in this nutrient enriched water to utilize this in co-operation with nearby farmers to increase the productivity of what may be termed marginal agricultural land to benefit both the farmers in the area and the governments of the Province of Saskatchewan and the City of Moose Jaw. A 5-000 acre area several miles south of the City of Moose Jaw has been tentatively identified as suitable for effluent irrigation of several similar crops.

It was suggested that an annual effluent application rate of 20 inches per year is suitable for effluent disposal and crop use in this area. Approximately twenty-four hundred and four thousand acres of net irrigation area are required for 1978 and two thousand projected wastewater flows. The area farmers appear receptive to the idea of partaking in an irrigation scheme.

Four alternative land-ownership-operation arrangements are discussed in respect to the irrigation scheme. These include private, private with City owned sprinklers, City owned and leased and City owned and operated. The cost of the irrigation alternatives range from 5 million to 7 million dollars for immediate future requirements. Further staged expansion of the alternatives would involve the expenditure of an additional one to two million dollars over the next 20 years.

The projected annual cost assuming total grant eligibility ranges from $390,000 per year to $214,000 in the immediate future. The most apparent alternative for the City to consider in respect to costs and implementation is suggested as being between alternative 2 and 3 where the City would construct and operate the head works, purchase the sprinklers and negotiate with the private farmers for effluent utilization.

Physical chemical treatment with lime chemical precipitation has been suggested as the most appropriate form of treatment of the alternatives considered for algae and phosphorous removal.

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Chemical recovery was found unfeasible, therefore, it was proposed that the precipitated phosphorous and chemical sludge generated in the process be de-watered and truck hauled to a disposal site approximately 15 miles south of Moose Jaw.

The irrigation and physical chemical treatment would remove 95% plus and 90% of the nutrients respectively with the exception of nitrogen. The present regulations do not require the removal of nitrogen.

In the event of more stringent effluent controls, the physical chemical plant alternative would have to be supplemented with additional treatment stages.

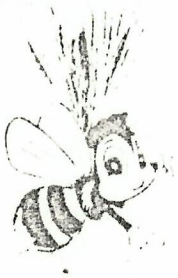
The estimated capital and annual operating cost of the lime physical chemical alternative is 3.2 million dollars and $450,000 per year respectively. In assessing the respective operating cost for a period in the future when the variable operating costs double, the irrigation alternative showed a decided cost advantage over physical chemical alternative.

The environmental impact of the irrigation has been identified as farming and employment opportunities. Negative aspects include the disruption of local wildlife habitat and the drainage of the leachate from the site tile drain into the Moose Jaw River. The drainage water would be similar to groundwater and is not anticipated to create problems in the drainage course. The physical chemical alternative would discharge its wastewater at the present location.

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Mr. Chairman

As a Baildon district dryland farmer, I note from your agenda, that I am the only participant in this seminar who is at present, not actively into irrigation like Mr. Rempel, but who is also not actively associated with effluent irrigation through an educational, governmental or commercial connection.

I am something like the effluent you are discussing - a raw product at this stage that has to be processed in one fashion or another.

To those of you who have been associated with past projects, my remarks could be a repetition of farm views and concerns. To those who may be looking at farm effluent systems for the future, a farmer viewpoint at this time might mirror concerns you will be faced with in your future building of like systems.

I would like to divide my comments into two sections. Firstly from a farm viewpoint what to me could be called "Potential Positive Aspects of Effluent Irrigation" as they directly relate to the farm level.

Secondly - "Some Farm Concerns Prior to Irrigation."

Put together they could be called "good news" and "bad news."

Firstly, the "good news."

1) More Varience in Selection of Crops:

In a province noted for a one shot economy (wheat), where we have continuing cycles of surpluses and quotas, the ability to produce cash crops is an appealing alternative.

2) Assurance of Moisture Supplies:

"If we had only had another rain" is probably the most oft repeated remark you hear at harvest time. The Baildon area has rain patterns that seem to consistently "go round" to the clay areas to the east. If farmers of our area had their choice of one more ingredient to produce better crops, water at the right time would be Number One.

3) Ability to Continuous Crop:

We are approaching a time when the advocates of "zero till", the pressures of land prices and the maximization of income per acre, are going to make continuous cropping more and more attractive. Soil moisture remains the key to this "switch over", especially in light land areas.

4) Prevention of Soil Drifting:

Our Baildon area was an area drastically hit by the Dirty Thirties. We still have areas of unreclaimed land considered too "touchy" to tangle with for fear of them taking off and spreading to areas which have been brought back to production through a good deal of patience and hard work. Trash farming, forage crops and tree rows have all been used in this area to combat soil drifting. Moisture when you need it is one of the best weapons to have in the fight to beat soil drifting.

5) Increase in Land Valuation:

This is an aspect I hesitate to mention because of our cost sharing negotiations with the City of Moose Jaw and Mr. Schwinghamer in particular. However even the briefest comparison of irrigated land values versus dryland would point out the obvious estate values of irrigated land.

These are just some of the advantages which could accrue to the farm level. You no doubt could point out many more.

Secondly, concerns:

1) Health of the Land:

There isn't a farmer who "loves his land" who doesn't want to pass it on to the next generation in better shape than when he started. This isn't only a sentimental concern, it's also a monetary one. Well kept land produces more dollars.

Under normal operations carried on over a number of years, the farmer knows it will be his decisions, his assessment, his building which will eventually determine the health of his land and the health of his pocketbook.

You will appreciate the reluctance of farmers accustomed to this pattern of self-assessing over many years to suddenly commit their farm practice, economic welfare and the future health of their land to the assessment of any "outside expert."

Needless to say if a project assessment were wrong, for example, salt accumulation, it is the farmer's future income that suffers, not the "outside expert's."

This can lead to a "bird in the hand is worth two in the bush" attitude by farmers. I mention it to show the reluctance to any swift and dramatic change which might affect the health of the land.

2) Time Frames for Participation, Education and Finance:

The meeting here will appreciate the desire of each level of participant, be it environmental, government or urban city to make sure that every aspect relating to their particular concerns be adequately discussed, explored, assessed, financed and okayed before putting on the rubber stamp of approval.

From a farm standpoint may I say we wouldn't want it any other way. Any "sin of omission" here might cost us dearly in the future.

However I would like to point out to this seminar that it is only when all of these august bodies have completed their decisions, that we as farmers can commence ours.

Our participation in a project this size is substantial for each individual farmer.

It isn't something you could commit a corner of land to and write it off as another experiment if it failed.

Education wise, it is a complete new concept with minimum time to become accustomed to. No time to "feel" your way in.

Finance wise, you are committing your whole future with no guarantees. In fact, I doubt if any of the participating agencies who have had to approve steps along the way, would want to guarantee any farmer's financial return, even to past performance.

Therefore, I would recommend that at least as much time be given to the farmers to consider their participation with its many decisions, as say each of the other participating bodies have had to date.

3) Management the Key:

Most of you have heard the story of the three persons, one of them a farmer, who each won a million dollars in Loto Canada. The first said he would now be able to travel all over the world - a lifelong ambition. The second said he could now retire and indulge in his many hobbies. The farmer when asked, hesitated, then said he would probably just keep on farming till it was all gone.

While farming probably isn't that much of a losing proposition, there are times when return on investment isn't that great. Farmers usually have to pick and choose when and where to put their time, money and effort. For example, a time to go into cattle and a time to go out. These decisions and timing are crucial management evaluations.

So the final concern that I submit today is that the timing and extent of entry into these types of projects will probably not be a luxury that cities and towns can afford to participating farmers. For many it will, of necessity, be a now or never proposition.

The key to a successful survival in a new specialized type of farming, one that employs considerable amounts of capital and labor, will be adequate management.

I believe that while farmers are always used to making management decisions, usually based on past experience, at this time they have a real concern that they face a fast timetable to equip themselves to the specialization of irrigation and in particular effluent irrigation.

If you can go broke under ordinary farming, the additional variables under specialized irrigation make management more acute.

My recommendation would be for a continuing program of direction to be made available to farmers entering into these types of programs.

Many of these programs are presently available; for example, information on cropping procedures and water management techniques.

Some additional services that I believe will be needed are:

a) Legal advice both for Water Users Groups and for individual farmers. For example, the greater use of capital requirements will necessitate incorporation in many cases.

b) Farm records analysis for individuals during the start up phase of the projects.

c) Clarification and, if at all possible, consolidation of grant and loan agencies for one-stop financing.

The success or failure for farmers of a decision to enter into these types of projects will be made during the very first years of the switch from dryland to irrigation farming.

They offer an exciting challenge.

Thank you for the opportunity to bring these thoughts to this seminar.

Don Swenson

OPERATION & MAINTENANCE OF IRRIGATION
EQUIPMENT

SEMINAR ON EFFLUENT IRRIGATION
UNDER PRAIRIE CONDITIONS

Presented by: CENTRAL IRRIGATION CO. LTD. - January, 1979

OPERATION AND MAINTENANCE OF IRRIGATION EQUIPMENT

THE SUPPLIER OF IRRIGATION EQUIPMENT SHOULD DEMONSTRATE THE STEPS INVOLVED IN START-UP, SHUT DOWN, PRE-SEASON AND OFF-SEASON CARE. BETTER KNOWLEDGE IS GAINED IN THESE AREAS ON PRACTICAL EXPERIENCE.

PUMPS

In most cases where surface water is being used, a Centrifugal pump is usually installed. These pumps require priming whether it be done with a hand primer, exhaust, or by manifold. In some cases where a well is the source of water, or the volume of water and the total dynamic head are too great for the capabilities of a centrifugal pump, a vertical turbine pump is used. These pumps are self-priming and installation is somewhat more costly.

POWER PLANTS

Throughout Saskatchewan, diesel engines are the most common source of power. Three phase power is the second source of power, but the availability is restricted in our rural areas. Liquid propane gas has proven to be too high in cost while natural gas hook-ups are not convenient. Since a diesel is the most common source of power, regular maintenance is required as there is on any other farm tractor: - Oil changes
Coolant level checks
Fuel service

All internal combustion engines that are sitting stationary should be equipped with safety gauges to protect against faults of:

- Oil pressure drops
- Temperature rise
- Loss of pump pressure

In any of the above cases the engine will automatically shut down.

ELECTRIC MOTORS

Maintenance on electric motors is limited; lubrication of bearings and rodent protection are the main concerns. An oil check is required when a vertical turbine pump is used. When either an electric vertical turbine or centrifugal is used, a foundation is required for support and in most cases a pump house is built for protection of wiring, panels and the electric motor in the case of a centrifugal installation. Usually the cost of installing electrically driven pumps (including power supply, panelling, etc.) is equally as high as a diesel operated system.

PIPE LINES

Aluminum Surface Lines:

- Most commonly used with hand line or side roll irrigation.
- Pipes are connected with a quick coupling usually in the style of a hook or band-lock clamp.
- In off-season periods, the tubing should be stocked and gaskets removed and stored in a dry place.
- Aluminum tubing must be free of water due to freezing.

Buried Plastic Lines:

- Buried PVC lines should be buried approximately 3' and the joints left open on installation for pressure testing.
- If possible, buried pipe of any type should be layed to grade to conveniently pump out or drain the water in the off-season. If this is not possible, pump out valves must be placed in all low spots for drainage. This is done to protect against freezing.

... 3

- Air relief vents should be installed at high points and at the end of lines to prevent collapsing of the pipe and to remove air pockets that reduce the capacity of the line. If there were to be a sudden shut down of the pump, there could be a reversal of water movement creating a vacuum, therefore possibly the collapsing action taking place.
- Buried lines must be backfilled and anchored to prevent splitting and buckling due to line surges.

OPERATION AND MAINTENANCE OF A LATERAL WHEEL MOVE

Operation:

- A main line is layed down the middle of the field with the wheel lines at right angles to the main line. (Main lines usually have a valve every 60'.)
- When a system of two wheel lines is installed, one wheel line is positioned at the far end of the main line and the other line at the valve closest to the pump; therefore, the pump is not required to push the full gallonage any further than the middle point of the main line where the laterals will meet and pass each other. This procedure requires less power than running the two lines together at the far end.
- Wheel lines are most commonly moved by a hydraulic mover situated in the middle of the lateral line. The user walks down to the mover, starts a small horse power air-cooled engine and moves the hydraulic lever into gear. The mover uses the pipe on wheels as an axle, moving the system in either a forward or reverse action.
- The wheel line is moved 60' to the next valve where a simple hook up is made and the water turned back on.
- Before the lines are moved, a period of 8 to 10 minutes is required to drain the lines. (Self-draining).
- Lines over the standard ¼ mile length require pressure

... 4

regulators at each sprinkler head over the ¼ mile. Pressure regulators are installed on the sprinkler heads closest to the mainlines where the higher pressure exists.

- A wheel line is operated from 40-45 P.S.I. and uses anywhere from 200-400 G.P.M.

Maintenance:

- Throughout the season, the only maintenance required on a wheel line system is to grease the hydraulic mover once or twice and check the level of the hydraulic oil.
- In off-season use, the line should be braced at three to four places along the wheel line on both sides of the mover due to winds; pipes should be split every four or five joints due to contraction movement in cold weather and the hydraulic drive engine should be stored.

CENTRE PIVOTS

Operation: Visual Presentation.

Maintenance:

- Greasing all drive joints at each tower with water resistant grease. This should be done monthly when in use.
- Grease the pivot point monthly when in use, using water resistant grease.
- Check electrical cables for wear seasonally.
- Check wheel drives for oil.
- Wheel drive oil should be drained completely in the fall and then refilled to recommended capacity.
- Check for structural abnormalities.
- Check security of all electrical panels and outlets.
- Check tire inflation.
- Check alignment mechanisms for freedom of movement.
- In the off-season, make sure all water has drained from the system and that the flush valve on the end boom is open and drained.

COSTS OF IRRIGATION EQUIPMENT

CENTRE PIVOT:

Centre Pivot Machine	$35,000.00
Pipe Line	5,500.00
Power (By portable generator)	6,500.00
Pumping Unit - Electric (Approx 100 h.p.)	3,500.00
Diesel	10,000.00

(Electric price does not include the price of panel or service)

* Per Acre Cost Using Diesel Power: Approximately $425.00
Electric : Approximately $350.00

The initial cost of either the diesel operated pump and pivot, or electric operated pump and pivot, is usually closer in price because of the cost of the power supply installation and panelling, etc. The per acre cost of electric power mentioned above does not include the additional supplies.

WHEEL MOVE:

Lateral Wheel Moves (2)	$11,000.00
Main Line (½ Mile)	9,500.00
Pump: Electric - (50 h.p.)	2,200.00
Diesel	9,000.00

Per Acre Cost Using Electric Power: $150.00
Diesel Power: $180.00

Per Acre Cost Using Four Wheel Lines: Electric Power: $210.00
Diesel Power: $255.00

* As mentioned in the Centre Pivot pricing, the electric per acre costs do not include power supply, panelling, etc.

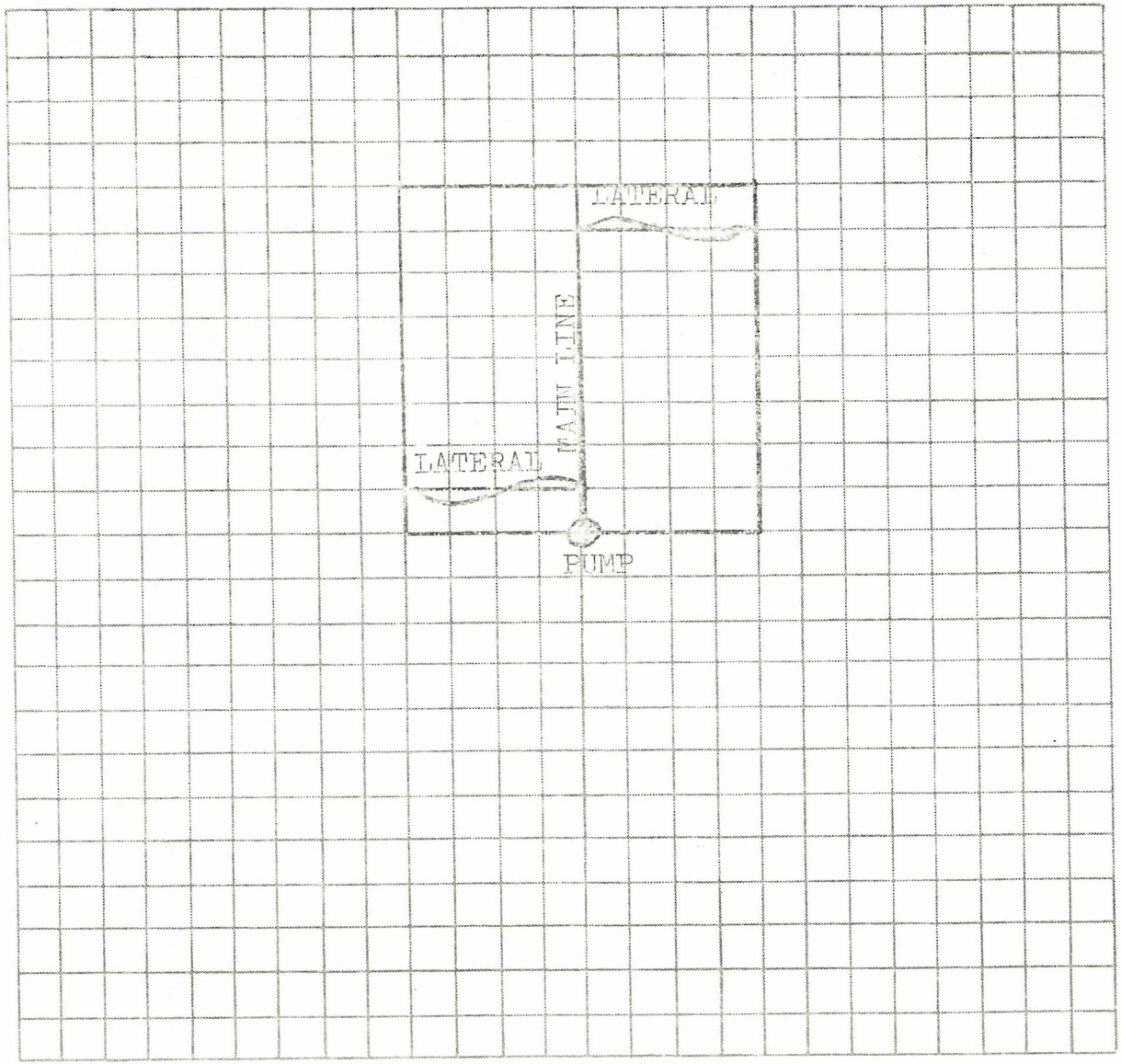
Central Irrigation Company Ltd.

PHONE (306) 867-8700 - 867-8800

SWIFT CURRENT, SASK. S9H 3X5 - OUTLOOK, SASK. S0L 2N0

For
Address
Location

SPRINKLER SYSTEM LAYOUT & ENGINEERING DATA



Scale: in. to ft.

No. of Acres	160
Type of Soil	SANDY
Suction Lift	10
Lift Beyond Pump	20
Friction Supply Line	
Friction Suction Line	31.41
Friction Main Line	15.50
Friction Lateral Line	18.09
Other	104.00
Pressure 45PST	199.00
Total Head in Ft.	86.16
Total Head in Lbs.	104
No. Ft. Water Spreads	7/32 x 1/8
Nozzle Size	12.5
Gal. per Min. per Head	64
No. Heads	12.5
Gal. per Min.	.48
In. per Hour	3.84
No. In. will be Applied	3
No. moves per Day	
No. Lateral Moves	14
No. days to cover Plot	24
No. Hrs. per Day	
Approx Eff. of	
Net Water on Ground	4 x 5
Size of Pump	1825
R.P.M. of Motor or Engine	1825
R.P.M. of pump	
Make and No. of Pump	
Type of Power	
H.P. of Motor	
Diam. of Impellar	78%
Eff. of Pump	54
B.H.P. Required	2640
Length of Main	7 - 6
Size of Main	1320
Length of Lateral	5
Size of Lateral	40 x 60
Spacing	

BY

DATE 19

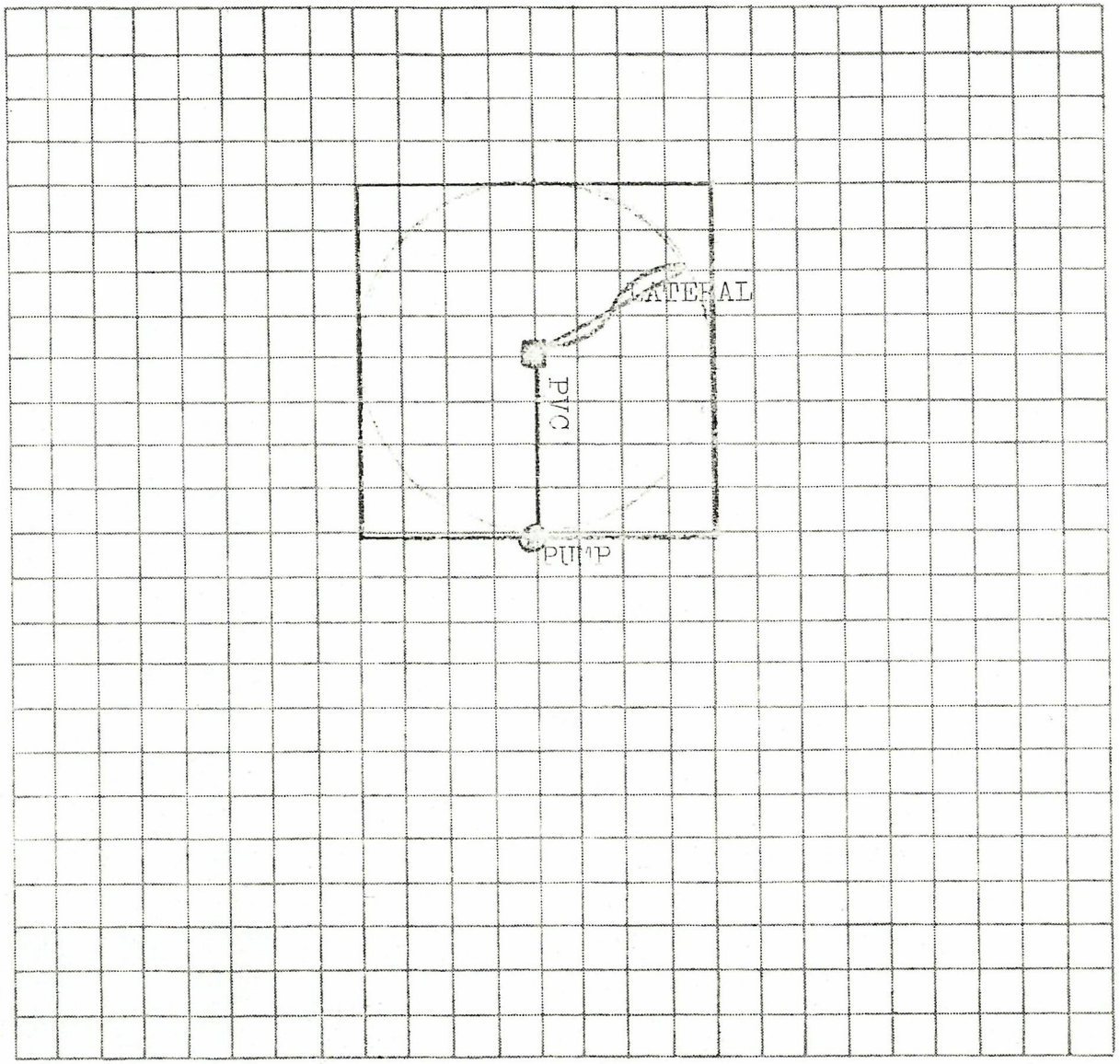
Central Irrigation Company Ltd.

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SWIFT CURRENT, SASK. S9H 3X5 - OUTLOOK, SASK. S0L 2N0

SPRINKLER SYSTEM LAYOUT & ENGINEERING DATA

For
Address
Location



Scale: in. to ft.

No. of Acres	130
Type of Soil	SANDY
Suction Lift	10
Lift Beyond Pump	20
Friction Supply Line	18.2
Friction Suction Line	—
Friction Main Line	—
Friction Lateral Line	—
Other	19.85
Pressure	150 15
Total Head in Ft.	218 19
Total Head in Lbs.	94.47
No. Ft. Water Spreads	VARIOUS
Nozzle Size	VARIOUS
Gal. per Min. per Head	
No. Heads	1000
Gal. per Min.	VARIOUS
In. per Hour	
No. In. will be Applied	VARIOUS
No. moves per Day	—
No. Lateral Moves	VARIOUS
No. days to cover Plot	"
No. Hrs. per Day	"
Approx Eff. of	"
Net Water on Ground	4 x 5
Size of Pump	1200
R.P.M. of Motor or Engine	1700
R.P.M. of pump	
Make and No. of Pump	
Type of Power	
H.P. of Motor	
Diam. of Impellar	
Eff. of Pump	25
B.H.P. Required	1320
Length of Main	0
Size of Main	
Length of Lateral	
Size of Lateral	
Spacing	

BY

DATE 19

CASE HISTORY OF THE TABER, ALBERTA WASTEWATER IRRIGATION PROJECT

Introduction

During the late 1960's it became apparent that the water quality of the Oldman River was rapidly deteriorating, particularly during the winter months when the discharge of the river may drop to a low of 400 cfs (11.3 m^3/s). Therefore various cities, towns and industries were required to reduce their pollution loads to the river. The town of Taber, with a population of about 5,000 and various food processing industries, was required to substantially reduce its pollution load. Various methods of wastewater treatment were considered and wastewater irrigation was selected for detailed feasibility studies in 1969.

The two major industries located in Taber were a potato dehydrating plant and a vegetable canning plant. The dehydrating plant used the lye-peeling process which rendered the effluent from the plant unsuitable for irrigation due to the high sodium concentration. However, when its wastewater was diluted with other wastewater, reduction of the sodium concentration to acceptable levels was obtained.

The combined domestic and industrial flows averaged 0.5 million gallons (1890 m^3) per day on an annual basis with peaks of 0.8 million gallons (3030 m^3) per day on a monthly basis.

The effluent from the sanitary sewage system now flows by gravity to a syphon under the Oldman River, then discharges to open storage on the north side of the river approximately three miles

(4.8 km) from the town. Metering is provided by a Parshall flume at the syphon.

One year after start-up of the system, the potato dehydrating plant ceased operation but two other small food processing plants eventually moved into Taber.

Preliminary Studies

Considerable government land was available for purchase by the Town, and Alberta Department of the Environment conducted a soil investigation for irrigability. This included drilling, logging and sample analysis to a depth of up to 12 meters. The amount of land required for the irrigation scheme was determined by taking into account the volume and quality of effluent available, the consumptive use of the crop, the mean annual precipitation and its distribution over the growing season. On this basis it was estimated that a four hundred acre (162 ha) area would be sufficient and a suitable portion of land (Chaplin loamy sand underlain by sand and gravel) was selected for effluent irrigation at a rate of 18 inches (45 cm) per year. The soils were non-saline, non-sodic with a water table at a depth of approximately 13 to 16 feet (4 to 5 m) from the surface. The land was vegetated with native grass, fairly characteristic of the short grass prairie. The mean total precipitation is 38 inches, (96 cm) 65% of which is received during the growing season.

Research and testing work was conducted in the field, laboratory and greenhouse. The laboratory work consisted of passing the lagoon-treated effluent through eight feet (2.5 m) of soil obtained

from the site and collecting the percolating solution at different depths of the soil column. Analysis was conducted on the soil and effluent before application and also on the percolating solution and the soil after the application of 120 inches (300 cm) of effluent.

Table 1

Effluent characteristics

pH	-	6.5	NH_3-N	-	20 mg/L
EC	-	2.2 mmhos/cm	HO_3-N	-	0.5 mg/L
SAR	-	6.0	P	-	7 mg/L
COD	-	1000 mg/L	Cl	-	50 mg/L

The results showed that 150 cm of this soil was effective in removing 90 percent of the calcium, 60 percent of the magnesium and practically all of the ammonium, phosphorus and BOD. Nitrates resulting from the oxidation of ammonium appeared to move freely through the soil. It was felt that some of the calcium and magnesium was precipitated out as carbonates. The effluent did increase the salinity and the sodium content of the soil to some extent but well within acceptable limits. Total nitrogen and phosphorus in the soil were increased considerably by the effluent application.

Application of the effluent to the soil in permeability tubes showed a distinct reduction in permeability during continuous innundation. The permeability was restored after a rest period of a few days.

A test plot of land was established adjacent to a temporary lagoon and a weekly application of about 15 cm was made to a soil

similar to that in the selected field. Analyses of soil samples taken inside and outside of the irrigated area indicated an increase in soluble salts, including sodium, similar to that found in the laboratory columns. Soil analyses of the same sites that were undertaken several months after effluent application ceased, showed a significant reduction of salinity problems due to natural leaching. No symptom of toxicity was noted in the native vegetation.

Barley grown in a greenhouse yielded 44 percent more dry matter when watered with the effluent than with tap water.

Design and Installation

The planning and design of the project was done by the Town of Taber, Reid Crowthers and Partners, and Alberta Environment. Due to cold weather during winter months and the high BOD loading of the sewage, which could not be discharged to the river, storage facilities with a volume of 400 acre feet (500,000 m^3) were constructed using earth embankments in a natural depression. The main storage unit is preceded by two small anaerobic settling basins each of which has a capacity of two days average flow.

A single pumping unit with a capacity of 1,000 gallons (0.4 m^3) per minute against a discharge pressure of 100 psi (4800 Pa) was installed to pump effluent through 5,000 feet (1500 m) of 18-inch (45 cm pipe and 5,000 feet (1500 m) of surface 12-inch (30 cm) pipe to the irrigation area. Four five-inch (13 cm) laterals, each 1,300 feet (400 m) long, with nozzles at 40 foot (12 m) spacings were used for spraying. Lateral connections were provided every 180 feet (54 m)

along the 12-inch (30 cm) lateral. Nozzle pressures were recorded at 55 to 70 psi (2460 to 3360 Pa) depending on the number of nozzles used for spraying.

Application of the effluent was at the rate of 0.5 inches (1.2 cm) gross per hour, with the duration of application controlled by the movement of the wheel-mounted laterals.

Groundwater observation wells and soil monitoring sites were established by Alberta Environment well in advance of actual irrigation in order to measure changes in groundwater and soils due to the application of effluent. Routine analyses of soils and groundwater samples include conductivity (EC), pH, Ca, Mg, Na, Cl^-, HCO_3^-, $CO_3^=$, Total P, NO_3-N, NH_4^-N and Total N. It was also planned to determine "heavy metals" in soils after the system has been operated for 5 years.

Operation and observations

Storage of effluent began in December 1970 and irrigation was initiated in July 1971 on the native sod. An attempt to establish grass and alfalfa by seeding directly into the sod in the fall of 1971 was not successful although reasonably good germination did result. Competition by the native species was probably responsible for the mortality of the domestic species as the native grasses (primarily spear grass), although inferior in quality, responded to irrigation with the effluent with rapid and dense growth.

Subsequent to this experience on half of the 320 acres

(128 ha) was cultivated and seeded to alfalfa on a two-year schedule. A diamgram of the system is shown in Figure 1.

The wastewater flow has increased from 0.5 million gallons per day (1890 m^3) in 1970 to 0.62 million gallons (2360 m^3) in 1978. Insufficent storage and land for irrigation has necessitated some release to the Oldman River during the past few winters. These releases are well within the allowable permitted loadings. Engineering studies are currently in progress with respect to up-grading the system. A number of treatment alternatives are being investigated.

Wastewater chemistry

The chemical characterization of a wastewater is of vital importance to the feasibility evaluation of a wastewater irrigation project, as these characteristics dictate the effect the wastewater will have on the soil. The wastewater chemistry is also necessary to determine the annual application with respect to the limiting loading factor, i.e. hydraulic, nitrogen, etc. The chemical characteristics of this actual effluent at Taber appear in Table 1.

Table 1 Some characteristics of Taber wastewater at pump site (mean of 40 samples)

Parameter	Value
pH	8.0
Electrical conductivity	1.3 mS/cm
Sodium adsorption ratio	3.0
Chloride	55 mg/L
Bicarbonate	300 mg/L
Sulfate	400 mg/L
Total nitrogen	17 mg/L
Total phosphorus	5 mg/L
Potassium	15 mg/L

The Taber wastewater is considered suitable for irrigation and the limiting factor is dependant on the amount of wastewater that can be used by plants, plus a small amount required for leaching.

Groundwater depths and chemistry

The data from three groundwater observation wells have been selected for discussion. Observation well #5 (Figure 1) is located one-half mile (0.8 km) down slope from the irrigated field and in a draw leading from the field to the Oldman River in the probable direction of groundwater flow. Data obtained from this well (Figure 11) have shown a slight rise in the water table and an increase in chloride to about one me/L. Nitrate-nitrogen levels generally have been below

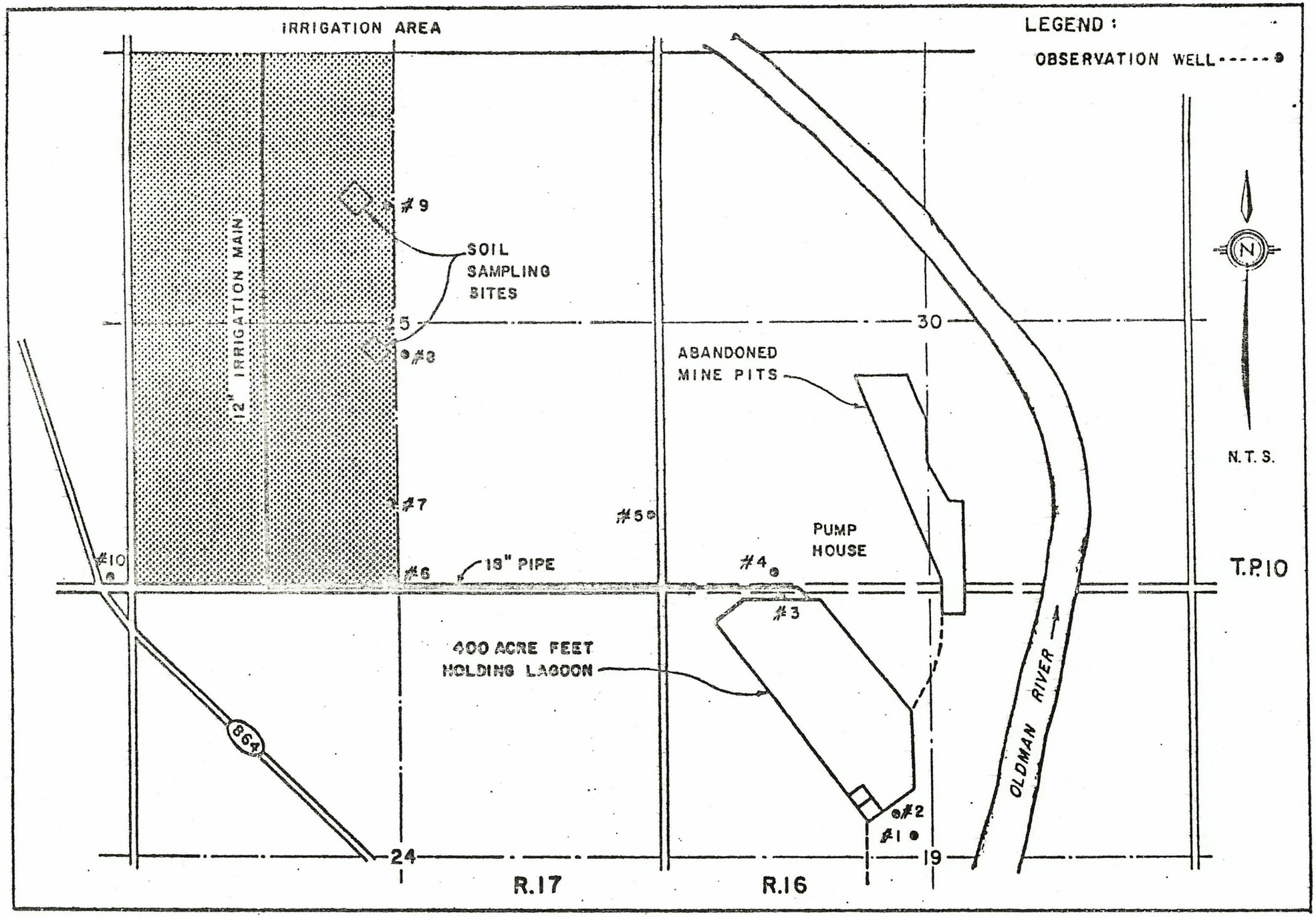


Fig. I Taber Project Layout

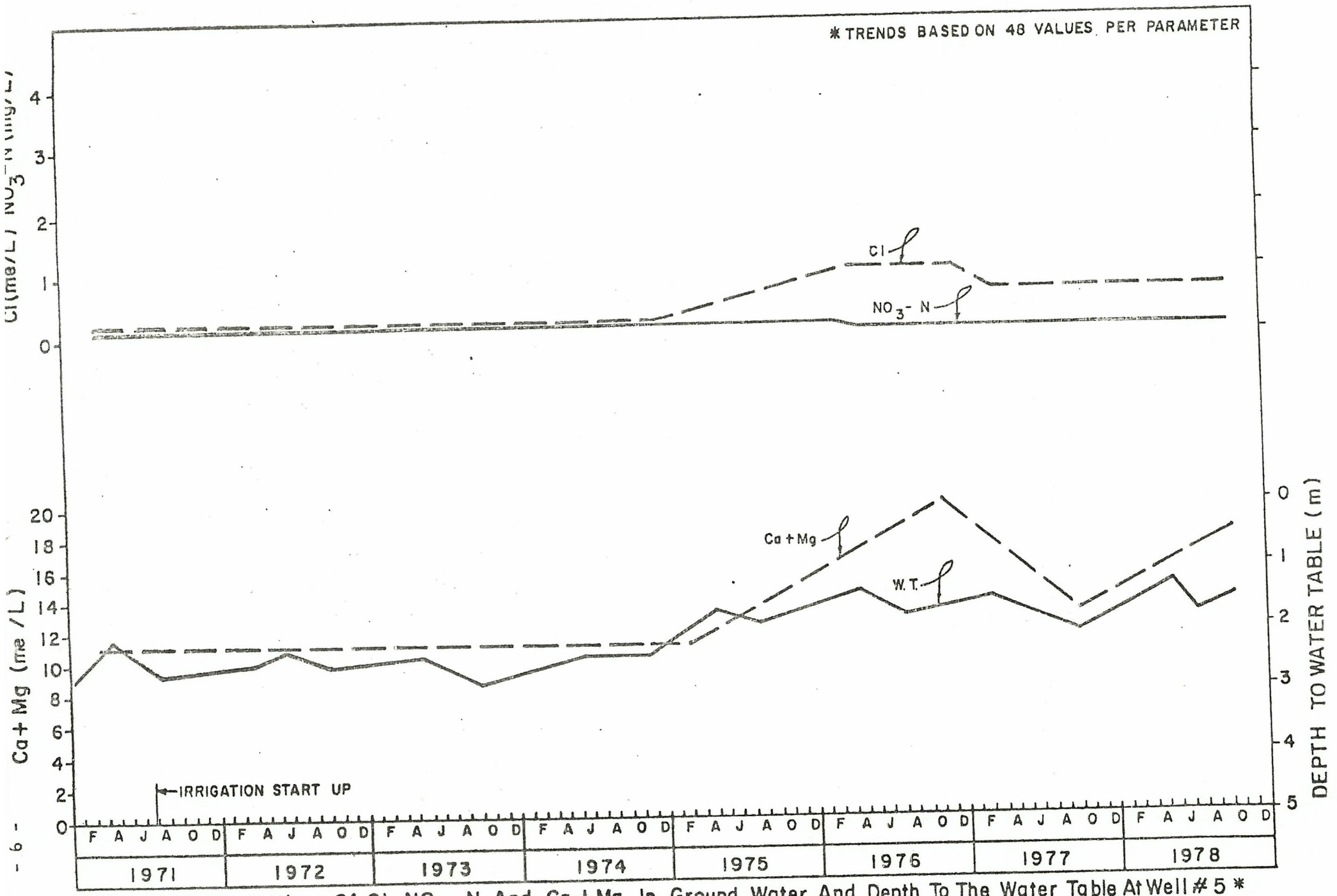


Fig. II - Concentrations Of Cl, NO_3-N And Ca + Mg In Ground Water, And Depth To The Water Table At Well # 5 *

DEC. 1978

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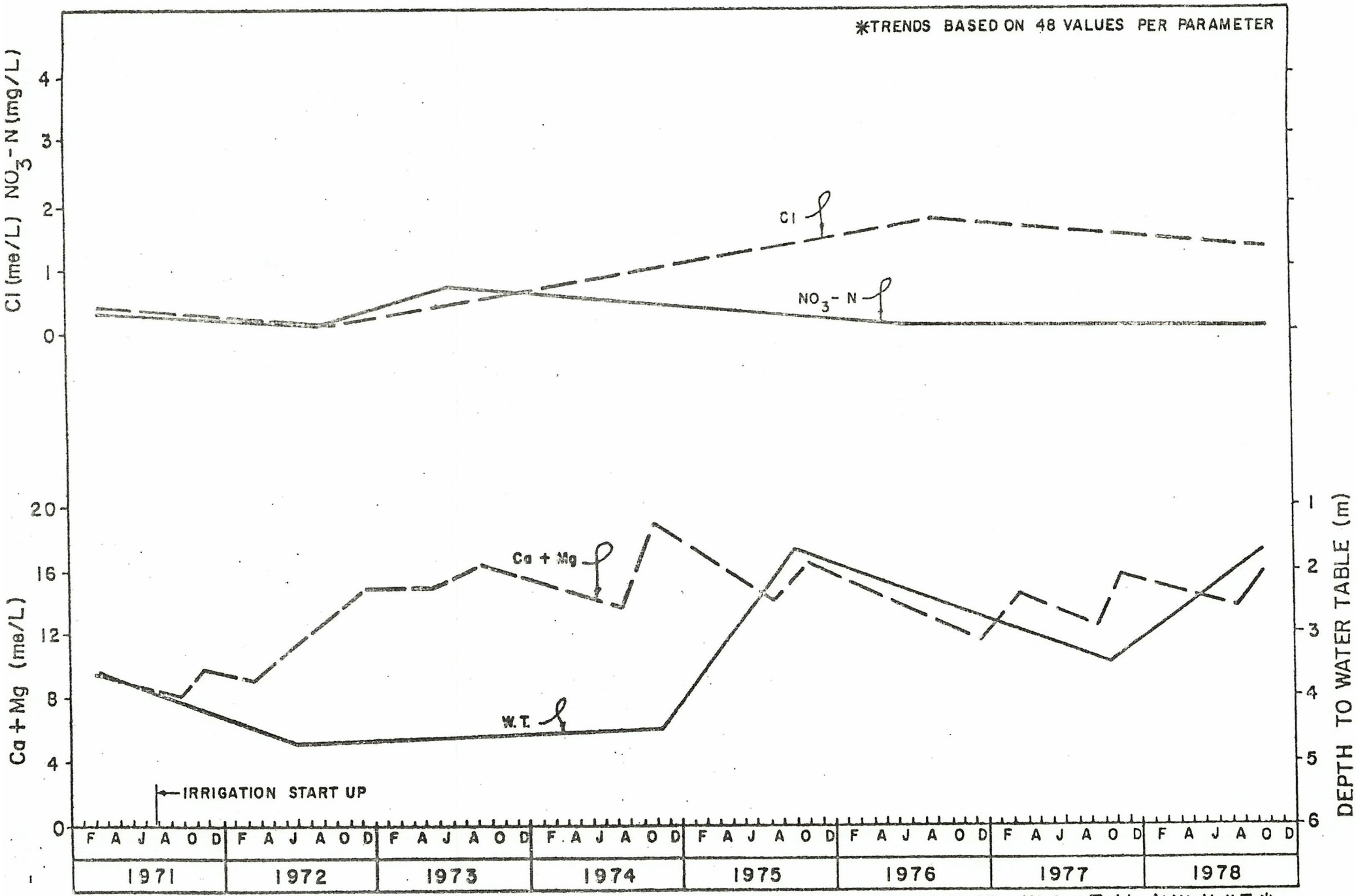


Fig. III - Concentrations Of Cl, NO_3-N And Ca + Mg In Ground Water, And Depth To The Water Table At Well #7 *

DEC. 1978

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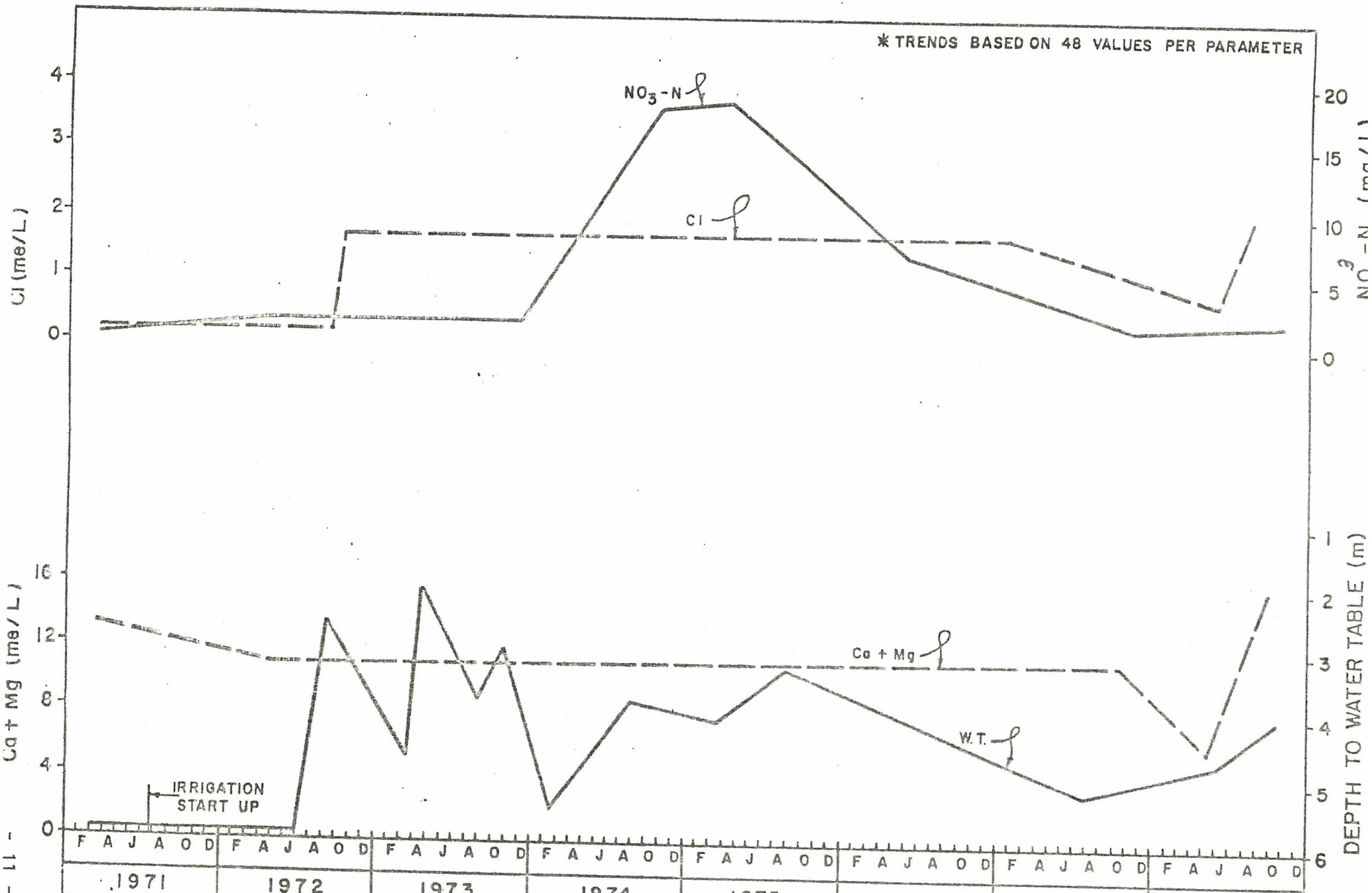


Fig. IV-Concentrations Of Cl, NO_3-N And Ca+Mg In Ground Water, And Depth To The Water Table At Well #9 *

DEC. 1978

0.1 mg/L, while hardness has increased by approximately 20%. Well #7 is immediately adjacent to a slight depression in which water will pond if irrigation or precipitation is excessive. The water table (Figure 111) has risen from a dpeth of 13 feet (4 m) to approximately nine feet (3 m) over the eight years of irrigation. The chloride and calcium plus magnesium concentration have also increased during this period. Well #9 is located at a higher elevation immediately adjacent to the irrigated field where surface drainage is good. The water table at this site, originally at a depth of 20 feet (6 m) before irrigation, has fluctuated between seven feet (2 m) and 17 feet (5 m) over the past eight years. Chloride concentrations have increased by approximately one me/L, while calcium plus manganese has remained reasonably stable. Nitrate-nitrogen levels in this well have fluctuated, reaching a high of 18 mg/L in 1974 and 1975, and then receeding to levels just slightly above those measured prior to irrigation.

The increase in chloride and hardness concentration was forecast at the outset of the project. It should be pointed out that this increase was measurable in this area because the original groundwater quality was good initially and that it would not be measurable in areas with poor quality groundwater.

Multiple tube sampling wells were installed in the saturated zone to determine if a horizontal strata of grossly contaminated water was present. Analyses of the samples showed no significant differences between samples taken at two foot (0.6 m) differences in elevation.

Soil chemistry

Chemical differences between the non-cultivated soils and the wastewater irrigated soils could be due to the effect of cultivation, or irrigation, or the addition of wastewater constituents. One can only speculate on the relative importance of each of the three possible causes of the changes.

Chemical analyses of soils (Table 2) indicate that there are highly significant differences in several parameters between irrigated and non-irrigated soils. Many of these differences, namely nitrate-nitrogen, available phosphorus, sodium adsorption ratio, extractable sodium and electrical conductivities are directly attributable to wastewater addition. Considering the nature of the soil, particularily texture, drainability and the composition of the wastewater (Table 1) these differences are not surprising, and for the most part were predicted in the planning stage of the project. The present values of electrical conductivity and sodium adsorption ratio are well below critical levels, and will not increase with time. It should be pointed out that the soils in this area are extremely non-saline, non-sodic and therefore only small additions of salts are required to result in significant increases.

Increases in available phosphorus occurred at greater depths than had been anticipated. One possible explanation of this is that part of the wastewater phosphorus is in the particulate form, and may move downwards through larger pores in these coarse-textured soils. In addition, some of the dissolved phosphorus may be in organic form and may be more mobile than orthophosphorus.

Table 2 Comparison of several characteristics of soils irrigated annually with wastewater for eight (8) years with those from an adjacent non-cultivated, non-irrigated area

(mean of 12 samples)

Cultivated Practice	Soil Depth	pH	Elect. Cond.	Carbonates as $CaCO_3$	NH_4OAc Extractable Ca	Mg	Na	K	NO_3-N	NH_4F Extractable P	SAR
	cm		mS/cm	%	me/100 gm				µg/gm		
Irrigated	0-5	7.3***	0.89***	0.11	7.5	3.3***	0.6***	0.64*	8.0***	26.4***	2.5***
	5-10	7.3	0.96***	0.37	9.1	3.1***	0.5	0.51	2.5***	10.0**	2.4***
	10-15		1.07***						2.2**	5.8***	2.7***
	15-30		0.74**						1.7**	5.6*	2.6***
	30-45		0.82***						0.9	3.6	2.4***
	45-60		0.88***						0.8	1.7	2.5***
Non-irrigated and Non-cultivated	0-5	6.7	0.43	0.28	12.2***	1.8	0.3	0.49	0.3	9.1	0.1
	5-10	7.3	0.37	1.58	17.8**	1.8	0.4	0.35	0.5	4.2	0.2
	10-15		0.34						0.4	2.6	0.2
	15-30		0.26						0.3	3.9	0.2
	30-45		0.34						0.5	3.5	0.2
	45-60		0.34						0.7	2.3	0.3

* Significantly higher at the 95% level

** Significantly higher at the 99% level

*** Significantly higher at the 99.9% level

Table 2 continued

Cultural Practice	Soil Depth	Total Nitrogen	Clay	Silt	DTPA Extractable Fe	Cu	Zn	Pb	Mn	Ni	Cd
	cm	%			µg/gm						
Irrigated	0-5	0.13	10	15	10.8	0.46	0.96	0.43	4.1	0.26	<0.2
	5-10	0.09			9.6	0.36	0.37	0.35	4.4	0.28	<0.2
	10-15				9.6	0.35	0.45*	0.40	4.4	0.31	<0.2
	15-30				7.9	0.31	0.28	0.35	3.9	0.36	<0.2
	30-45				8.6	0.46	0.38	0.28	3.2	0.45	<0.2
	45-60				7.7	0.46	0.25	0.30	2.6	0.55	<0.2
Non-irrigated and Non-cultivated	0-5	0.14	12*	20**	16.2*	0.41	1.01	0.68*	8.5***	0.61***	<0.2
	5-10	0.10			10.7	0.41	0.35	0.38	7.2***	0.68***	<0.2
	10-15				11.1	0.40	0.22	0.41	6.0	0.71***	<0.2
	15-30				10.7*	0.45	0.22	0.40	5.1	0.83***	<0.2
	30-45				8.8	0.45	0.19	0.43	4.8**	0.83	<0.2
	45-60				8.1	0.40	0.19	0.46	3.9	0.68	<0.2

* Significantly higher at the 95% level

** Significantly higher at the 99% level

*** Significantly higher at the 99.9% level

Non-irrigated soils have significantly higher clay, silt and total extractable cations in the surface (0 - 5 cm) samples than irrigated soils. This strongly suggests that some fine soil particles have been moved downward in the irrigated soils. Extractable magnesium contents, however, are significantly higher in the irrigated soils (0 - 5 and 5 - 10 cm depth). This may be due, in part, to the differences in calcium to magnesium ratios of the wastewater and the soil. Furthermore, dolomite was probably brought to the surface by cultivation of the irrigated area. Subsequent dissolution of the dolomite may have contributed to the increase of magnesium on the exchange complex, and an increase in pH.

In most instances, no significant difference exists in levels of DTPA-extractable metals between the irrigated and non-irrigated soils.

Where significant differences do occur (usually in the 0 - 5 and 5 - 10 cm depth), the non-irrigated samples contained the higher amounts. The differences, which do occur, cannot be accounted for by net removal from the system of the harvested portion of the crop (data not presented). One possible explanation does exist in that some metals tend to concentrate in the roots of most plant species, and as the biomass of alfalfa roots probably far exceeds the root biomass of the native grass, relatively large amounts of metals may be bound in the root mass. One other partial explanation, particularily for the 0 - 5 cm depth, is that the lower pH in the non-irrigated soils resulted in greater extraction of some of the metals.

Annual costs and returns

The Town of Taber has generally supplied annual irrigation

operating costs and revenues received from product sales for the years 1976 and 1977. Costs do not include those incurred to control odour in the lagoon as these costs would be independent of the final fate of the effluent.

1976

Wages	$12,000
Materials	1,000 app
Power	4,300
Total annual variable cost	17,300
Revenue received*	$24,900
Net return	7,600

* 1385 tons of alfalfa or (4.3 tons/acre or 11 tonnes/ha)

1977

Wages	$ 9,700
Matarials	300
Power	5,330
Total annual variable cost	15,330
Revenue received*	$26,000
Net return excluding fixed costs	10,670

* 1300 tons of alfalfa (4.1 tons/acre or 10.2 tonnes/ha)

The net return was more than offset by the purchase of an organic compound, which was added to the raw sewage for odour control, most of which emanates from the lagoon.

Conclusion

1. The project has been effective in the maintenance of Oldman River water quality.
2. Odours from the lagoon have been a problem in some years.
3. Irrigation has resulted in a slight rise in the water table.
4. Irrigation has resulted in a significant increase in salinity, adsorbed sodium, nitrogen, potassium and phosphorus in the soil.
5. Chloride and hardness levels have increased in the groundwater due to wastewater irrigation.
6. The irrigated soils contain significantly less DPTA extractable iron, lead, manganese and nickel than does the non-irrigated, non-cultivated soils.
7. Financial returns of wastewater irrigation at Taber has more than compensated for the operation costs of the irrigation system.

This paper simply relates what has happened at one particular location, and the results cannot be transcribed to all other areas. Each project must be evaluated separately.

D.N. Graveland,
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December, 1978.

EFFLUENT IRRIGATION DEVELOPMENT

SEWAGE LAGOON - TOWN OF BALGONIE, SASKATCHEWAN

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Conservation and Land Improvement Branch
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In the Province of Saskatchewan there are in excess of four hundred municipal lagoon systems in operation. It is estimated that beneficial usage of the effluent, as a supply of water for agricultural crops, would be possible in over three hundred cases. In addition, it is estimated that about one hundred urban centres are faced with serious disposal problems, ranging from vocal complaints to pending law suits. Effluent irrigation can be utilized to solve the disposal problems in many, if not most, of these cases. Development of an effluent irrigation project can be viewed by the urban centre as a method for drainage of the lagoon for which the Town of Eatonia is an example or viewed by a local farmer as an available source of water for increased crop production for which the Town of Balgonie is an example. The following provides a brief history of the Balgonie development with pertinant comparisons to other developments not totally initiated by the farmer.

The irrigation development located at Balgonie is situated on the SE 1/4 33-17-17-2 and incorporates the irrigation of 52.5 acres by the wheel move method. A drawing depicting the irrigation development is presented in Figure 1. The development is owned and operated by Donsdale Farms Co., a partnership in the business of dairy farming and comprised of Messrs Geoffrey Miles, Dale Keith and Donald glen Strudwick. Due to the farming operations carried out by Donsdale Farms Co., a need existed for good quality feed and consequently, the Balgonie sewage lagoon was viewed as a source of water for the production of alfalfa forage.

The project was initiated by Donsdale Farms Co. by submission of an Application for Investigation to the Conservation and Land Improvement Branch of the Saskatchewan Department of Agriculture under the policy for irrigation development on indidivudal farms. This policy was set up to assist individual farmers, partnerships, co-operatives and corporations in development of

irrigation projects and provides engineering and technical assistance for such development, as well as limited financial assistance. In addition, the policy provides assistance to small urban centres for disposal of sewage lagoon effluent by irrigation methods. The application was received in May, 1975 and during the summer of that year, investigations were carried out to determine the physical potential for development and to enable a design and cost estimate to be prepared. At the time that the application was acknowledged, the Water Pollution Control Branch of the Saskatchewan Department of the Environment was made aware of the interest for development. The investigation included an inspection of the area, evaluation of the soil suitability and effluent quality, estimation of the available annual effluent volume and engineering surveys.

Samples of the effluent were obtained and analysis by the Soil Testing Laboratory at the University of Saskatchewan in Saskatoon indicated a range of from 900 ppm to 1400 ppm of total dissolved solids. Soil samples were obtained and evaluated by O. P. Bristol (Soils Specialist for the Conservation and Land Improvement Branch). Analysis of the samples, as provided by the Soil Testing Laboratory, are presented in Table 1. Mr. Bristol reported the soil as belonging to the Weyburn Association. They are dominantly chernozemic dark brown soils developed on medium textured calcareous glacial till. Surface textures are dominantly loams with an estimated basic infiltration rate of 0.35 to 0.4 inches per hour. Bristol rated the soils of the area as good for irrigation and placed them in Group II under the classification system for irrigation.

Determination of the amount of effluent that may be available for irrigation usage and hence, the acreage that should be developed is generally a matter of the best guess since effluent discharges are generally not metered by small urban centres. The project sizing, to be effective as a

means for effluent disposal, must be sufficient to utilize all the available effluent. In addition, the economics of development on a per acre basis, are usually more favourable as the project becomes larger. However, the area developed must take into account the crop grown and subsequent water requirements. Development of too large an area for the available water supply will result in reduced yields with subsequent poor project economics, while development of too small an area will result in either continued disposal problems for the urban centre or the application of water in excess of what the crop can utilize and resultant increased operating costs. In general, a farmer will wish to restrict the amount of water applied to obtain a realistic balance between crop yields and operating expenditures. For example, alfalfa grown on the prairies will utilize an average net irrigation application of approximately 17 inches from optimum growth. Realistically, however, the amount of water a farmer will apply rarely exceeds a gross application of 17 or 18 inches which results in a net application of about 12 inches considering application efficiencies in the range of 70 to 75 percent. This is particularly true for sprinkler irrigation methods due to the operating costs involved. The above points to a potential problem in applying insufficient water to meet the leaching requirements inherent in irrigation and particularly required with effluent irrigation.

For the Balgonie development, three methods were utilized to estimate the volume of effluent. Considering a population of 600 and the discharge rate of effluent at 60 g.c.d. the annual volume was estimated at 13,000,000 imperial gallons or approximately 48 acre-feet. The two lagoon cells were estimated at holding seven million gallons and were, prior to the irrigation taking place, emptied by discharging into a natural run twice each year. The third method employed considered the domestic water consumption during the winter months for a two year period (averaged out at approxi-

mately 1,400,000 per month) and by applying a factor of 80% provided a volume 13,700,000 imperial gallons or 50 acre-feet. The three estimates were very close and for design purposes, it was felt that the project could be based on an available water supply in the order of 50 acre-feet. The acreage developed could range therefore from a low of 35 acres considering an 18 inch application to a high of 50 acres, considering a 12 inch application.

During the summer of 1975, engineering surveys were completed which enabled the project to be designed and a cost estimate prepared. The details of the design are shown in Figure 2. The design details and cost estimate were submitted to Donsdale Farms Co. for their consideration in November, 1975. The equipment suggested was capable of irrigating in the order of 60 acres by modifications to the length of main line. However, the cost estimate was based on irrigating approximately 50 acres. It was further explained that this would only provide in the order of 12 inches of water and yields would undoubtedly be better if the application was in the order of 18 inches and the development limited to around 35 acres. It should be noted, however, that the acreage could be reduced at any time by restricting the number of irrigation sets. Also, as the town grows in population, the available water will increase and the number of irrigations, and thus applied water can be increased accordingly. The material submitted to Donsdale Farms Co. provided an estimated cost of $15,000 excluding the Saskatchewan Power Corporation capital levy for providing power or approximately $290 per acre. In addition to the design details and cost estimate, Donsdale Farms Co. were informed that an agreement would be required with the Town of Balgonie for use of the effluent and that the Town of Balgonie would require a Certificate of Approval to Operate from the Department of the Environment. Further to the above, land control would be required for access to the pumpsite at the lagoon and for placement and operation of

the main line through the NW 34-17-17-2.

In the early spring of 1976, Donsdale Farms Co. contacted irrigation equpment dealers, obtained a private easement for access to the lagoon, and negotiated an agreement with the Town of Balgonie to allow for and ensure continued diversion of the sewage effluent for irrigation purposes. The equipment was purchased in May, 1976 and the equipment details are indicated on Figure 1. A "Certificate of Approval to Operate" was issued on February 17, 1977 to the Town of Balgonie under the authority of the Water Resources Management Act, 1972. The Certificate of Approval was issued by the Saskatchewan Department of the Environment in connection with the operation of the sanitary sewage works and included approval to operate the effluent irrigation project. The approval includes a requirement for the maintenance of certain records and submission of these records annually to the Department of the Environment for documentation. The records are to include: (a) period of irrigation; (b) volume of effluent used for irrigation; (c) area of land irrigated; (d) type of crop grown; (e) estimated crop yield. It must be pointed out at this time that the information submitted by Balgonie and the other towns and villages with effluent irrigation development is rather sketchy and incomplete. The Department of the Environment is endeavouring at this time to arrange for the collection of the data on a more consistent and complete basis.

In the spring of 1976, the area to be irrigated was seeded to alfalfa with an oats nurse crop. Irrigation was initiated in July, 1976. During 1977 and 1978, the area received four irrigations each year which emptied the lagoon by the fall of each year. The four irrigations applied 50 acre-feet in total or approximately 12 inches of water to each acre. This corresponds exceptionally well with the original estimates for the volume of effluent annually available. Yields have been exceedingly good amounting with two cuts each year, to seven tons/acre during 1977 and five and one-half

tons during 1978. The reduced yield in 1978 is attributed to an extreme hailstorm during the end of May which destroyed all growth up to that time. As a result of the high yields Donsdale Farms Co. are extremely pleased with the project development thus far.

To monitor the effect on the groundwater two water table wells were installed by the Conservation and Land Improvement Branch for annual sampling by the Department of the Environment, and to monitor any changes in the surface salts, two sites were selected for sampling every second year by the Conservation and Land Improvement Branch. The water table wells are indicated as W.T.W. #1 and W.T.W. #2 on Figure 1. The analysis of the samples are shown in Table 2. The soil sampling sites are indicated as S.S.S. #1 and S.S.S. #2 on Figure 1. The analysis of the samples are shown in Table 3. The depth to the water table is at approximately fourteen feet and has not increased. There would seem to be, however, a general increase in the total dissolved solids, particularly for Water Table Well No. 1. The significance of this increase has not been determined. In addition, due to the limited water application, it would be suspected that the change in the groundwater may not be attributal to the irrigation. The analysis of the soil samples taken in 1976 and 1978, as shown in Table 3, indicate a slight rise in the total salts as indicated by the electrical conductivity but more significantly a rise in the S.A.R. The rise indicates a sharp increase in sodium, although the readings are still within acceptable limits. The data is too limited at this time to properly assess and additional samples will be obtained during 1979 in the spring prior to irrigation in the late fall.

Effluent irrigation developments of this type are eligible for financial assistance under the Conservation and Land Improvement Branch Assistance Policy for Irrigation Development on Individual Farms. Currently, this policy provides financial assistance of one-third of the cost to a

maximum of $35 per acre for a maximum of 50 acres. This assistance is available for up to three members of a partnership, co-operative or corportion. Donsdale Farms Co. development amounted to a capital cost of $18,144.00 including the Saskatchewan Power Corporation capital levy and electrical hookup. Consequently, the development qualified for the maximum assistance of $35/acre for the 52.5 acres developed or a total of $1,837.50. It must be pointed out at this time that since the project was initiated and developed totally by the farmer, financial assistance was limited to that indicated above. Effluent irrigation projects at most other small urban centres are initiated by the urban centre and thus, the capital development costs are paid for by the village or town or shared between the village or town and the farmer in some manner. In these instances, since the village or town make the expenditures, additional financial assistance may be available through the Municipal Water Assistance Board amounting to one-third of the capital cost.

As indicated initially, effluent irrigation development may be initially promoted by an urban centre as a means of effluent disposal or initiated by an interested farmer as a source of water for irrigated agriculture. The Balgonie project was developed with the capital cost and operating costs being borne by the interested local farmer. The development at Eatonia, on the other hand, was initiated by the town as a means of solving their effluent disposal problem. Consequently, the capital cost was borne by the town. The operational costs are, by agreement with the farmer operating the project, borne by the farmer. The basic differences in the project initiation and development are, besides the eligibility for available financial assistance, reflected in the agreements between the urban centre and the operating farmer.

In the case of Balgonie, the intent of the agreement is to allow use of the effluent by the farmer and provide protection for continued usage.

The following clauses extracted from the actual agreement indicate this intent:

> Now, therefore, this agreement witnesseth:
>
> 1. That the Town shall permit the diversion of water from the second cell of sewage lagoon by the applicant for irrigation purposes on the NE 33-17-17-W2 and no charge will be assessed the applicant for the said diversion.
>
> 2. That the quantity of water diverted and the rate of diversion will be dependent on the irrigation requirements of the applicant and shall not be restricted by the Town except by the physical capabilities of the Town's sewage lagoon and associated sewage works.
>
> 3. That the Town will not permit or enter into other agreements for the diversion of water from the sewage lagoon except by mutual agreement between the applicant and the Town.
>
> 4. That the Town shall permit the installation of a pump house, pumping plant and necessary accessories on land owned by the Town and adjacent to second cell of the sewage lagoon and shall allow free access by the applicant to such works as may be necessary for the construction, operation and maintenance procedures necessary for operation of the irrigation system.
>
> 10. That this agreement may be terminated by the applicant should the sewage effluent detrimentally affect the composition of the soil to be irrigated or for any cause whatsoever upon thirty days prior notice in writing to the Town.
>
> 11. That this agreement may be terminated by the Town upon one year prior notice in writing to the applicant in the event that the applicant without cause does not utilize the effluent throughout one irrigation season.
>
> 12. This agreement shall be effective from the date hereof to the 31st day of December, 1985 A.D., and shall thereafter continue in force and effect unless or until terminated by the Town upon one year prior notice in writing to the applicant. The agreement may be re-negotiated or amended at any time by mutual consent of the parties hereto.

In the case of Eatonia, Coronach and other towns and villages, the intent of the agreement is to ensure adequate and continued disposal of the effluent in a satisfactory manner. The following clauses extracted from the Coronach agreement indicate this intent:

Now, therefore, this agreement witnesseth:

1. That the Village will purchase the irrigation equipment necessary to enable irrigation on the NW 12-2-27-2 by the thirty-first day of May, A.D. 1980 in accordance with suggested specifications and requirements of the Conservation and Land Improvement Branch of the Saskatchewan Department of Agriculture and that such equipment will be shown on a drawing depicting the development to be prepared by the said Conservation and Land Improvement Branch and designated as drawing 50413-1 and that a detailed list of the equipment shall be made upon purchase and such list form an addendum to this agreement.

2. That the Village agrees to demise and lease to the Applicant the irrigation equipment indicated in Article 1 for a period of time from the date upon which said equipment is in place and in operation up to and including the thirty-first day of December, A.D. 1988. The Applicant shall have an option to renew this agreement for a further ten (10) years upon the same terms and conditions.

3. That both the village and the applicant agree that this agreement may be terminated in any year of the said agreement by giving written notice of intention to terminate to the other party. The said notice to be given at least three (3) months prior to the thirty-first day of December in any given year. Upon said notice being properly given, the agreement shall terminate on the thirty-first day of December in the said year. Should the agreement be terminated at the option of the applicant, then in that event, the village shall have an option to purchase the lands irrigated by the said equipment. The within parties further agree that in the event that the within parties cannot agree on the purchase price of the land, then the question of price shall be determined by an arbitrator agreed to by the within parties. Further, should the within parties fail to agree upon an arbitrator, then one shall be appointed by the courts.

4. That the village will not permit or enter into other agreements for the diversion of water from the sewage lagoon except by mutual agreement between the APPLICANT and the VILLAGE, provided that the applicant is fulfilling the terms of the agreement and making satisfactory disposal of the effluent.

5. That the applicant agrees to return the irrigation equipment free of expense in as good condition as received, reasonable wear and tear excepted.

6. That the applicant agrees to pay all costs, expenses and repairs incurred in the operation and maintenance of the irrigation equipment.

7. That both the village and the applicant agree that any replacement costs that cannot be reasonably considered as maintenance and repair shall be shared jointly by the within parties according to the hereinafter mentioned formula, that is to say:

   The village will be responsible to pay towards the cost of replacement a sum equal to one-fifteenth of the total replacement cost times the number of years that the said irrigation equipment has been in use on the above mentioned land.

   The applicant shall be responsible for the balance of the replacement cost.

   Provided, however, the village shall in no case be responsible for replacement costs caused by negligence or improper operation.

   The village shall carry sufficient insurance on the irrigation equipment to cover the replacement cost of the said equipment.

8. That ownership of and equity in the said irrigation equipment shall remain with the village and it shall be their decision as to when any part of the said equipment shall be replaced, however, in this determination, the rationale of this agreement shall be the primary consideration.

9. That the village shall permit the diversion of water from the second cell only of the sewage lagoon by the applicant for irrigation purposes on the NW 12-2-27-2.

10. That the applicant agrees to follow good irrigation practices throughout the irrigation season in the utilization of the lagoon effluent and irrigation equipment, such that the volume of effluent required to be discharged by the first day of November in each and every year during the currency of this agreement will be discharged.

11. That the applicant agrees to use the said irrigation equipment only to irrigate from the said sewage lagoon and shall not remove the equipment except to make repairs.

Both methods of development incorporate into the agreement certain general clauses applicable to both. The following clauses will be found in both agreements:

- That the applicant agrees to keep accurate records of his irrigation practices consisting of the hours of pumping, irrigation timing, and crop yields during each and every year and agrees to submit said records to the village at the conclusion of each irrigation season.

- That the village shall not be responsible for failure to provide water when prevented due to required maintenance or construction of the sewage treatment works or for alterations or when prevented as a result of floods, washouts, droughts, disasters, Acts of God, or for any other cause for which the village has no control.

- That the applicant shall hold the village harmless from all claims, losses and damages associated with or arising from the water diversion.

- That the applicant shall accept full responsibility for the quality of the water diverted and shall save the village harmless from all claims, losses or damages resulting therefrom.

- That both the applicant and the village agree that the operation of the irrigation system and the diversion of the sewage effluent shall be subject to any and all requirements issued under The Water Resource Management Act and/or The Department of the Environment Act and regulations thereto.

- That this agreement may be re-negotiated or amended at any time by mutual consent of the parties hereto.

- That this agreement may not be transferred or assigned by either of the parties hereto.

There are currently eight effluent irrigation projects operating throughout the province and investigations are proceeding and development pending at twelve additional sites. Technical assistance may be provided by the Conservation and Land Improvement Branch, Saskatchewan Department of Agriculture and Environment Saskatchewan, Water Pollution Control Branch, as financial and manpower resources are available. The technical assistance will include the following:

a) preliminary evaluation of the proposed irrigation site, including soil sampling, soil assays, effluent analyses, engineering surveys and recommendations on crop type, irrigation methods, and preliminary cost estimates;

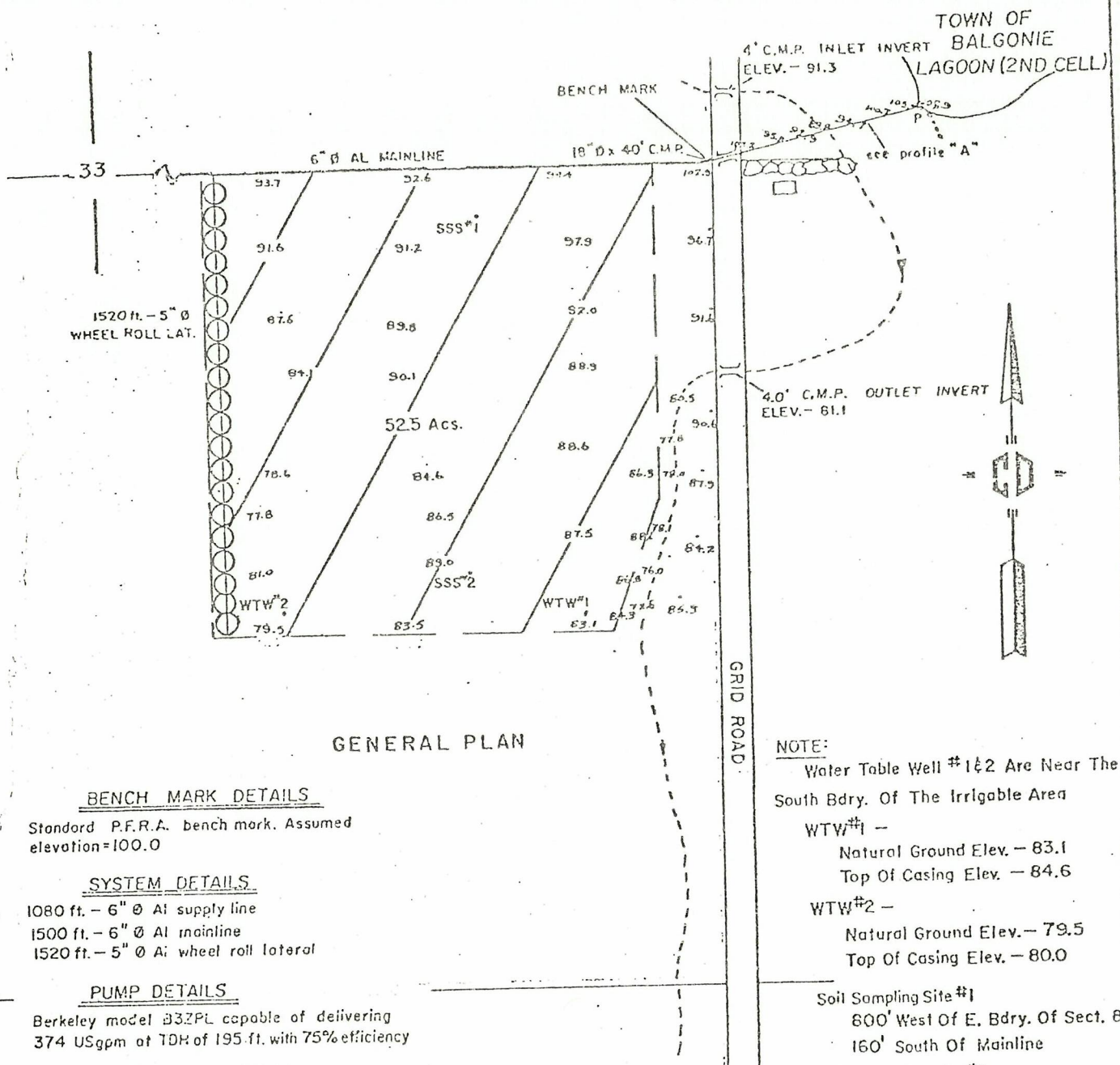
b) system design, cost estimates and operating recommendations;

c) monitor well installation; and

d) advice on collection of soil and monitor well water samples.

Initiation of a project and request for assistance by either the town or village and/or interested farmers, can be made by contacting either of the above agencies directly. Additional information on development requirements and assistance is provided in the "Sewage Effluent Irrigation Guidelines" prepared by Environment Saskatchewan.

FIGURE 1



GENERAL PLAN

BENCH MARK DETAILS

Standard P.F.R.A. bench mark. Assumed elevation = 100.0

SYSTEM DETAILS

1080 ft. – 6" Ø Al supply line
1500 ft. – 6" Ø Al mainline
1520 ft. – 5" Ø Al wheel roll lateral

PUMP DETAILS

Berkeley model B3ZPL capable of delivering 374 USgpm at TDH of 195 ft. with 75% efficiency

POWER UNIT DETAILS

25 bhp three phase electric motor

IRRIGATION ACREAGE

SE. 33 – 17 – 17 – W2M ..... 52.5 acres

OWNER & APPLICANT

Donsdale Farms

NOTE:

Water Table Well #1 & 2 Are Near The South Bdry. Of The Irrigable Area

WTW#1 –
Natural Ground Elev. – 83.1
Top Of Casing Elev. – 84.6

WTW#2 –
Natural Ground Elev. – 79.5
Top Of Casing Elev. – 80.0

Soil Sampling Site #1
800' West Of E. Bdry. Of Sect. 8
160' South Of Mainline

Soil Sampling Site #2
800' West Of E. Bdry. Of Sect. 8
200' North Of S. Bdry. Of The Irrigable Area

NO.	DATE	REVISION	BY	CK'D
2	JULY 1976	Water Table Wells & Soil Sampling Sites Added	W.E.R.	W.E.R.
1	FEB. 13/76	AS CONSTRUCTED DETAILS ADDED		

SASKATCHEWAN
DEPARTMENT OF AGRICULTURE
CONSERVATION AND DEVELOPMENT BRANCH

GENERAL PLAN
showing
INDIVIDUAL IRRIGATION PROJECT
of
DONSDALE FARM CO.
S.E.¼ sec. 33 TWP. 17 RGE 17 W2 M

SCALE – as shown
SUBMITTED Bryan Ireland
RECOMMENDED
APPROVED W.C. Campbell

DRAWN M.R.
TRACED
CHECKED
EXAMINED

DATE: OCT. 14/75

50300 – 1

FIGURE 2

SPRINKLER EVALUATION

Date Oct. 1974

Applicant Donsdale Farms Co. File No: 50300

Area Land Location S.E. 33-17-17-2 Acres: 52.5

Source of Water Town of Balgonie Lagoon

DESIGN INFORMATION

Soil Texture	Loam	Time Per Set	7 1/2 Hrs.
Moisture Holding Capacity	approx 2 In/Ft	Gross Water Applied	3.0 Ins.
Infiltration Rate	0.4 In/Hr.	Application Efficiency	75 %
Kind of Crop	various	Net Water Applied	2.25 Ins.
Working Root Depth	3-4 Ft.	Irrig. Interval	10.23 Days
Peak Use Rate	0.22 In/Day	No. of Sets	25
Irrig. Interval Desired	Days	No. of Laterals	1
Minimum Water Req'D	Ins.	Sets/Day	3
Sprinkler Spacing	40 x 60	Acres Per Set	2.15
Discharge / Sprinkler	10.1 G.P.M.	Acres Per Day	6.45
Application Rate	96.3xG.P.M. / A = 96.3 x 10.1 / 2400 = 0.4 In/Hr.	Operation Time/ Irrig.	8 1/3 Days
		Relocation Time	1.9 Days

SYSTEM DESIGN

Lateral Lines

Length of Lateral Lines 5"ø - 1520 Ft. _____ Ft.

Sprinkler Nozzle, Size 3/16" x 1/8" G.P.M. 10.1 @ 45 P.S.I. Ave.

Allowable Pressure Loss in Line 20% of Ave. P.S.I. = 9 P.S.I.

Line	Size In.	Length Ft.	No. of Sprinklers	G.P.M./ Sprinkler	Capacity	Friction Loss P.S.I.	Elev. Dif.P.S.I.	Pressure Loss P.S.I.
	5	1520	38	10.1	384	6.6	-5	1.6

P.S.I. Req'd @ Inlet of Lateral = Ave. P.S.I. 44½ Friction Loss 5 +Elev.Diff.-5 =45 P.S.I.

Total System Capacity 384 G.P.M.

Main Line

Total Length of Main Line _____ Ft.

Selection of Main Line:

Pipe Size	Capacity G.P.M.	Length	Friction Loss/100'	Friction Loss	Elev. Diff.	Total Head Loss
6"	384	2600	1.25	33	-10	25

Main Line Selected Size 6 "x _____ ': Size ____ " x _____ '

PUMP UNIT

Maximum Capacity Req'd 384 G.P.M.

Pressure Req'd @ Lateral 45 P.S.I. or 104 Ft.

Head Loss in Main Line _____ 25 Ft.

Static Lift _____ 5 Ft.

Miscellaneous Losses _____ 16 Ft.

Total Dynamic Head _____ 150 Ft.

Pump Efficiency _____ 70 %

Horsepower Required $\frac{150 \times 384}{3,960 \times 0.7}$ = 21 B.H.P. Continuous

Designed By: B.I.

AC 501 Rev./Mar/70

TABLE 1

SOIL EVALUATION

HOLE NO.	DEPTH	TEXTURE	SAT.%	COND. mmhas/cm	pH	SOLUBLE SALTS/ppm Na^+	Ca^{++}	Mg^{++}	K^+	CL^-	$SO_4^=$	SAR
#1	0-8"	L	46	1.19	7.5	24	218	50	25	28		0.38
	8-20"	CL	44	1.36	7.2	30	157	108	12	8		0.45
	20-32"	CL	38	7.25	7.7	258	791	1024	33	8		1.47
#2	0-8"	L	48	0.87	7.2	9	138	42	26	16		0.17
	8-20"	CL	44	0.96	7.8	24	85	36	13	9		0.55
	20-36"	CL	46	1.38	8.1	95	80	101	22	16		1.67
#3	0-8"	L	48	1.17	7.0	16	158	82	35	36		0.26
	8-20"	CL	44	6.32	7.5	66	1448	524	39	11		0.38
	20-26"	CL	44	4.56	7.8	168	658	420	40	10		1.26
#4	0-8"	L	49	1.08	7.5	13	197	45	35	17		0.22
	8-18"	CL	51	0.70	7.7	17	110	40	11	7		0.35
	18-30"	CL	44	4.70	7.9	159	586	477	31	8		1.18

Note: Analysis by Soil Testing Laboratory - University of Saskatchewan.

TABLE 2

WATER TABLE MONITORING

	WATER TABLE WELL NO. 1					WATER TABLE WELL NO. 2				
DATE	15/12/76	26/04/77	31/10/77	07/06/78	02/10/78	15/12/76	26/04/77	31/10/77	07/06/78	02/10/78
pH	7.7	7.7	7.5	7.3	7.3	7.5	7.6	7.2	7.2	7.3
BICARBONATE mg/1	498	478	476	386	429	566	510	493	505	447
CARBONATE mg/1										
CHLORIDE mg/1	28	22	94	166	138	190	194	216	190	284
SULPHATE mg/1	480	405	1300	3000	2000	1450	1450	1600	1500	1800
CALCIUM mg/1	139	16	318	424	360	252	170	411	392	448
MAGNESIUM mg/1	90	154	189	467	292	321	323	220	219	272
POTASSIUM mg/1	11	8	13	12	11	17	13	15	11	12
SODIUM mg/1	84	84	155	272	270	159	158	165	163	186
CONDUCTIVITY umho/cm	1400	1300	2400	3700	3300	2500	3000	2800	2400	3200
SUM OF IONS (TDS) mg/1	1338	1171	2547	4766	3516	2970	2824	3123	2987	3454
TOTAL HARDNESS mg/1 as $CaCO_3$	720	672	1572	2980	2100	1950	1752	1932	1880	2240
TOTAL ALKALINITY mg/1 as $CaCO_3$	408	392	390	316	352	464	418	404	414	366

Note: - The samples were obtained by the Water Pollution Control Branch, Saskatchewan Department of the Environment.

- Analysis by Provincial Laboratories.

TABLE 3

SOIL MONITORING

SITE	DATE	DEPTH	TEXTURE	SAT.%	COND. mmhos/cm	pH	SOLUBLE SALTS/ppm Na^+	Ca^{++}	Mg^{++}	K^+	CL^-	$SO_4^=$	SAR
Soil Sampling Site #1	Aug. 1976	0-6"	L	44	1.3	6.6	18	205	70	27	27	80	0.3
		6-12"	CL	44	1.3	7.0	18	170	75	14	14	170	0.3
		12-24"	CL	42	1.0	7.5	34	80	70	14	17	57	0.7
		24-30"	CL	43	7.2	7.5	354	665	850	30	98	6700	2.1
	Dec. 1978	0-6"	L	48	1.6	7.2	134	100	70	18	41	310	2.5
		6-12"	CL	47	1.5	7.3	113	115	60	9	91	315	2.1
		12-24"	CL	46	1.5	7.6	75	75	60	11	100	335	1.6
Soil Sampling Site #2	Aug. 1976	0-6"	L	41	1.4	7.3	11	225	50	94	18	190	0.2
		6-12"	CL	45	1.3	7.6	14	140	50	140	20	85	0.3
		12-24"	CL	33	1.9	7.7	31	160	110	166	22	730	0.5
		24-36"	CL	32	6.7	7.7	255	690	800	122	56	6600	1.6
	Dec. 1978	0-6"	L	46	1.0	7.4	66	70	40	12	60	185	1.6
		6-12"	CL	50	1.5	7.2	90	125	80	10	128	330	1.5
		12-24"	CL	48	4.5	7.4	237	385	405	21	180	3600	2.0

Note: Analysis by Soil Testing Laboratory - University of Saskatchewan.