1976

Suitability of Lagoon Effluent for Irrigation in South Dakota

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SUITABILITY OF LAGOON
EFFLUENT FOR IRRIGATION
IN SOUTH DAKOTA

BY

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A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science, Major in
Engineering, South Dakota
State University

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser Date

Major Adviser Date

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ACKNOWLEDGEMENTS

The author wishes to express sincere appreciation to Mr. David Odens, for the many hours and valuable guidance received from him throughout the study. Gratitude is also extended to Dr. James N. Dornbush, for his many ideas and assistance.

Appreciation is extended to Mr. Dale Johnson, for the preparatory work done for the study.

The author would also like to thank Dr. Robert Lacher, for his assistance in the statistical analyses.

Funds for this study were provided by the South Dakota State University Water Resources Institute, project number 3575-8590.

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INTRODUCTION

The use of stabilization ponds, often called lagoons, has gained wide popularity in South Dakota. Relatively low construction costs and ease of operation have made lagoons a widely accepted wastewater treatment method for South Dakota's small rural communities. Many communities in the state have been able to provide wastewater treatment by using lagoon systems where other methods of treatment were not economically feasible. The South Dakota Committee on Water Pollution has recognized lagoons as adequate treatment facilities (1).

Recent requirements of the National Pollutant Discharge Elimination System (NPDES) probably can not be met by present lagoon effluents (2). In order to meet the requirements of the NPDES by 1985, alternative methods for the elimination of pollutant discharge must be evaluated on a cost-benefit basis. One alternative to meet these requirements is through land disposal of lagoon effluents.

Land disposal can be accomplished by several methods, some of which are: crop irrigation, overland flow, and infiltration-percolation. "Irrigation is the most reliable land application approach evaluated on the basis of direct wastewater recycling, renovation, long term use, and minimization of adverse environmental effects" (3-2). Since South Dakota is a water deficient area, and crop irrigation provides both a potential method of meeting NPDES requirements and an irrigation water resource, this method should be among those considered as the best practicable treatment.

The universal application of this method of treatment is not practical; therefore, it is necessary that the constraints for the use of effluents for irrigation be identified, and the classification of waters of all lagoons in South Dakota as to their suitability for irrigation is then necessary. The classification of these lagoon waters will be a valuable asset to engineers designing new treatment facilities, and to farmers considering lagoon water as an irrigation resource.

In order to classify the water quality of all lagoons on the basis of existing data, a relationship between the water quality of the municipal water supply and the water quality in the lagoon was established. The objectives of this study have been established as follows:

1. To evaluate and classify lagoon effluents with respect to their suitability for irrigation, and

2. To establish a method of determining the probable water quality in the lagoons on the basis of the water quality of the municipal water supply.

CLASSIFICATION OF IRRIGATION WATERS

The classification of irrigation waters is based on certain guidelines. These guidelines are not exact, but they represent general categories of water quality for use for irrigation purposes.

> "Classification of irrigation waters is based on the assumption that the water will be used under average conditions with respect to soil texture, infiltration rate, drainage, quantity of water used, climate, and salt tolerance of the crop. Large deviations from the average for one or more of these variables may make it unsafe to use what, under average conditions, would be a good water; or make it safe to use what, under average conditions, would be a water of doubtful quality." (4)

Guidelines to the classification of irrigation waters have been established in accordance with this assumption. Three distinct hazards from the use of certain waters for irrigation are recognized. These hazards are: (a) The salt or salinity hazard, (b) the alkali or sodium hazard, and (c) specific toxins or poisons (5).

Salinity Hazard

Electrical conductivity, commonly called specific conductance, has been used as an indicator of the total salt content of water (6-24). Based on this indicator waters are divided into four classes with respect to conductivity. The dividing points of these class limits are as follows: 250, 750, and 2250 micromhos/cm. These class limits were selected in accordance with the relationship between the electrical conductivity of irrigation waters and the electrical conductivity of saturation extracts of soil (4). Figure 1, adapted from the U.S. Salinity Laboratory Handbook No. 60, incorporates the above class

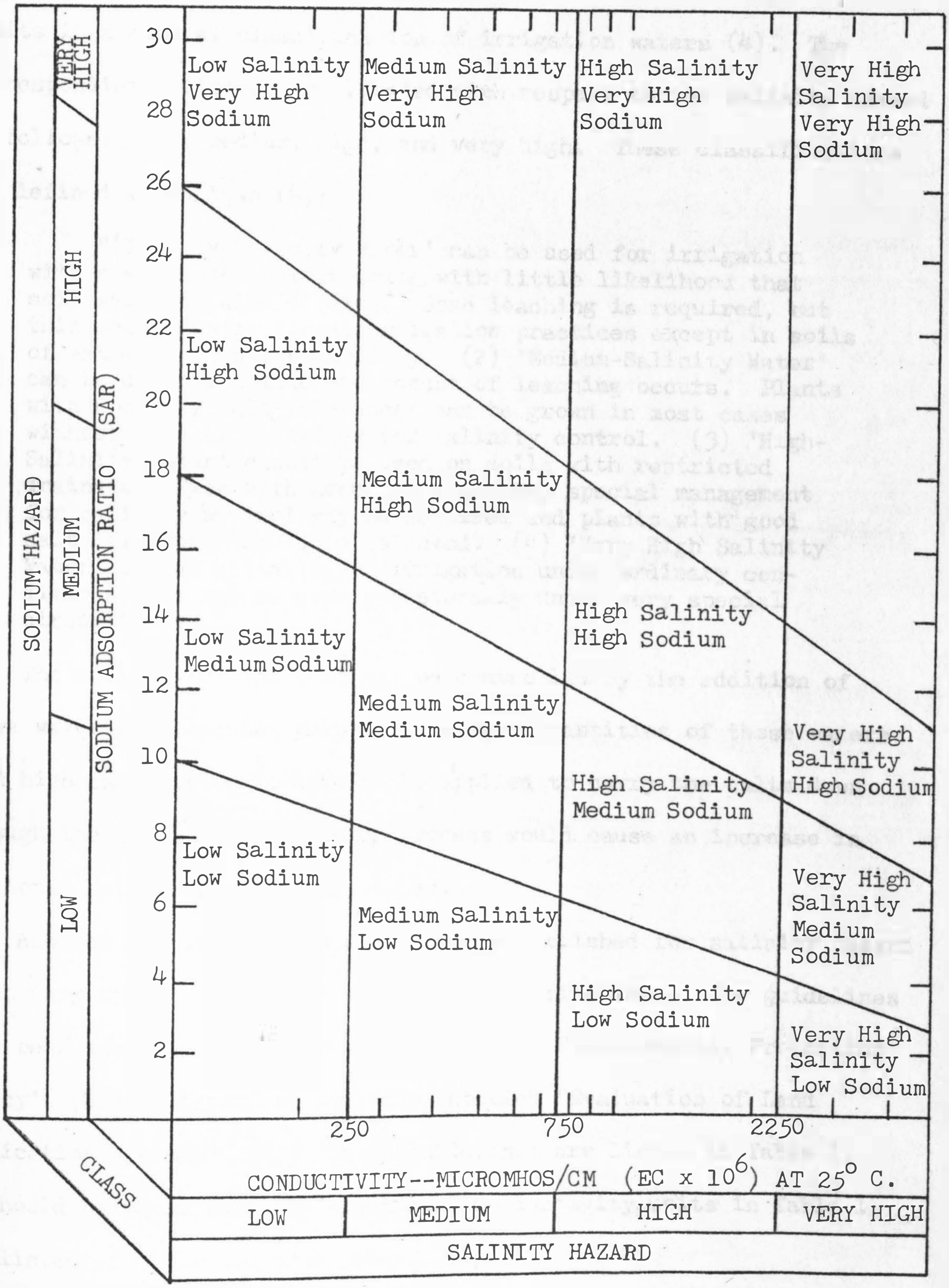

Figure 1. Irrigation classification guidelines (4)

limits in a general classification of irrigation waters (4). The corresponding divisions are labeled with respect to the salinity hazard as follows: low, medium, high, and very high. These classifications are defined as follows (4):

> "(1) 'Low-Salinity Water' can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability. (2) 'Medium-Salinity Water' can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerances can be grown in most cases without special practices for salinity control. (3) 'High-Salinity Water' cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected. (4) 'Very High Salinity Water' is not suitable for irrigation under ordinary conditions, but may be used occasionally under very special circumstances."

The salinity of the soil may be controlled by the addition of extra water for leaching purposes. Larger quantities of those waters with high salinity would have to be applied to carry the salts down through the soil. This leaching process would cause an increase in the total solids of the ground water.

Another set of guidelines has been established for salinity hazard which vary somewhat from the previous classifications. The guidelines have been accepted for reference in the U.S. Environmental Protection Agency's (EPA's) technical bulletin entitled "Evaluation of Land Application Systems" (6). These guidelines are listed in Table 1. It should be noted that the electrical conductivity units in Table 1 are listed in millimhos/centimeter.

Table 1. Water-Quality Guidelines (6-27)

Problem and Related Constituent	Guideline Values: No Problem	Increasing Problems	Severe
Salinity[a]			
EC of water, in mmhos/cm	<0.75	0.75-3.0	>3.0
Permeability			
EC of water, in mmhos/cm	>0.5	<0.5	<0.2
SAR (Sodium Adsorption Ratio)	<6.0	6.0-9.0	>9.0

a. Assumes water for crop plus needed water for leaching requirement will be applied. Crops vary in tolerance to salinity.

Sodium Hazard

The effect of exchangeable sodium on the physical condition of the soil is the primary factor in the classification of irrigation waters with respect to the sodium adsorption ratio (SAR). The sodium adsorption ratio has been defined as (4):

$$SAR = \frac{[Na]}{\left[\frac{[Ca + Mg]}{2}\right]^{1/2}} \qquad \text{(Eq. 1)}$$

where Na, Ca, and Mg are the concentrations of the respective ions in milliequivalents per liter (meq/l). This SAR value has been used to classify waters according to the sodium hazard of the water. The following classifications are based on the SAR intervals outlined in Figure 1 (4):

> "(1) 'Low-Sodium Water' can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. (2) 'Medium-Sodium

Water' will present an appreciable sodium hazard in fine-textured soils having high cation-exchange-capacity, especially under low-leaching conditions, unless gypsum is present in the soil. This water may be used on coarse-textured or organic soils with good permeability. (3) 'High-Sodium Water' may produce harmful levels of exchangeable sodium in most soils and will require special soil management--good drainage, high leaching, and organic matter additions. (4) 'Very High Sodium Water' is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity, where the solution of calsium from the soil or the use of gypsum or other amendments may make the use of these waters feasible."

Again, a somewhat different set of guidelines is presented in Table 1. These guidelines were also presented by the EPA (6-27). It should be noted that the sodium hazard in Figure 1 increases with increasing salinity, but in Table 1 the salinity and sodium are not directly related. Based on the guidelines in Table 1, waters having SAR values greater than 9 will probably have adverse effects on the permeability of soil. The Committee on Water Quality Criteria has reported that waters having SAR values greater than 8 may have adverse effects on the permeability of soils containing large amounts of clay (7-115).

Sodium hazard may be increased if the water contains a high concentration of bicarbonate ions. A convenient term to express the bicarbonate value in water is "residual sodium carbonate (RSC)", which is defined as (8-110):

$$RSC = \text{Total Alkalinity} - \text{Total Hardness} \qquad \text{(Eq. 2)}$$

when ionic constituents are defined as meq/l.

Water and soil analyses at the U.S. Salinity Laboratory led to the conclusion that waters with more than 2.5 meq/l of residual sodium carbonate are probably not suitable for irrigation (4). The salinity laboratory staff also concluded that marginal waters may possibly be used successfully where good management practices are followed (4).

Toxins or Poisons

The third general hazard associated with irrigation waters is that of specific toxins or poisons. Boron is one element of primary concern associated with toxins and poisons (4). Elements such as boron and others have a specific toxicity to crop growth when present in certain concentrations. However, the boron content in South Dakota waters is generally much below the minimum which will cause harmful effects among crop plants (5). It should be noted that toxins or poisons may be introduced to wastewater by some industrial wastes. If industrial processes which may produce a toxic waste are present in the community, the possibility of toxins or poisons in the lagoon effluent should be considered.

Water Classification

In appraising the quality of an irrigation water, first consideration should be given to the sodium and salinity hazards. Then the other independent characteristics, toxic elements, and bicarbonate of the water should be given consideration.

The classifications of this study have been primarily concerned with the salinity and sodium hazards. The danger of boron in most South Dakota waters is generally not a concern when considering irrigation water (5). Therefore, the effects of specific toxins or poisons were not considered in this study.

The classification of irrigation waters will be based on the guidelines outlined in Figure 1 and those in Table 1. In order to classify waters under this system, it is necessary to know the following parameters; sodium, total hardness, and total alkalinity concentrations, and the specific conductance of the water.

LAGOON EFFLUENT SUITABILITY

In order to determine the suitability of lagoon effluents for irrigation, 33 lagoons in South Dakota were selected for laboratory analyses. These lagoons were selected on the basis of population, geographic location, and probable water quality. The selection methods were determined in another portion of this project, but are not yet published (9).

Lagoon Sampling

The lagoons were sampled twice during the peak irrigation months of July and August. The laboratory analyses performed, which were determined necessary from the irrigation water classification section, are as follows: sodium, total hardness, specific conductance, and total alkalinity. These analyses were performed twice for each lagoon. The raw data from these analyses is presented in Appendix A. The results of the two water quality analyses for each lagoon were averaged, and this average value has been used in the classification of the lagoon waters as to their suitability for irrigation. The SAR and RSC values for each of the sampling sites have been calculated, and they are listed in Appendix A.

Lagoon Classification

The guidelines presented in Figure 1 have been used to classify each lagoon water on the basis of its salinity and sodium hazards. The results of this classification are presented in Table 2. The lagoons were also classified according to the guidelines in Table 1.

The results of this classification are presented in Table 3. The two classifications appear to be approximately equivalent.

Lagoon Water Suitability

The suitability of the lagoons sampled has been based on the previous irrigation water-quality guidelines and on recommendations by Dr. Lawrence Fine of the Extension Service at South Dakota State University[1]. The resulting classifications in Table 2 show that 15 of the 33 lagoon waters sampled are possibly suitable for irrigation. Based on the classifications in Table 3, 17 of the 33 lagoons show some possibility as an irrigation water resource.

In both classifications, Table 2 and Table 3, the salinity hazard is at least high or increasing for each of the lagoon waters sampled. The high salinity hazard does not exclude these waters from possible use for irrigation. High salinity water cannot be used on soils with restricted drainage, but with adequate drainage and special management these waters could be used for irrigation purposes (4). Dr. Fine has indicated that high salinity waters will not pose a large problem if they are applied to well drained soils.

The sodium hazard does not present any problem in approximately one third of the lagoons sampled. Based on the sodium hazard alone, approximately two thirds of the lagoon waters sampled could be used for irrigation with some management and proper soil conditions.

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[1]Dr. Lawrence Fine, Extension Service, South Dakota State University, Personnal Communication, (April, 1976).

Table 2. Classification of Lagoon Effluents for Irrigation Based on the Guidelines from Agricultural Handbook No. 60 (4)

City	Salinity Hazard	Sodium Hazard
Aberdeen	High	Medium
Andover*	Very High	Medium
Baltic*	Very High	Medium
Belle Fourche	High	Low
Beresford	High	Low
Brookings	High	Low
Canton	High	Medium
Colman*	Very High	Medium
Estelline	High	Low
Groton*	Very High	Very High
Howard*	Very High	Very High
Huron*	Very High	Very High
Lennox*	Very High	Medium
Madison*	Very High	Medium
Milbank*	Very High	Medium
Murdo	High	Medium
New Underwood	High	Medium
Parkston*	Very High	Very High
Platte*	Very High	High
Redfield*	Very High	Very High
Spearfish	High	Low
Springfield	High	Medium
Sturgis	High	Low
Tea*	Very High	Medium
Tripp*	Very High	Very High
Tyndall*	Very High	Medium
Volga	High	Low
Wall*	High	Very High
Watertown	High	Low
Webster*	Very High	High
Whitewood	High	Low
Winner	High	Low
Woonsocket*	Very High	High

*Unsuitable for irrigation according to these guidelines, under normal conditions

Table 3. Classification of Lagoon Effluents for Irrigation Based on the Guidelines Presented by the EPA (6-27)

City	Salinity Problem	Sodium (SAR) Problem
Aberdeen	Increasing	No Problem
Andover*	Severe	Increasing
Baltic	Increasing	Increasing
Belle Fourche	Increasing	No Problem
Beresford	Increasing	No Problem
Brookings	Increasing	No Problem
Canton*	Increasing	Severe
Colman	Increasing	No Problem
Estelline	Increasing	No Problem
Groton*	Severe	Severe
Howard*	Severe	Severe
Huron*	Severe	Severe
Lennox*	Severe	Severe
Madison	Increasing	Increasing
Milbank*	Increasing	Severe
Murdo	Increasing	Increasing
New Underwood*	Increasing	Severe
Parkston*	Severe	Severe
Platte*	Severe	Severe
Redfield*	Severe	Severe
Spearfish	Increasing	No Problem
Springfield*	Increasing	Severe
Sturgis	Increasing	No Problem
Tea*	Severe	Increasing
Tripp*	Increasing	Severe
Tyndall	Increasing	No Problem
Volga	Increasing	No Problem
Wall*	Increasing	Severe
Watertown	Increasing	No Problem
Webster	Increasing	Increasing
Whitewood	Increasing	No Problem
Winner	Increasing	No Problem
Woonsocket*	Severe	Severe

*Unsuitable for irrigation according to these guidelines, under normal conditions

The effect of residual sodium carbonate was not significant in the lagoon waters sampled. The RSC exceeded the maximum recommended limit of 2.5 meq/l in only four of the lagoon waters sampled. In one lagoon, the high RSC did have some significance in the classification of that lagoon as an irrigation water resource; although, the RSC of this particular lagoon's water quality was only slightly greater than the recommended limit. In the other three lagoon waters with high RSC values, the other classification parameters were so high that these waters were classified as unsuitable without considering the RSC.

The RSC does not appear to be a significant problem in lagoon waters in South Dakota. For this reason, no attempt was made to develop a relationship to predict the parameters necessary to calculate the RSC value. However, before a final decision has been reached regarding the suitability of a particular lagoon, the RSC value should be considered.

There appear to be good possibilities for the use of lagoon effluents for irrigation in South Dakota. Approximately one half of the lagoons sampled have shown good possibilities for use as an irrigation water resource. It must be noted that in all cases, a final determination on the potential use of lagoon effluents for irrigation should not be made without knowledge of the soil and specific characteristics of the area to be irrigated. Some of the other factors which should be considered are the amount of available water and the crops which are to be irrigated.

PREDICTING PROBABLE WATER QUALITY

Because there is a good probability of lagoon effluents being suitable for irrigation in South Dakota, all lagoons should probably be classified on the basis of existing data. The existing data available is the water quality of the municipal water supply (10). The water quality data for the water supplies used in this study are presented in Appendix B.

A comparison has been made between the lagoon effluent water quality and the water quality of the municipal water supply for the lagoon waters sampled. This comparison has been used to determine the probable water quality of lagoons in South Dakota.

The first step in developing the relationship between the quality of the water supply and the lagoon effluent was to classify the water quality of the water supply for each of the sampling sites according to their suitability for irrigation. The same guidelines as those used in Table 2 were used to classify the sampling sites with respect to their water supply data. In order to classify the water quality of the water supplies according to these guidelines, it was necessary to estimate the specific conductance of the water. The Public Water Supply Data handbook lists the total solids concentration for each of the water supplies (10). The EPA has presented a factor for estimating the specific conductance based on the total solids concentration of a water (6-25). The factor presented was: 1.5 times the total solids concentration (mg/l) equals the specific conductance (μmhos/cm) (6-25). This factor was used to estimate the specific conductance for each of the water supplies. The results of this classification are presented in Table 4.

The irrigation suitability classification of the lagoon effluent was either the same as or less suitable than the classification for the water supply. For this reason, it is believed that if the water supply is not suitable for irrigation; then the lagoon effluent will not be suitable for an irrigation water resource.

The classification of the sampling sites based on the quality of the water supply shows that the water supply for 12 of these sites was not suitable for irrigation under most conditions. The salinity hazard for nine of the municipal water supplies was very high. The sodium hazard was very high for four of the water supplies (Groton, Redfield, Wall, and Woonsocket).

An empirical relationship has been developed for use in estimating the lagoon water quality where the quality of the water supply was suitable for irrigation. If the salinity hazard was very high, the data for that location was not used in the regression analysis to estimate specific conductance. If the sodium hazard was very high, the data for that location was omitted from the regression analyses to estimate sodium and total hardness, necessary to calculate the SAR value.

The data from two other lagoons was omitted from all regression analyses. The lagoon at Baltic was nearly dry at the time samples were collected. Therefore the sample collected probably was not representative of the typical lagoon effluent at Baltic. The water

Table 4. Classification of the Water Quality of Water Supplies for Irrigation Based on the Guidelines from Agricultural Handbook No. 60 (4)

City	Salinity Hazard	Sodium Hazard
Aberdeen	High	Medium
Andover	High	Low
Baltic	Low	Low
Belle Fourche	Medium	Low
Beresford	High	Low
Brookings	High	Low
Canton	High	Low
Colman*	Very High	Medium
Estelline	Low	Low
Groton*	Very High	Very High
Howard*	Very High	Medium
Huron	Medium	Low
Lennox*	Very High	Low
Madison	High	Low
Milbank	High	Low
Murdo	High	Low
New Underwood	Low	Medium
Parkston*	Very High	Medium
Platte*	Very High	High
Redfield*	Very High	Very High
Spearfish	Medium	Low
Springfield	Medium	Low
Sturgis	Medium	Low
Tea*	Very High	Low
Tripp	High	Medium
Tyndall*	Very High	Low
Volga	High	Low
Wall*	High	Very High
Watertown	Medium	Low
Webster*	High	High
Whitewood	Low	Low
Winner	Medium	Low
Woonsocket*	High	Very High

*Unsuitable for irrigation according to these guidelines, under normal conditions

supply data available for Huron does not appear to be representative of the normal water quality in the James River. The principal water supply for Huron is the James River. The water quality in the James River has a large seasonal variation according to Young (11-73). The water supply data appears to have been collected when the water quality in the James River was much better than normal. According to Young, the dissolved solids in the James River near Huron varied from about 200 mg/l to approximately 1,800 mg/l (11-58). According to the Public Water Supply Data, the total solids concentration in the water supply at Huron was 238 mg/l (10). This sample was collected during May, when the flow in the James River was probably high (10). Young showed that the total solids concentration in the James River was relatively low during this time period (11-66). Both the data from Huron and from Baltic were not used in the regression analyses for the previous reasons, leaving 31 lagoons for developing the empirical relationship.

The regression analyses were performed using the computer at the South Dakota State University computing center. A step-wise linear regression program, which is on file at the computing center, was used to compute the regression analyses. These analyses were performed using the data from the remaining 31 sampling sites. The analyses were used to establish an equation which could be used to estimate the sodium and total hardness concentrations and the specific conductance of lagoon waters in South Dakota based on the water quality data for the community water supply.

Sodium

Several analyses were performed to derive an equation to estimate the sodium concentration in lagoon effluents based on the water supply data. The best estimate of the sodium concentration in the lagoon waters was obtained by performing a step-wise multiple regression between the sodium concentration in the lagoon water and the sodium and total hardness concentrations in the water supply. This analysis was performed with 27 observations. The data from Huron, Baltic, Groton, Redfield, Wall, and Woonsocket were not included in this analysis. The following equation to estimate sodium concentrations in lagoon waters was developed:

$$Y = 27.2(X_1)^{1/2} + 0.2(X_2) - 10.7 \qquad \text{(Eq. 3)}$$

Y = Sodium--Lagoon (mg/l)

X_1 = Sodium--Water Supply (mg/l)

X_2 = Total Hardness--Water Supply (mg/l as $CaCO_3$)

The regression analysis showed that the variability of sodium and total hardness concentrations in the water supply accounted for 63.6 per cent of the variation of the sodium concentration in the lagoon water. The multiple correlation coefficient adjusted for degrees of freedom is 0.788 for this relationship. The variability of sodium in the water supply accounted for 56.5 per cent of the variability of sodium in the lagoon waters. The addition of the variation of total hardness in the water supply to this relationship accounted for an additional 7.1 per cent of the variability of sodium concentrations in the lagoon effluents.

The correlation coefficient between total hardness of the water supply and sodium concentration in the lagoon effluent was 0.523. The use of home water softeners, which generally exchange sodium for calcium and magnesium, may explain the correlation between the total hardness of the water supply and the sodium in lagoon waters (12-519).

A portion of the variability of sodium in lagoon waters has not been accounted for in Equation 3. There appear to be other variables which have not been isolated in this study that are responsible for variability of sodium in lagoon waters. Equation 3 does not account for all the variability of sodium in lagoon waters, but it should provide an adequate estimate of sodium concentration for preliminary investigations of the suitability of a lagoon as a potential irrigation water resource.

Equation 3 cannot be graphed in two-dimensional form, therefore only the relationship between sodium in the water supply and sodium concentrations in the lagoon waters has been graphed in Figure 2. This relationship was developed through regression analysis.

$$Y = 31.6(X)^{1/2} + 32.8 \qquad \text{(Eq. 4)}$$

Y = Sodium--Lagoon (mg/l)

X = Sodium--Water Supply (mg/l)

The variation of sodium in the water supply accounted for 56.5 per cent of the variation of sodium in the lagoon waters in this relationship. The correlation coefficient for this relationship is 0.752. This equation does not represent the best estimate of lagoon sodium concentration, but it can be plotted in two-dimensional form to show the fit of the curve to the data points used for this analysis.

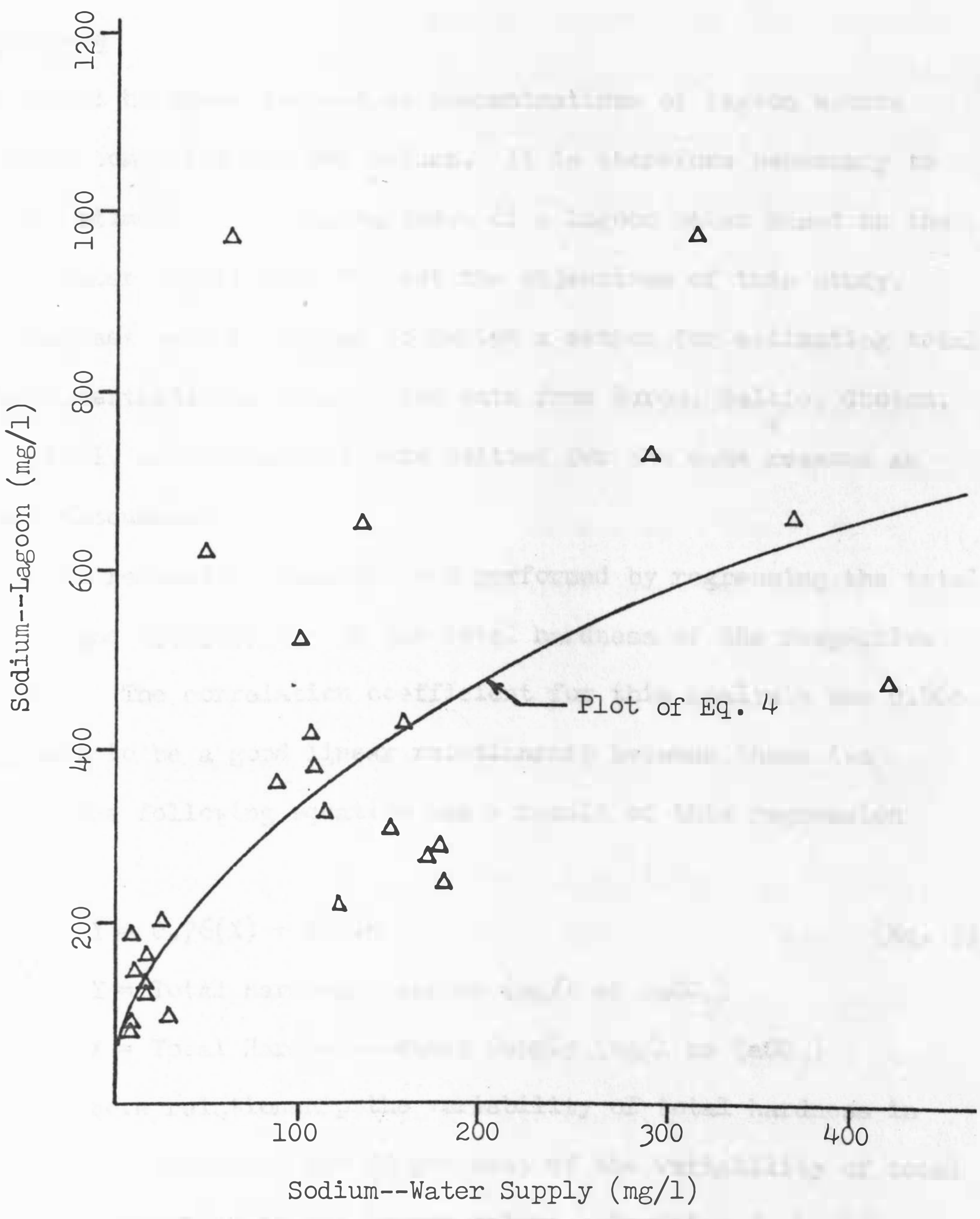

Figure 2. Scatter Diagram of Data Used to Develop Eq. 4

The data points used and the line resulting from Equation 4 are shown in Figure 2.

Total Hardness

The total hardness and sodium concentrations of lagoon waters were used in computing the SAR values. It is therefore necessary to be able to estimate the total hardness of a lagoon water based on the respective water supply data to meet the objectives of this study. Several analyses were attempted to derive a method for estimating total hardness concentrations. Again, the data from Huron, Baltic, Groton, Redfield, Wall, and Woonsocket were omitted for the same reasons as previously discussed.

A linear regression analysis was performed by regressing the total hardness of the water supply on the total hardness of the respective lagoon water. The correlation coefficient for this analysis was 0.866. There appears to be a good linear relationship between these two variables. The following equation was a result of this regression analysis:

$$Y = 0.76(X) + 108.4 \qquad \text{(Eq. 5)}$$

Y = Total Hardness--Lagoon (mg/l as $CaCO_3$)

X = Total Hardness--Water Supply (mg/l as $CaCO_3$)

In the above relationship the variability of total hardness in the water supply accounted for 75 per cent of the variability of total hardness concentrations in the lagoon waters. Equation 5 should provide a reasonably good estimate of the total hardness based on the total hardness concentration of the respective water supply.

The scatter diagram of the data used in this analysis is plotted in Figure 3. The line resulting from Equation 5 is also plotted on the scatter diagram. It can be seen from Figure 3 that this equation represents an approximate value for the total hardness of lagoon waters. There is variance from the line plotted in this figure, but for preliminary investigations this estimate should be adequate.

Specific Conductance

It is necessary to know the specific conductance of a water in order to determine the salinity hazard of that water for irrigation. The total solids concentration of a water has been used as an indicator of the specific conductance (6-24). The South Dakota Public Water Supply Data does not give specific conductance data, but rather total solids for water supplies in South Dakota (10). This total solids concentration for water supplies has been used in a regression analysis to provide a method of estimating the specific conductance of lagoon effluents.

Those water supplies which had a very high salinity hazard were omitted from the regression analysis. Also the data from Huron and Baltic were omitted for previously discussed reasons. If the salinity hazard of the water is very high to begin with, it probably will not decrease in the lagoon. Therefore, the water supplies for the following communities with very high salinity hazard were omitted: Colman, Groton, Howard, Lennox, Parkston, Platte, Redfield, Tea, and Tyndall. The regression analysis was then performed using data from the remaining 22 sampling locations.

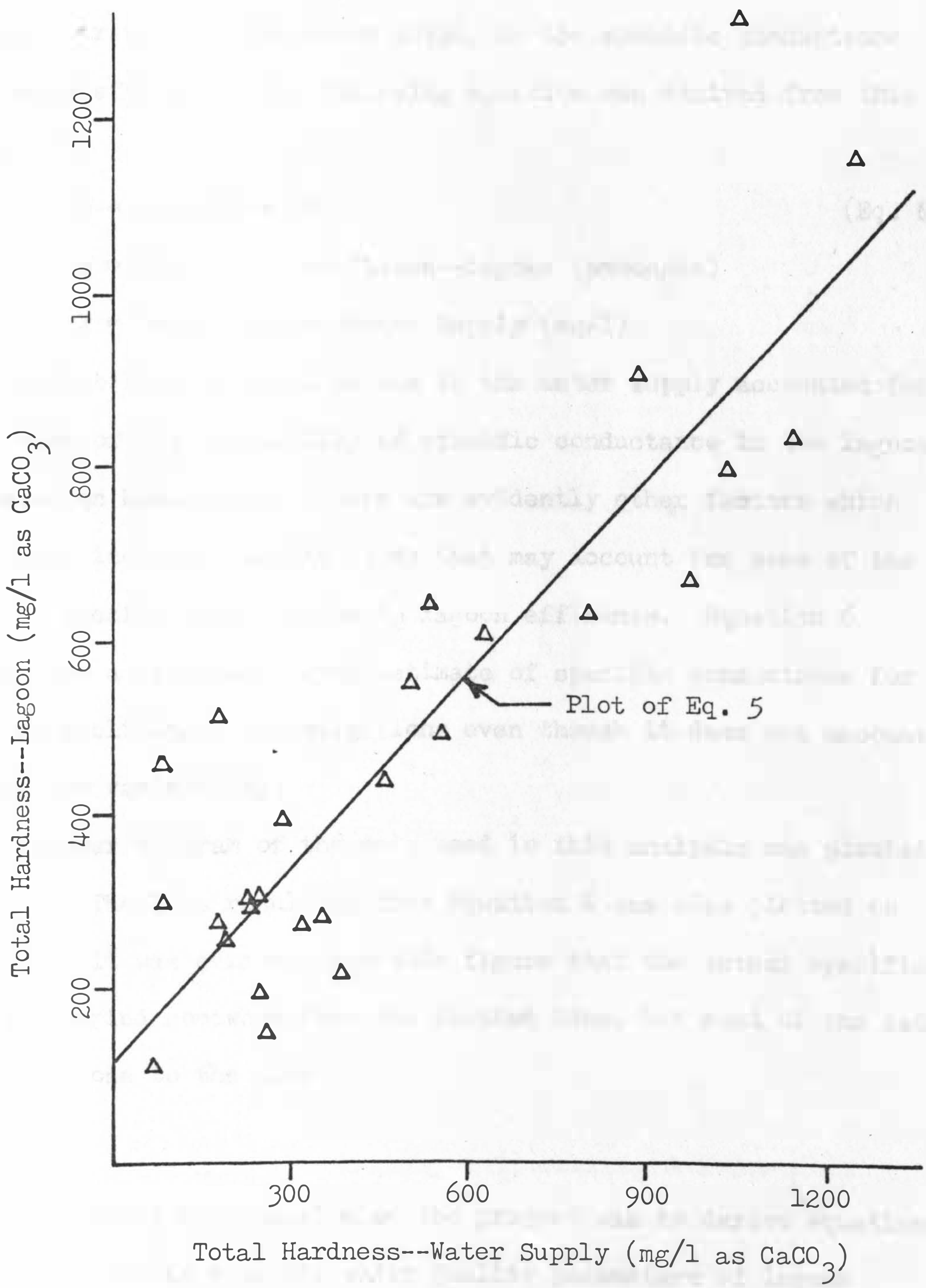

Figure 3. Scatter Diagram of Data Used to Develop Eq. 5

A linear regression analysis was performed by regressing the total solids concentration of the water supply on the specific conductance of the lagoon effluent. The following equation was derived from this analysis:

$$Y = 2.02(X) + 345 \qquad \text{(Eq. 6)}$$

Y = Specific Conductance--Lagoon (μmhos/cm)

X = Total Solids--Water Supply (mg/l)

The variability of total solids in the water supply accounted for 77.7 per cent of the variability of specific conductance in the lagoon waters based on Equation 6. There are evidently other factors which have not been isolated in this study that may account for some of the variance of specific conductance in lagoon effluents. Equation 6 should provide a reasonably good estimate of specific conductance for purposes of preliminary investigations even though it does not account for all of the variability.

The scatter diagram of the data used in this analysis was plotted in Figure 4. The line resulting from Equation 6 was also plotted on this figure. It was evident from this figure that the actual specific conductance varied somewhat from the plotted line, but most of the data fall fairly close to the line.

Summary

The purpose of this portion of the project was to derive equations that could be used to estimate water quality parameters of lagoon waters. Based on the data available, the preceding equations have been developed to fulfill this purpose. These equations may be used

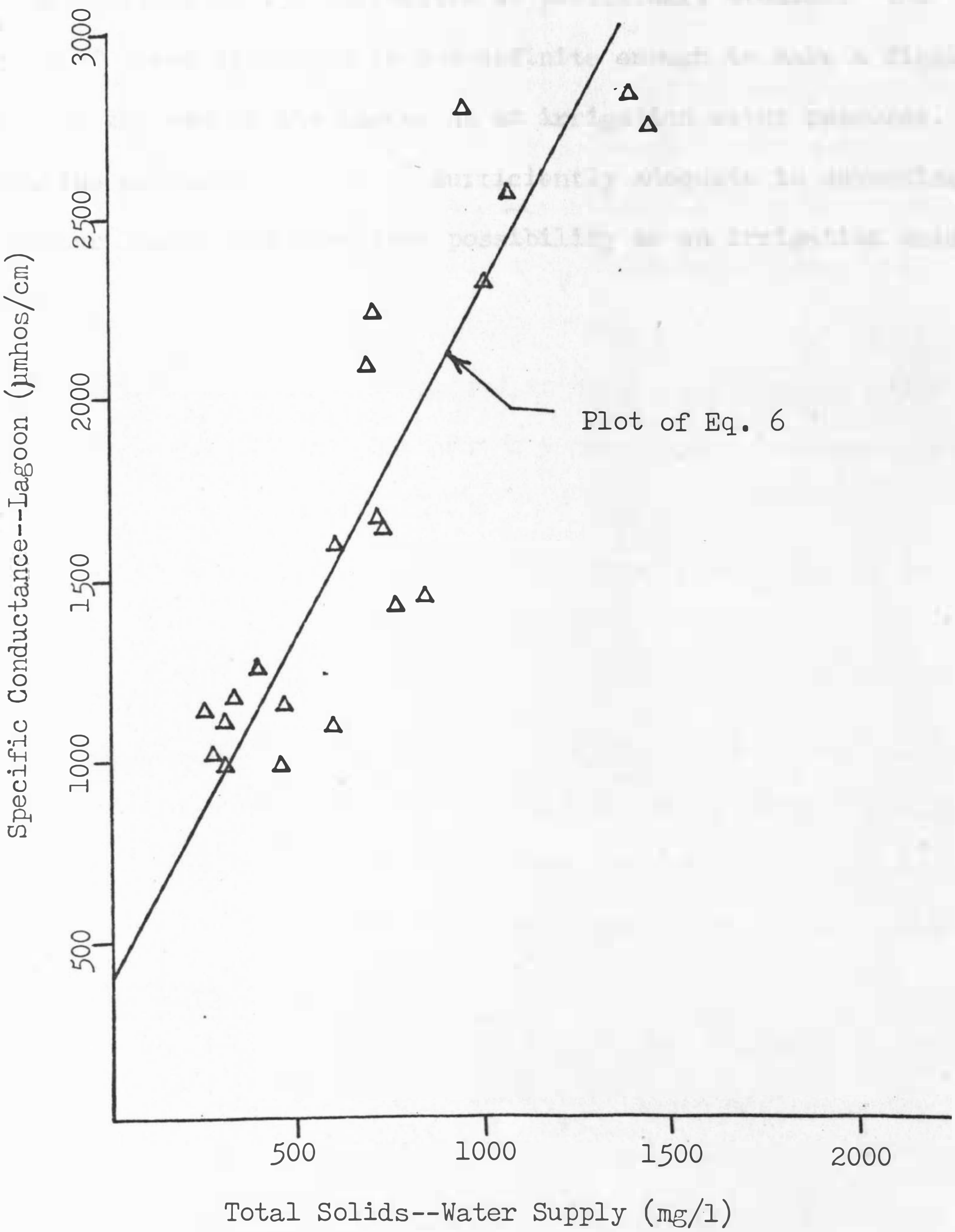

Figure 4. Scatter Diagram of Data Used to Develop Eq. 6

to estimate the quality of lagoon waters based on the water supply data. These estimates should provide a means of classifying a lagoon water as to its suitability for irrigation in preliminary studies. The precision of these equations is not definite enough to make a final decision on the use of the lagoon as an irrigation water resource. However, the estimates should be sufficiently adequate to determine if a particular lagoon may have some possibility as an irrigation water resource.

CONCLUSIONS

The objectives of this study were to evaluate and classify lagoon effluents with respect to their suitability for irrigation, and to establish a method of determining the probable water quality in lagoons on the basis of the water quality of the municipal water supply. Thirty-three lagoons in South Dakota were sampled during the peak irrigation season of July and August, 1975. The water quality of these lagoons was determined by laboratory analyses.

The lagoon waters were classified as to their suitability for irrigation based on existing irrigation water quality criteria. From this classification, it was concluded that there is a good probability of lagoon waters being suitable for irrigation. Approximately one-half of the lagoon waters sampled showed good possibilities as an irrigation water resource.

The second objective in this study was met by establishing a relationship between the lagoon water quality and the water quality of the water supply. Three equations were derived by regression analyses to estimate the sodium and total hardness concentrations, and the specific conductance of the lagoon waters based on the respective water supply data. These equations were derived for use in preliminary investigations concerning the suitability of lagoon effluents for irrigation.

RECOMMENDATIONS

The results from this study were based on the water quality of lagoons in South Dakota during July and August, 1975. Further studies over a longer period of time may increase the reliability of these results. Also, if further studies are attempted it may prove valuable to sample the water supply at the same time the lagoon water sample is collected.

There appear to be other variables which were not isolated in this study that are responsible for variation of the water quality in lagoons. It may be possible to isolate some of these variables and increase the reliability of probable water quality predictions.

Future research concerning lagoon effluent and irrigation may be considered in the areas of quantity of lagoon effluent, fertilization benefits, and in classifying soil characteristics compatible with certain water quality classifications. The classification of soil characteristics suitable to certain irrigation water quality should provide a valuable addition to this study.

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APPENDIX A

Water Quality Data
for Lagoons in South Dakota
Sampled During July and August, 1975

and

SAR and RSC Values
Calculated for These Lagoon Waters

Table A-1. Lagoon Water Quality For July and August, 1975

CITY	SODIUM (mg/l)			SPECIFIC CONDUCTANCE (μmhos/cm @ 25°C)			TOTAL HARDNESS (mg/l as $CaCO_3$)			TOTAL ALKALINITY (mg/l as $CaCO_3$)		
	July	Aug.	Ave.	July	Aug.	Ave.	July	Aug.	Ave.	July	Aug.	Ave.
Aberdeen	265	209	237	2278	1873	2076	556	372	464	246	214	231
Andover	490	335	413	3563	4222	3893	820	998	909	404	494	449
Baltic	384	332	358	2853	2221	2537	650	580	615	305	269	287
Belle Fourche	170	195	183	1129	1347	1238	252	294	274	120	169	145
Beresford	110	120	115	1420	1445	1433	498	474	486	308	309	309
Brookings	180	200	190	1773	1518	1646	462	414	438	276	212	244
Canton	280	314	297	1602	1604	1603	188	204	196	260	266	263
Colman	275	270	272	2586	2625	2605	798	794	796	320	339	330
Estelline	80	80	80	877	1033	955	240	320	280	254	312	283
Groton	680	740	710	3551	4114	3833	286	308	297	268	256	262
Howard	585	714	650	3796	4555	4176	608	614	611	194	80	137
Huron	520	490	505	3313	3242	3278	500	264	382	358	332	345
Lennox	510	500	505	3502	3282	3392	838	831	835	157	176	168
Madison	320	312	316	2792	2655	2724	640	620	630	164	175	170
Milbank	360	435	398	2635	2951	2793	574	530	552	316	184	250
Murdo	367	370	369	2196	2263	2230	388	390	389	160	146	153
New Underwood	245	315	280	1354	1513	1434	136	134	135	178	201	190
Platte	840	1100	970	5951	6808	6380	1265	1340	1303	150	124	137

Table A-1. (continued)

CITY	SODIUM (mg/l)			SPECIFIC CONDUCTANCE (μmhos/cm @ 25°C)			TOTAL HARDNESS (mg/l as $CaCO_3$)			TOTAL ALKALINITY (mg/l as $CaCO_3$)		
	July	Aug.	Ave.	July	Aug.	Ave.	July	Aug.	Ave.	July	Aug.	Ave.
Parkston	680	770	725	3894	4188	4041	652	640	646	484	472	478
Redfield	700	880	790	3894	4482	4188	222	238	230	316	344	330
Spearfish	150	120	135	1158	1082	1120	306	296	301	233	205	219
Springfield	210	209	210	1131	1085	1108	106	97	102	267	217	242
Sturgis	60	83	72	957	1038	998	264	332	302	202	169	186
Tea	650	650	650	4727	4433	4580	1187	1137	1162	220	260	240
Tripp	570	625	598	2718	2968	2843	300	276	288	566	576	571
Tyndall	332	375	349	2640	2792	2716	626	702	664	140	169	155
Volga	165	150	158	1082	1063	1073	220	187	204	296	254	275
Wall	385	453	419	1607	1799	1703	80	83	82	540	612	576
Watertown	133	98	115	1163	1173	1168	274	274	274	186	171	179
Webster	438	475	457	2620	2949	4785	514	514	514	200	208	204
Whitewood	70	83	77	916	1029	973	280	292	286	298	322	310
Winner	133	115	124	1148	1024	1086	254	240	247	333	267	300
Woonsocket	707	880	794	3999	4555	4277	514	560	537	900	1028	964

Table A-2: SAR and RSC Values Calculated for the Lagoon Effluents

CITY	SAR	RSC
Aberdeen	4.8	0
Andover	6.0	0
Baltic	6.3	0
Belle Fourche	4.8	0
Beresford	2.3	0
Brookings	4.0	0
Canton	9.2	1.3
Colman	4.2	0
Estelline	2.1	0.1
Groton	17.9	0
Howard	11.4	0
Huron	11.6	0.7
Lennox	7.6	0
Madison	4.8	0
Milbank	7.4	0
Murdo	8.1	0
New Underwood	10.5	1.1
Platte	11.7	0
Parkston	12.4	0
Redfield	22.6	2.0
Spearfish	3.4	0
Springfield	9.0	2.8

Table A-2: (continued)

CITY	SAR	RSC
Sturgis	1.8	0
Tea	8.3	0
Tripp	15.3	5.7
Tyndall	5.9	0
Volga	4.8	1.4
Wall	20.2	9.9
Watertown	3.0	0
Webster	8.8	0
Whitewood	2.0	0.5
Winner	3.4	1.1
Woonsocket	14.9	8.5

APPENDIX B

Water Quality Data
for Municipal Water Supplies
in South Dakota

Table B-1: Water Quality Data for the Municipal Water Supply (10)

CITY	SODIUM (mg/l)	TOTAL SOLIDS (mg/l)	TOT. HARDNESS (mg/l) as $CaCO_3$	SAR VALUE (calculated)
Aberdeen	136	885	341	8.5
Andover	161	1444	886	2.4
Baltic	33	1075	740	0.2
Belle Fourche	6	392	326	0.1
Beresford	18	769	562	0.3
Brookings	26	966	659	0.5
Canton	151	718	259	4.2
Colman	168	2020	1063	2.3
Estelline	34	463	358	0.8
Groton	630	2201	219	19.2
Howard	368	2033	626	6.4
Huron	97	755	392	1.9
Lennox	101	1837	1131	1.2
Madison	139	1578	834	1.8
Milbank	107	956	491	2.0
Murdo	54	560	241	2.9
New Underwood	183	851	265	10.6
Parkston	294	1600	538	5.6
Platte	321	2085	930	12.8
Redfield	676	2177	144	21.6
Spearfish	4	251	220	0.1

Table B-1: (continued)

CITY	SODIUM (mg/l)	TOTAL SOLIDS (mg/l)	TOT. HARDNESS (mg/l) as $CaCO_3$	SAR VALUE (calculated)
Springfield	119	471	82	5.7
Sturgis	5	279	228	0.2
Tea	141	2134	1225	1.7
Tripp	44	1390	78	2.2
Tyndall	88	1588	963	0.9
Volga	14	600	406	0.3
Wall	248	704	8	48.2
Watertown	14	529	363	0.4
Webster	116	1496	720	1.9
Whitewood	5	298	244	0.1
Winner	16	305	192	0.9
Woonsocket	478	1338	53	33.9