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Raw Sewage Stabilization Ponds as a Means of Sewage Treatment

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RAW SEWAGE STABILIZATION PONDS AS A MEANS

OF SEWAGE TREATMENT

By

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This thesis is approved as a creditable, independent investigation by a candidate for the degree, Master of Science, and acceptable as meeting the thesis requirements for this degree; but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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J. R. A.

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INTRODUCTION

The successful operation of sewage stabilization ponds by a number of North and South Dakota communities during the past few years has shown this method of disposal to be adequate in taking care of the needs of small communities. Stabilization ponds have been developed as a final disposal method principally because of the high cost of construction of more conventional types of sewage treatment. In many of the smaller cities the cost of final disposal facilities has been the deciding factor, whether or not the city could install a sewage system. Even the cost of primary treatment facilities, such as an Imhoff tank, in most cases has been too great for the cities to consider in conjunction with the installation of new sewerage systems. Since land is relatively cheap compared to construction work involved in the building of a sewage treatment plant, and since the actual construction cost of a stabilization pond is a comparatively small figure, this type of treatment has been readily accepted by the smaller communities. In the case of the larger communities, the cost of necessary secondary treatment of sewage, which includes not only the initial cost but costs of operation and maintenance, has often been prohibitive and the use of stabilization ponds has again appeared to be the answer from an economic standpoint.

Nature of the Project

The literature contains many references concerning the use of such stabilization ponds as secondary treatment devices, particularly in Oklahoma, Texas and California. In the Dakotas, stabilization ponds have been used successfully for complete sewage treatment, but very little had been published as the Dakota development has evolved since 1950.

Research in the Dakotas, up to the time of this study, has been limited to brief observations, including laboratory studies of short duration, by the State Departments of Health of North Dakota and South Dakota. The units that were being installed had practically been designed by the rule of thumb. Some biological work had been performed on the various stabilization ponds throughout the Dakotas, but nothing had been done concerning the engineering data that is necessary for an economic design of a stabilization pond.

The State Health Departments of North Dakota and South Dakota requested a cooperative research project with the U.S. Public Health Service and upon realization of the study, invited South Dakota State College to participate in the research. At that time the author started on the project through South Dakota State College's Engineering Science and Research.

The first planning conference for this project was held in Pierre, South Dakota, on October 25, 1954. The project began with a conference at Bismarck, North Dakota, with the U.S. Public Health Service and the North and South Dakota Health Departments along with other interested parties. During the first two weeks, engineering data was gathered at 40 stabilization ponds throughout the two state area. After the necessary engineering information had been gathered by visits to the various stabilization pond installations and talking with the city officials that were concerned with the stabilization ponds, the U.S. Public Health Service compiled the data in cooperation with the two states and selected three stabilization ponds in South Dakota and two ponds in North Dakota for biological investigation with biologists and engineers of the coop-

erating states and South Dakota State College.

Scope of Data

Because stabilization ponds are primarily successful due to solar radiation and vary according to climatic seasons, the concentrated study was for a three-day period during each of the four seasons in 1955. The first field study was begun in January, 1955, at which time all stabilization ponds were heavily covered with ice. The other three seasonal studies were carried out in the spring, shortly after the transition from ice cover to open water, but before hot summer weather, during the summer, and during the fall just before freeze up.

The five installations listed below were selected for study on the basis of variation of design, loading, depth, area, type of inlet and outlet structures, and other considerations and characteristics. (Appendix I)

Kadoka, South Dakota: Irregular in shape and depth, this installation had been subject to some complaints of odor by nearby residents. Population served: 550-850; Area: 3.0 acres (at the time of the survey); Average loading: 22.9 pounds of biochemical oxygen demand (BOD) per acre per day.

Wall, South Dakota; The most shallow of all Dakota installations. Population served: 556-1000; Area: 8.9 acres: Average loading: 7.0 pounds biochemical oxygen demand (BOD) per acre per day.

Lemmon, South Dakota: The deepest of all Dakota installations, served the largest population at the time this study was initiated. Population served: 2760; Area: 27.1 acres; Average loading: 6.8 pounds of biochemical oxygen demand (BOD) per acre per day.

Maddock, North Dakota: The only pond with three cells in series. Population served: 741; Area: 11.7 acres (First pond); Average loading: 9.4 pounds of biochemical oxygen demand (BOD) per acre per day.

Wishek, North Dakota: Regular in shape and depth, and completely enclosed by dikes. Population served: 1241; Area: 7.8 acres; Average loading: 13.0 pounds of biochemical oxygen demand (BOD) per acre per day.

Plan views of each of the five stabilization ponds are shown in Figure I. Inlets, outlets, shape, and relative sizes are illustrated.

Three types of observations were made throughout the investigation and all conforming to the 10th Edition of Standard Methods for the Examination of Water and Sewage published by the American Public Health Association. The types of investigations made were:

1. Physical: Raw sewage and stabilization pond effluent flows, wind velocity and directions, air and pond temperatures, light intensity, structural features, and volume of pond contents.

2. Biological: Plankton and bottom organisms (kinds and quantity), coliform bacteria (MPN), and special tests.

3. Chemical: Dissolved oxygen; biochemical oxygen demands (BOD); pH; alkalinity; nitrogen: total organic, ammonia, nitrite and nitrate; phosphate: total and ortho; sulfides; chlorides; turbidity; and suspended solids.

The pH, dissolved oxygen and alkalinity chemical tests are directly related to algal activity. These analyses fluctuate in proportion to the degree of photosynthesis occurring at the time the sample was collected.

The biochemical oxygen demand is the standard yardstick for

measuring stabilization efficiency.

Oxidation or reduction will occur by bacterial action if the environment is aerobic or anaerobic respectively. Status of nitrogen balance will indicate degree to which either is occurring.

Soluble ortho phosphate is an essential nutrient for algae, and is rapidly consumed to become part of the plant cells. Total phosphate should be relatively unaffected.

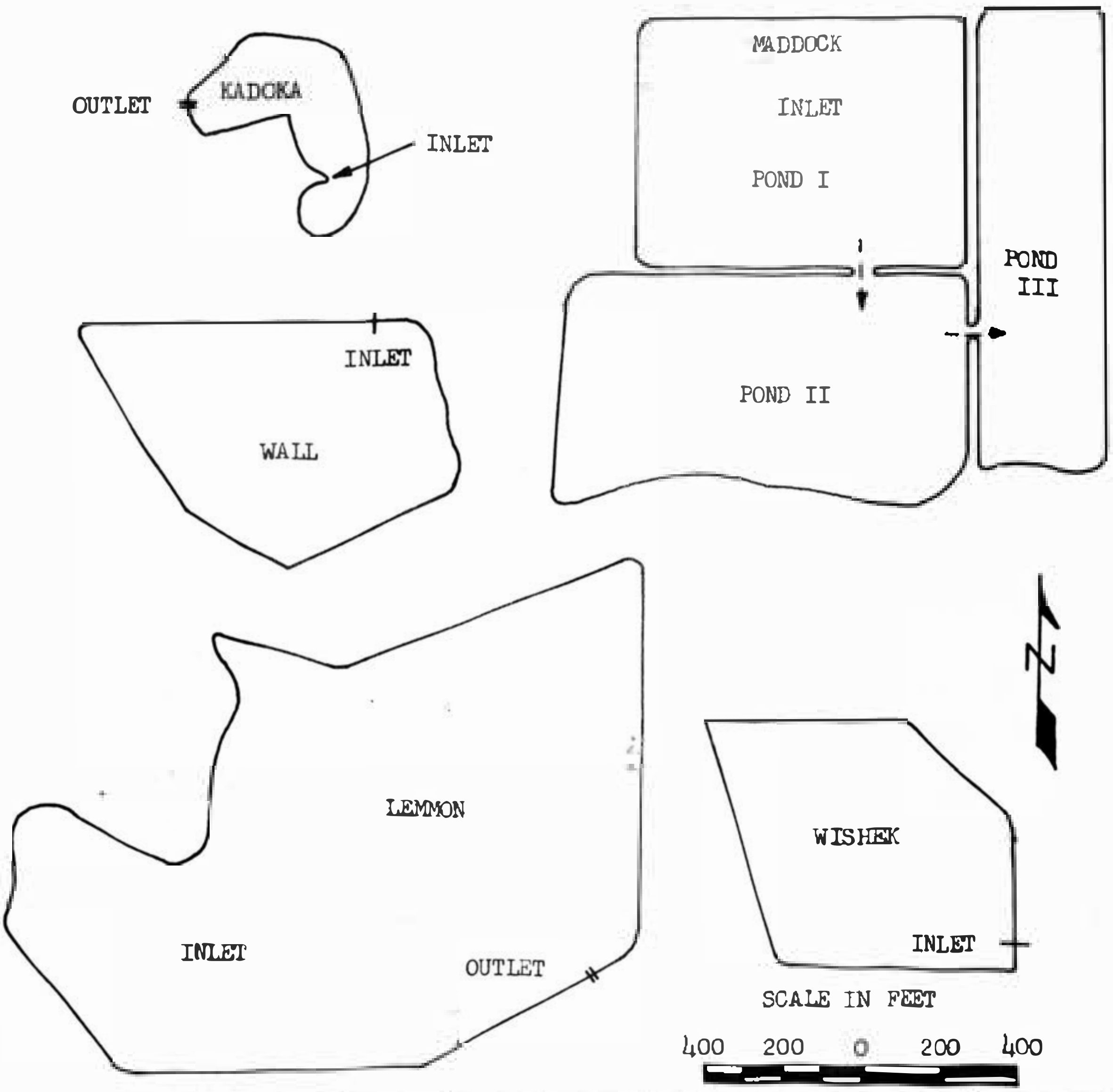
The sulfides indicate the degree of septicity and the potential for odor production.

The chloride concentration is not normally affected by natural chemical or biological action. However, it is increased by evaporation and removed only by seepage or effluent discharge.

Turbidity and suspended solids are grouped together to relate relative particle size and weight, and restriction of light penetration.

Coliform bacteria is a measure of bactericidal efficiency.

There were 4000 chemical laboratory determinations made during the course of this study. Questionnaires for 53 sewage stabilization pond installations were filled out. Some 3200 observations were made of weather, climate, temperature, etc. at the pond sites. The author has no record of the numerous biological determinations and light intensity readings that were taken. A total of 20 persons worked on the study at various times. The author was one of the four men who participated on every seasonal survey plus the additional studies made.



LOCATION	KADOKA, S.D.	WALL, S.D.	LEMMON, S.D.	MADDOCK, N. D.			WISHEK, N.D.
				POND 1	POND 2	POND 3	
Surface Area (acres)	3.0	8.9	27.1	11.7	12.3	8.0	7.8
Depth, Max. (feet)	7.7	2.2	14.0	5.0	3.6	5.7	3.8
Depth, Ave. (feet)	4.4	1.2	5.7	4.0	2.8	4.4	3.0

Figure I

Physical Dimensions of
Five Selected Stabilization Ponds

REVIEW OF LITERATURE

History of Sewage Treatment

Our earliest knowledge of man's attempt to control his actions and those of his fellow men by moral and legal codes is to be found in the Mosaic law. In that part of the law that might properly be called the first sanitary code are found basic instructions for the disposal of human wastes.[1] These rules were satisfactory for the simple life of that early civilization, and at the present time the fundamental principle stated in those rules -- that health could be safeguarded only by the disposal of human wastes in such a manner as to prevent infection by contact -- is still a good public health doctrine.

As civilization advanced, towns and cities were formed, with the congestion of population occurring, contacts increased and consequently, the occurrence of communicable diseases. History records the terrible lack of sanitation and the resulting endemic plagues. History need not repeat itself if the more complete rules of sanitation that the modern sanitary sciences have made available are recognized and applied in our present and future civilization.

Civilization, as we know it today, is outstanding in the history of the world because of the great emphasis that is given to the problems of public health. Few among the nations of the world give to sanitation the emphasis that it receives in these United States. Because of this interest, we realize that it is of prime importance to remove all sewage wastes from a city to a safe place for treatment and final disposal.

1. Deuteronomy 23: 10-13

In 1906, these same thoughts were profoundly expressed as follows: "The disposal of waste is a fundamental problem for all living organisms, and the attempt at scientific waste disposal is comparatively recent. The Cloaca Maxima and other so-called sewers of antiguity were drains rather than sewers, and their function was to lower the ground water level and not primarily to remove excretal wastes."[2]

Until 1815, the discharge of any waste but kitchen slops into the drains of London was prohibited by law, and the same regulations persisted in Paris up to 1880. Sewerage and sewage disposal proper really date from the epoch-making report of the Health of Towns Commission of Great Britain in 1844, which revealed the accumulation of an astonishing amount of decomposing organic matter and filth of all kinds in the cities. Only three years after the report of the Health of Towns Commission, it was made obligatory to discharge all sewage into these drains.[3]

In other countries the example set in England was more or less promptly followed. In the United States, numerous drainage systems existed, one in Boston, for example, dating from the seventeenth century; but the first comprehensive sewerage project was designed by E. S. Chesbrough from the City of Chicago in 1855. On the continent of Europe a sewer system was constructed at Hamburg after the great fire of 1842, by Lindley, an English engineer. Berlin installed sewerage in 1860 and other German systems quickly followed. No law of sanitation is now more clearly recognized than the principle that the wastes of human life

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2. C. E. A. Winslow and Earle B. Phelps, "Water-Supply and Irrigation Paper Number 185," House Documents, LXIII (1906), 9-13

3. Ibid

must be diluted with an adequate supply of water and quickly removed from the region of habitation.[4]

With the establishment of the water-carriage system, the difficulty was shifted from the individual to the community. The insanitary conditions surrounding the dwelling were relieved, but at some point on the outskirts of the city the concentrated filth from its entire population must be disposed of.[5]

This great need for the removal of sewage wastes from a city frequently made it necessary to appropriate the use of rivers and lakes into which the wastes drained from the sewerage system of that city might be discharged. As long as those receiving waters were isolated and were not being used by others it was presumed that the wastes could be disposed of in that manner without danger. The safety of this method was dependent on the isolation of the place of disposal. The discharge of untreated sewage can be tolerated as long as it serves the sanitary needs of the city and at the same time does not create a health hazard elsewhere. Unfortunately, few cities are so situated that they can have for their use a body of water for sewage disposal by dilution, without creating a condition adverse to the interests of others.[6]

Reasons for Sewage Treatment

In the past fifty years methods for sewage disposal have received a great deal of study and during this time marked progress has been shown, especially in the line of sewage treatment devices.

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4. Ibid
5. Ibid
6. Ibid

First, perhaps we should try to define the main purpose of the sewage treatment processes before discussing any methods by which the desired results are to be obtained.

The effluent from a properly operating sewage treatment device might be defined as one which may be discharged without cause for further concern on the part of those responsible for its production. An effluent of this nature would be the result of treatment adequate to remove the objectionable properties of the sewage to a degree sufficient to permit its discharge into the receiving body of water. That is without causing such receiving water to become more dangerous to the public health or to lose value or usefulness to the general public or to those whose riparian claims entitle them to special privileges. However, in case there is not dilution of the effluent by a receiving body of water, the sewage as discharged upon the surface of the ground must be in such condition as to prevent any cause for health or nuisance complaint. Logically it follows that the requirements for a good effluent vary widely with the local situation. Climate, topography, concentration of population, stream usage and many other factors are involved in determining just how far it is necessary to carry the purification process in a treatment device. For example, where dilution may be available in a receiving body of water, local conditions may permit its use in the destruction of at least a portion of the objectionable properties of the sewage.

If sewage is treated uniformly to such a degree that the final effluent creates no problem or handicap to other uses of the receiving waters; first, from a standpoint of an objectionable demand for further oxygen; second, from a standpoint of a dangerous bacterial content; and

third, from the standpoint of inert chemical compounds that have characteristics that make their presence in water a limiting factor in the use of such water; then it would seem that the essential requirements of a good effluent from good treatment have been met. The effluent from stabilization ponds do meet these above requirements. Later, data from actual operation of stabilization ponds will attempt to prove this point.

Theory of Treatment Action

The purpose of any treatment of sewage is to change its characteristics so that when the final effluent is disposed of no nuisance or menace to health is caused. All present day treatment devices accomplish this by bacterial action; however, since anaerobic bacterial action proceeds without oxygen, hydrogen sulfide and other foul smelling gases are released. Therefore, it is necessary to provide oxygen to prevent any nuisance condition from odors.

Many of the sewage treatment methods prevent such nuisance conditions from arising by bringing large quantities of air into contact with the sewage during treatment. However, this induced air requires very expensive equipment such as pumps, filters, tanks and other mechanical equipment.

In the stabilization pond a different process of obtaining oxygen is utilized. Low forms of plant life called algae which contain chlorophyll, have the characteristic of releasing oxygen when they digest their food. This food consists of many dfferent things but the two basic ones in which we are interested are nitrates and carbon dioxide. Aerobic bacteria, utilizing the oxygen the algae produce, oxidize the

sewage organic matter, thereby making carbon dioxide, ammonia, and other growth essentials available to the algae. In addition to the carbon and nitrogen supply from the bacteria, the algae require energy in the form of visible light. The radiant energy from the sun is the principle source of this required light.[7] This is a very simple statement as to the method by which the process works. (See Figure II for a diagram of this statement.)

Dr. Imhoff, in his early writings on pond type treatment for sewage, stated in 1931:

> The increase in oxygen concentration, which is the best index of the progressive self-purification of streams during the time of flow, shows that the natural purification is augmented as the time of flow is lengthened. If therefore, the river waters are impounded and the time of flow thereby increases, it is possible to attain the same effect in a shorter river stretch. Thus an impounding reservoir, or artificial lake, acts in a similar manner to a sewage-treatment plant in maintaining the cleanliness of a stream. The treatment plant reduces the pollutional load in the stream by reducing the oxygen demand of the waste waters, or the deoxygenation of the stream. The impounding reservoir acts in an opposite manner by increasing the reoxygenation or reaeration of the waters.[8]

Imhoff goes on to state that there are two prerequisites to the construction of impounding reservoirs as a substitute for sewage treatment plants. First, the sewage should be free from sludge forming solids as far as possible in sedimentation tanks. If this is not done, sludge will accumulate on the bottom of the pond and putrefy in summer.[9] Present day results from actual stabilization ponds receiving raw sewage discharges show that the best efficiency of ponds is during the summer

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7. W. J. Oswald, H. B. Gotaas, H. F. Ludwig, and V. Lynch, "Photosynthetic Oxygenation," Sewage and Industrial Wastes XXV, No. 6 (1953), 692.

8. Karl Imhoff, "Impounding Reservoirs as a Substitute for Biological Sewage Treatment Works in the Ruhr District," Sewage Works Journal, III No. 1 (January 1931), 120-124.

9. Ibid.

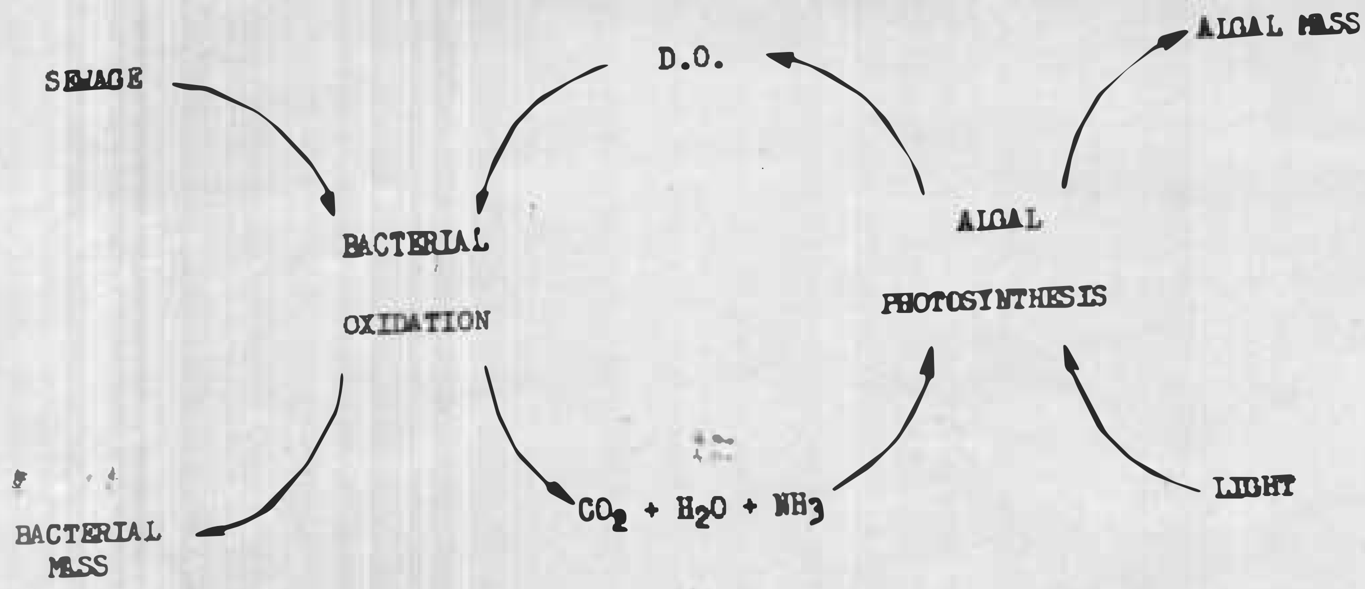

Figure II

Mechanism of Stabilization

months. Imhoff also thought that ponds could well replace biological treatment, but not sedimentation. His statements were again disproved with the utilization of ponds receiving raw sewage discharge.

Imhoff's second point was that the river must carry adequate amounts of water during the winter because during cold weather natural self-purification is greatly reduced as in the German reservoirs. This point has also been shown to be misleading because good efficiencies of BOD reduction are being obtained in the Dakotas during winter months.

Early History and Development of Stabilization Ponds.

The first stabilization ponds were almost simultaneously constructed in the States of California, North Dakota and Texas. Reportedly the first unit was at Santa Rosa, California, in 1924.[10] The first pond of which this author found written record was that reported and described in 1928 and 1929 by C. G. Gillespie, Chief of the Bureau of Sanitary Engineering for the State of California. Gillespie is quoted as follows:

> In the past two or three years a couple of cities have systematically developed ponds for oxidizing septic tank effluent. With ponds about two feet deep, and some care in proportioning the amount of incoming sewage to the size of the pond so that a green or brown growth is maintained, oxidation proceeds forthwith and within eight days a stability equal to that of an average sprinkling filter is obtained throughout the year. B Coli removals are fully as high as by a sprinkling filter and in fact after about sixteen days storage, a B Coli count as low as 10 to 25 per cc is frequently obtained. In clarification the effluent is not quite as good as that of a sprinkling filter. The investment cost is exceedingly low but operating costs to keep down weeds and occasional mosquito control probably results in a maintenance expense equal to that of a sprinkling filter.[11]

10. D. H. Caldwell, "Sewage Oxidation Ponds -- Performance, Operation and Design," Sewage Works Journal, XVIII, No. 3 (May 1946), 443

11. C. G. Gillespie, "The Sewage Situation in California," Sewage Works Journal, I No. 4 (July, 1929), 460-75

Gillespie first reported on the two towns in 1928, and a portion of his report on Vacaville, California, which is of interest here is as follows:

> Town Engineer suggested that it might be possible to pass settled sewage over the local sewage farm in such a manner that it could be stored in ponds without nuisance during the dry months. Following his suggestion the septic tank effluent was run into a header ditch, into the banks of which were inserted a number of pipe ports at intervals of 15 to 20 feet. The clarified sewage was released through these ports in a thin sheet which flowed through a thick growth of grass down a slope of about one foot per 100 feet.[12]

The flow was 125,000 gallons per day. The area of the farm was eight acres and the pond held 3.5 million gallons. In the eight months dry period, when sewage was held back, some thirty million gallons of sewage was discharged but not more than three million gallons ever accumulated in the ponds. Because the soil was of gumbo or adobe they considered it quite unfavorable and doubted if much of the sewage soaked into the ground. Most of the sewage was undoubtedly lost by evaporation and by the heavy growth of grass. No nuisances were caused in the ponds during the summer operation. According to Caldwell this pond was also built in 1924; however, the state granted permission only after the observations of the ponds at Santa Rosa. The ponds at Vacaville were built in order to prevent injury to private property by the septic tank effluent.[13]

According to Svore and Van Heuvelen of the North Dakota State Department of Health, the first installation put into operation in that

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12. C. G. Gillespie, "Simple Application of Fundamental Principles of Sewage Treatment," Sewage Works Journal, I No. 1 (October, 1928) 68-70.

13. Caldwell, Loc. cit.

state was at Fessenden in 1928. This installation was not a true stabilization pond, but many of the features of modern ponds were present. A pothole was dammed off and the municipal sewage discharged along the berm directly into the pothole area. This installation worked successfully for more than 20 years and is still in operation.[14] At the time this writer saw the pond it was filled with cattails and of a very shallow depth.

Schroepfer in writing a section concerned with a historical review of biological methods of removal, pointed out that Abilene, Texas, constructed a pond sometimes during the 1920's. Later in his review: "At Lund, Sweden, where climatological conditions are reportedly very similar to those in Madison, Wisconsin, a pond has been used since 1934 to dispose of settled sewages. Lund is a community of approximately 32,000 inhabitants."[15]

The Ruhr District of Germany planned construction of eight artificial lakes as units for secondary sewage treatment and during the middle of 1931, Dr. Imhoff wrote that two of the eight such lakes were completed. Hengsteysee, a lake about 0.6 square miles in area was completed in 1927, and Harkortsee, about 0.5 square miles was finished in 1931.[16]

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14. W. Van Heuvelen and J. H. Svore, "Sewage Lagoons in North Dakota," Sewage and Industrial Wastes Journal, XXVI, No. 6 (June, 1954), 771

15. G. J. Schroepfer, and others, "The Madison Lakes Problem" Part II, Report for Oscar Mayer and Company, (September 15, 1955)

16. Karl Imhoff, "The Ruhrverband," Sewage Works Journal, III No. 3 (May 1931), 517-18.

Ponds in series have been used in Europe to treat settled and screened sewage without dilution. In Moscow, Russia, a series of six fish ponds averaging two to two and a half feet in depth treated 13,100 gallons of sewage per acre per day. The effluent of the last pond could be safely discharged into a stream, and the last three ponds supported fish life. Fish production which was quite general in European ponds was reported to be over 300 pounds per acre.[17] In fact, stabilization ponds as we know them were called "fish ponds" in Europe, and anyone reviewing the literature should keep this in mind.

In commenting on the advantages of ponds Svore and Van Heuvelen state:

> The sewage lagoon fills all the requirements for a satisfactory sewage disposal system. The sewage is carried out of the city limits and disposed of in such a manner that nuisance conditions do not develop. It also disposes of the sewage so that it neither pollutes surface or underground waters nor creates a health hazard or nuisance condition at the lagoon site. Water from a sewage lagoon can be discharged into a flowing stream because it has been satisfactorily stabilized and the pollution load of the raw sewage has been greatly reduced. However, a majority of the lagoons now operating in North Dakota have been built to provide adequate capacity to hold the entire flow of sewage in the lagoons and provide for no discharge to any watercourse.[18]

Present Status of Stabilization Ponds

Table I indicated acceptance by the different states of the mid-west. The table from French is probably complete and accurate only up to early 1955, because it is realized that many more ponds exist both in the Dakotas and Wisconsin than is indicated.

In the formulation of standards for the location, design, and

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17. E. W. Steel, Water Supply and Sewerage, Second Edition, p. 491

18. Van Heuvelen, and Svore, op. cit. p. 776

construction of stabilization ponds for the State of South Dakota, Carl, Director of the Division of Sanitary Engineering of the State Health Department, prefaced the standards with the following remarks.

"The use of stabilization ponds as a method of sewage treatment has progressed to the point that there is little controversy as to the application of this process for sewage treatment. By 1953, the method had received enough acceptance in South Dakota to warrant the formulation and issuance of minimum standards in December of that year."[19]

At the present time South Dakota has fifty-four overflowing type ponds and only two ponds of the non-overflowing type. The latter two ponds are located in the western half of the state which has low rainfalls and high evaporation rates.

Table II shows the stabilization pond installations in South Dakota. Also is indicated: the population served, the size of each installation, the number of cells, the type of overflow, the type and location of the inlet, and the kind of sewage that the ponds receive.

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19. Suggested Minimum Standards for Sewage Stabilization Ponds, November, 1955. p-1.

Table I

STATUS OF SEWAGE TREATMENT BY LAGOONS IN MIDWESTERN STATES[20]

STATE	Number in Operation	Number Approved	Results
Arkansas	0	0	-------------
Colorado	6	7	mostly good
Illinois*	3	4	good
Indiana	0	0	-------------
Iowa	0	0	-------------
Kansas	16	---	good
Kentucky	0	0	-------------
Michigan	0	0	-------------
Minnesota*	0	2	-------------
Missouri*	0	5	-------------
Montana*	12	2	Excellent
Nebraska*	6	---	good
North Dakota*	31	36	Excellent
Ohio	0	0	-------------
Oklahoma	19	---	good
South Dakota*	11	several	good
Texas	100+	100+	good
Wisconsin	0	2	-------------
Wyoming*	3	2	good

*States in which construction of raw sewage lagoons has been approved.

20. D. E. French, "Municipal Sewage Lagoons in the Midwest," Water and Sewage Works, CII, No. 13, (December, 1955), 539

TABLE II[21]
STABILIZATION PONDS IN SOUTH DAKOTA

LOCATION	POPULATION 1950 CENSUS	TOTAL AREA ACRES	NUMBER OF CELLS	KIND OF SEWAGE	INLET TYPE / LOCATION	OUTLET TYPE
Beresford	1,686	16.5	2	Raw	Gravity / Center	Overflow
Bison	457	3.0	1	Raw	Gravity / Side	Overflow
Bonesteel	485	5.4	1	Raw	Gravity / Center	Overflow
Bowdle	781	8.6	1	Raw	Gravity / Center	Overflow
Burke	829	8.2	2	Imhoff Effluent	Gravity / Center	Non Overflow
Canton	2,530	30.0	2	Raw	Pumped / Center	Overflow
Castlewood	497	16.0	2	Raw	Gravity / Center	Overflow
Chancellor	193	2.0	1	Raw	Gravity / Center	Overflow
Clear Lake	1,105	12.0	1	Raw	Gravity / Center	Overflow

TABLE II (CONTINUED)

LOCATION	POPULATION 1950 CENSUS	TOTAL AREA ACRES	NUMBER OF CELLS	KIND OF SEWAGE	INLET TYPE LOCATION	OUTLET TYPE
Colton	521	6.2	1	Raw	Pumped Center	Overflow
Eagle Butte	375	8.4	1	Raw	Gravity Center	Overflow
Edgemont	1,151	20.4	1	Raw	Gravity Center	Overflow
Elk Point	1,366	15.5	1	Raw	Gravity Center	Overflow
Freeman	940	10.0	1	Raw	Gravity Center	Overflow
Gettysburg	1,555	20.0	2	Raw	Gravity Center	Overflow
Groton	1,084	14.6	1	Raw	Gravity Center	Overflow
Hayti	413	5.0	2	Raw	Gravity Center	Overflow
Howard	1,246	15.0	2	Raw	Gravity Center	Overflow
Humbolt	450	12.3	1	Raw	Gravity Center	Overflow

TABLE II (CONTINUED)

LOCATION	POPULATION 1950 CENSUS	TOTAL AREA ACRES	NUMBER OF CELLS	KIND OF SEWAGE	INLET TYPE LOCATION	OUTLET TYPE
Isabel	511	2.7	1	Raw	Gravity Center	Overflow
Kadoka	584	8.2	2	Raw	Gravity Center-Side	Overflow
Langford	456	5.3	1	Raw	Pumped Center	Overflow
Lemmon	2,760	27.1	1	Raw	Gravity Center	Overflow
Mission	383	4.1	2	Raw	Gravity Center	Overflow
Murdo	739	9.3	1	Raw	Gravity Center	Overflow
New Effington	367	3.7	2	Raw	Pumped Center	Overflow
Onida	816	11.5	1	Raw	Gravity Center	Overflow
Orient	205	2.0	1	Raw	Gravity Center	Overflow
Parkston	1,354	15.5	1	Raw	Gravity Center	Overflow

TABLE II (CONTINUED)

LOCATION	POPULATION 1950 CENSUS	TOTAL AREA ACRES	NUMBER OF CELLS	KIND OF SEWAGE	INLET TYPE LOCATION	OUTLET TYPE
Philip	810	5.7	2	Raw	Pumped Center	Overflow
Pollock	400	4.6	2	Raw	Gravity Center	Overflow
Redfield	2,655	30.2	1	Raw	Pumped Center	Overflow
Selby	700	10.0	2	Raw	Gravity Center	Overflow
Sisseton	2,871	27.0	2	Raw	Gravity Center	Overflow
Springfield	800	18.8	2	Raw	Gravity Center	Overflow
Tabor	373	4.9	1	Raw	Pumped Center	Overflow
Valley Springs	389	5.8	2	Raw	Gravity Center	Overflow
Veblen	476	2.5	2	Imhoff Effluent	Pumped Center	Overflow
Wagner	1,528	21.0	1	Raw	Gravity Center	Overflow

TABLE II (CONTINUED)

LOCATION	POPULATION 1950 CENSUS	TOTAL AREA ACRES	NUMBER OF CELLS	KIND OF SEWAGE	INLET TYPE LOCATION	OUTLET TYPE
Wall	556	8.9	1	Raw	Gravity Side	Non Overflow
White River	465	5.0	1	Raw	Gravity Center	Overflow
Whitewood	304	4.2	1	Raw	Gravity Center	Overflow
Wilmot	583	7.5	1	Raw	Gravity Center	Overflow
Federal Installations						
Badlands National Monument		2.0	2	Raw	Gravity Center	Overflow
Cherry Creek Indian School		0.34	2	Septic Tank Effluent	Gravity Side	Overflow
Gettysburg Radar Station	175	1.35	2	Raw	Gravity Center	Overflow
Kyle Indian School	195	1.0	2	Raw	Gravity Center	Overflow
Oahe Administration	100	0.88	2	Raw	Gravity Center	Overflow

TABLE II (CONTINUED)

LOCATION	POPULATION 1950 CENSUS	TOTAL AREA ACRES	NUMBER OF CELLS	KIND OF SEWAGE	INLET TYPE LOCATION	OUTLET TYPE
Pierre Indian School	450	5.1	1	Raw	Gravity Center	Overflow
Red Scaffold Indian School	25-50	0.30	2	Raw	Gravity Center	Overflow
Rosebud Boarding School	100-200	0.8	4	Septic Tank Effluent	Gravity Center	Overflow
White Horse Indian School		0.36	2	Septic Tank Effluent	Gravity Center	Overflow
Industrial Installations						
Greenlee Packing Company		2.5	1	Imhoff Effluent	Gravity Center	Overflow
Private Installations						
Bethesda Home (Beresford)	150	1.8	1	Raw	Gravity Center	Overflow
Wasta	140	0.5	1	Septic Tank Effluent	Gravity Center	Overflow
Weaver	50	0.5	1	Raw	Gravity Center	Overflow

21 South Dakota State Department of Health files.

Applications Other Than For Municipal Sewage.

Various installations in the Midwest have utilized sewage stabilization ponds for the biological treatment of wastes from typical local types of industry. Mainly the two types of industry that have utilized stabilization ponds for treatment are the Dairy Industry and the Meat Packing Industry.

From June 1955 to June 1956 the Minnesota State Department of Health conducted surveys at Albany, Minnesota, to determine the type and degree of treatment that was being obtained in the first sewage stabilization pond constructed in Minnesota. Conditional permit for construction was granted by the Minnesota Water Pollutional Control Commission in April of 1954. The provisions mainly called for the village to assume all responsibility in the operation and if the system did not operate effectively upon trial, they were to construct a conventional type of sewage treatment plant to effectively treat the wastes.[22]

Albany's main disposal problem was the huge quantity of milk wastes that were being contributed by two dairy processing plants in the village. Essentially it was a large milk and whey drying plant.[23]

The total pounds of 5-day biochemical oxygen demand (BOD) and sewage solids for the period of the two raw sewage sampling surveys is shown in the following table:

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22. Report on Investigation of Operation of Raw Sewage Stabilization Ponds at Albany, Minnesota, June 16, 1955 to June 1, 1956, p 2

23. Ibid p 3

TABLE III[24]

5-DAY B.O.D. AND SUSPENDED SOLIDS, ALBANY MINNESOTA

	February 2 - 3	June 20 - 21
Flow - Gallons per 24 hours	172,000	197,000
5-Day BOD - Pounds	790	805
Population equivalents	4,740	4,830
Suspended Solids - Pounds	315	394

The average 5-day BOD of the samples of sewage from the primary pond during the June 20, 1956, survey was less than 5 per cent of the average BOD of the raw sewage sample, while during the February 2 survey, the average BOD of the primary pond samples was about 27 per cent of the BOD of the raw sewage sample. As in the other determinations, there was only a slight variation in BOD of samples taken at the various stations in the ponds. The average BOD of samples taken in the secondary pond during each of these surveys was about half the average BOD of samples from the primary pond. The average BOD of samples from the primary pond on June 20, 1956, was 22.5 parts per million and from the secondary pond, 11 parts per million. "These figures demonstrate the remarkable reduction in BOD accomplished by the ponds during periods of no ice cover when the plankton organisms thrive and produce the necessary oxygen for stabilization of the waste."[25]

Other uses of stabilization ponds are for the U & I Sugar Beet factory in Belle Fourche, South Dakota; The Greenlee Meat Packing Company in Sioux Falls, South Dakota; and the Homestake Mining Company

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24. Ibid p 7

25. Ibid p 9

in Lead, South Dakota, who use ponds for trail wastes. All of these installations have been observed by the author and some seem to be doing phenomenal work; especially the Greenlee pond in Sioux Falls which is greatly overloaded in respect to the standards that have been established by the South Dakota State Department of Health. At present the Greenlee pond is being observed and some laboratory determinations are being made.

ANALYSIS OF TREATMENT OBTAINED

On the Dakota Sewage Stabilization Pond study the treatment obtained has been evaluated on the basis of changes in coliform density, BOD reductions, and suspended solid reductions.

Reduction of Bacteria

Reductions in coliform density, the most probable number (MPN), were 90 per cent during more than fifty per cent of the time, and except for one sampling period at two installations, were 95 per cent or greater at all times. These per cent reduction values are based upon the geometric mean of all MPN values of the stabilization pond influent. Also, in installations at Wall, Maddock and Wishek, where there is no overflow, reductions were calculated on all stabilization pond samples collected more than 50 feet from the inlet structure.

Certain algae have been reported to produce anti-bacterial substances,[26] and the reductions in coliform densities accomplished by ponding may be due in part to such substances; however, the detention time alone, as observed in this study, should be sufficient to account for the reductions stated. It was also noted that reductions at different seasons were not appreciably different. Table IV shows the reductions for all seasons at the five installations studied.

Biochemical Oxygen Demand (BOD) Reductions

In spite of differences in loading, shape, depth, area, and

26. E. A. Birge, and C. Juday, "Solar Radiation and Inland Lakes," Transactions Wisconsin Academy of Science, XXIV (1929), 23

TABLE IV

SEASONAL PER CENT REDUCTION OF COLIFORMS (MPN)

(MPN/100 ml. (x 1000)

Season		Kadoka	Wall	Lemmon	Maddock**	Wishek
WINTER	Raw	23700	13420	19000	32000	60300
	Effluent (max.)*	24	2200	46	1330	3380
	(min.)	1	420	20	580	1430
	(min.)	23676	11220	18954	30670	56920
	(max.)	23699	13000	18980	31420	58870
	% Reduction (max.)	99.9	96.9	99.9	98.2	97.6
	(min.)	99.9	83.6	99.7	95.9	94.4
SPRING	Raw	43000	3170	4580	2580	19950
	Effluent (Max.)*	230	13	43	27	250
	(min.)	120	4	21	19	45
	(min.)	42770	3157	4537	2553	19700
	(max.)	42880	3166	4559	2561	19905
	% Reduction (max.)	99.7	99.9	99.5	99.3	99.8
	(min.)	99.5	99.6	97.1	99.0	98.7
SUMMER	Raw	101000	63240	34900	32200	42000
	Effluent (max.)*	240	340	93	298	1710
	(min.)	43	40	15	80	234
	(min.)	100760	62900	34807	31902	40290
	(max.)	100957	63200	34885	32120	41766
	% Reduction (max.)	99.9+	99.9+	99.9+	99.8	99.4
	(min.)	99.8	99.5	99.8	99.1	95.9
FALL	Raw	46000	46000	2300	930	
	Effluent (max.)*	430	460	930	43	
	(min.)		240	43	23	
	(min.)	45570	45540	1370	887	
	(max.)		45760	2257	907	
	% Reduction (max.)	99.1	99.5	98.1	97.5	
	(min.)		99.0	59.6	95.4	

* Where no effluent is discharged, average of all stations is used.
** First Pond only.

presence or absence of an overflow, no striking differences in reduction were noted among the five ponds during the four seasons. At a given pond seasonal differences that were evident tended to show up in winter rather than at other times. Table V shows the seasonal percent reductions in BOD concentration for all seasons at the five installations studied.

In terms of BOD, the organic load was reduced by a minimum of 43.6 percent and a maximum of 98.4 percent. The minimum figure was obtained at Wall, South Dakota, under ice cover where, due to the shallowness of the pond beneath the ice, it was difficult to obtain a sample without picking up bottom material. Furthermore, the ice formation had concentrated the original pond contents into a much smaller volume. The minimum BOD reduction at the other locations was 70.0 percent which was also during ice cover. During open water conditions, pond and effluent samples contained large quantities of algae which join with bacteria and other organisms in utilizing oxygen during the incubation of BOD samples in darkness. Such BOD values are not strictly comparable to those of the influent sewage, although they were necessarily used in obtaining the BOD reductions. They do not reliably indicate the probable effect upon the receiving stream, as the algae may actually produce oxygen under proper light conditions.

At Kadoka and Lemmon, where the ponds are provided with an overflow structure, BOD reductions were calculated in pounds. At Kadoka, the mean reduction during spring, summer and fall was 92 per cent. It was 99.3 per cent during the summer at Lemmon. In addition to the decrease in BOD concentration, these percentage reductions are obtained partly by seepage and evaporation losses, which are indicated by the low

TABLE V

SEASONAL PER CENT REDUCTION IN B. O. D. CONCENTRATION*

Season		Kadoka	Wall	Lemmon	Maddock***	Wishek
WINTER	Raw	560	298	400	357	499
	Effluent**	22	168	35	83	150*****
		538	130	365	274	349
	% Reduction	96.2	43.6****	91.2	76.8	70.0
SPRING	Raw	422	410	252	137	195
	Effluent**	51	52	29	16	51
		371	358	223	121	144
	% Reduction	88.0	87.2	88.4	88.2	73.8
SUMMER	Raw	463	256	142	390	219
	Effluent**	60	29	10	11	24
		403	227	132	379	195
	% Reduction	87.0	88.5	93.0	97.2	89.0
FALL	Raw	256	278	165	185	---
	Effluent**	35	41	12	3	---
		221	237	153	182	
	% Reduction	86.2	85.4	92.8	98.4	

* All values shown except per cent reductions are in parts per million.

*** First pond only.

**** Bottom material in the sample

***** Drawn down in the fall.

** Where no effluent is discharged, average of all stations is used

rates of overflow. At Lemmon, for example, the volume of pond overflow was only about 10 per cent of the raw sewage inflow, while at Kadoka it was close to 50 per cent. It was noted that the BOD concentration at sampling stations within the pond itself was not significantly different than the effluent sample even though some of the sampling stations located within the pond proper were relatively close to the inlet.

At the Maddock installation, which consists of 3 cells arranged in series, the BOD is further reduced in each cell. Here there is no overflow and seepage and evaporation losses tend to maintain a uniform level. In Cell number 3, BOD was reduced to 2 to 6 parts per million. Here also, as at other installations without an overflow, dissolved solids as shown by chlorides were concentrated by freezing out in the winter and by evaporation at other times. The mean chloride concentration in raw sewage was 144 parts per million. During open water in the first cell, it was 77 parts per million, and in the succeeding cells, 227 and 228 parts per million, respectively. During ice cover, chloride concentration in the first cell was about three times that in the influent sewage. At Wall, where ice occupied a greater proportion of the pond volume, the winter chloride concentration was three and one-half times that of the raw sewage. At Kadoka and Lemmon, which utilize an overflow, increases in chloride concentration were negligible at all seasons.

Suspended Solids Reduction

Reductions in suspended solids are affected by two antagonistic processes; deposition on the one hand, and production of free floating algae on the other. During the winter, when algal production is at a standstill, suspended solids were reduced from 68 to 98 per cent.

During open water seasons, mean reductions have ranged from 13 to 96 per cent, and at Wall, the suspended solids increased 190 per cent during one of the test periods. The dark green color of the pond contents left no doubt as to the origin and nature of the new suspended solids.

Table VI shows the per cent reductions of suspended solids at the five installations during each season. Where there was no overflow the average of the concentrations for each station is used for comparison.

TABLE VI

SEASONAL PER CENT REDUCTION IN SUSPENDED SOLIDS*

Season		Kadoka	Wall	Lemmon	Maddock***	Wishek
WINTER	Raw	1,030	287	370	394	885
	Effluent**	124	92	39	13	79
		1,006	195	331	381	806
	% Reduction	97.7	67.9	89.5	96.7	91.1
SPRING	Raw	300	298	384	297	277
	Effluent**	107	782	145	30	241
		193	+484	239	267	36
	% Reduction	64.3	+61.9	62.2	89.9	13.0
SUMMER	Raw	383	287	228	270	137
	Effluent**	119	245	58	18	72
		264	42	170	252	65
	% Reduction	68.9	14.6	74.6	93.3	47.4
FALL	Raw	320	200	316	197	---
	Effluent**	108	640	104	8	---
		212	+440	212	189	
	% Reduction	66.3	+68.8	67.1	95.9	

* All values shown except per cent reductions are in parts per million

** Where no effluent is discharged, average of all stations is used.

*** First pond only.

DEVELOPMENT OF CRITERIA FOR POND DESIGN, CONSTRUCTION, OPERATION AND MAINTENANCE.

A number of factors jointly determine the cause and effectiveness of stabilization pond treatment of sewage. These factors can be divided into two parts; those that are controllable by man and those that are uncontrollable by man.

Among the controllable factors are:

1. Area
2. Depth
3. Shape
4. Size
5. Loading as to sewage quantity and quality
6. The type of soil as influencing percolation and compaction
7. Type and location of inlet and outlet structures
8. Site location
9. Method of operation

The following factors are not controllable and to a large extent determine how the controllable factors can and should be manipulated.

1. The direction and velocity of the wind
2. The amount and intensity of precipitation
3. The evaporation and humidity
4. The air and water temperatures
5. Intensity of solar radiation for photosynthesis
   a) Seasonal variation
   b) Daily variation

c) Hourly variation

d) Relation to latitude, elevation and cloud cover

e) Penetration of incident light for oxygen production

Solar Radiation

Solar radiation is important in the stabilization of sewage in ponds in three different ways. First, regional variations in annual solar radiation which differ with latitude, elevation, and cloud cover, will determine how well a pond will operate in a given location. Second, seasonal changes in daily solar radiation suggest the seasonal difficulties to be expected. Finally, penetration of incident light determines how much of the pond volume will participate in oxygen production. This will give an indication of desired pond depth.

Photosynthesis varies directly with solar radiation and is an important factor in stabilization pond performance. Light penetration into the pond was measured during each season, using matched surface and submerged phototonic cells. Because of the extremely dense growth of algae, light penetration in sewage ponds is strikingly less than that in most bodies of water which have been measured. Murdo Lake, a water supply reservoir for Murdo, South Dakota, falls within the general range of light extinction commonly reported for lakes, and absorbs 99% of the incident light in the upper 23½ feet.[27] In contrast to this, the layer absorbing 99% of the light in the pond at Kadoka is only 6 inches

27. G. L. Clarke, "The Utilization of Solar Energy by Aquatic Organisms," Problems of Lake Biology, American Association for the Advancement of Science, No. 10, p 31.

thick. This difference in light absorption with depth, results for the most part from the difference in algal density. The layer absorbing 99% of the incident light, is called the euphotic zone and is the stratum in which all appreciable photosynthesis occurs.[28]

Area, Loading and Size

The principal design criteria used in South Dakota relate the area, loading and size together. In all pond installations the criteria used was loading in persons, or biochemical oxygen demand (BOD) equivalents, per acre of water surface. Assuming an average per capita sewage flow of fifty gallons per day, the total annual flow from 100 people would be slightly in excess of 5.5 acre feet. Assuming the size requirements must be 100 persons or BOD equivalents per acre, this would require an acre of land 5.5 feet deep per 100 population or BOD equivalents. However, in South Dakota, the annual evaporation ranges from approximately 30 to 75 inches and the precipitation from 10 to 29 inches; therefore an absence of overflow is not unusual. To maintain a constant operating level or to have an overflow, the incoming flow plus precipitation must equal or exceed evaporation plus seepage. If the seepage is excessive, sufficient water depth for proper pond operation will not be maintained.

To minimize odors during the critical period of operation - from the anerobic conditions of complete ice cover to aerobic conditions of open water - the loading must be reduced below that of 100 persons or BOD equivalents, per acre. This study of present loadings seemed to indicate that the spring recovery requires a minimum number of days.

28. Ibid

During maximum algal activity and photosynthesis a much heavier loading could be maintained with excellent efficiencies resulting.

Depth

Optimum depth is controlled by many factors ; some require a shallow pond while others require a deeper pond.

For maximum oxygen production a depth of a few inches might be the most efficient. Shallow depths permit better mixing and spreading of settleable solids over the entire pond area by wind action. Spring recovery with maximum oxygen production in a shallow pond would of course take place more rapidly.

From a practical viewpoint, it has been found desirable to maintain sufficient depth to discourage the growth of rooted aquatic plants. A depth of approximately 3 feet has generally been adequate to control such plant growth.[29] In the cold climate of South Dakota, when ice thickness may vary from a few inches to over 3 feet, a total depth of 5 feet does not appear unreasonable. During high temperatures of the summer months, a deeper pond would be in order to maintain a more uniform temperature for optimum algal activity.

Controlled plant or pond operation would permit operation levels consistent with the seasons. The states of North and South Dakota recommend operating depths of 3 to 5 feet and this appears reasonable. It is also desirable that the depth be uniform over the entire pond, because deep pockets tend to retard mixing of the pond contents.

Shape

The shape of the pond is probably of little importance except that

29. Cadwell, loc. cit.

coves, peninsulas, and islands should be avoided. Such irregularities provide a place for any surface scum of floating material to accumulate. The flow pattern and the currents in the pond appear to be much less affected by shape and ratio of length to width than they are by wind action and temperature. Non-overflowing ponds must, of course, depend entirely upon wind action and convection currents for effective mixing of the contents. That such mixing does occur is evidenced by the uniformity of analytical results on samples collected at various points throughout the ponds during this four season study.

Site Location

To minimize possible odor complaints, stabilization ponds should be located as far as practicable from any present built-up area or any area which will probably be built up within a reasonable future period. A suitable site should be located approximately one-half mile from a community and one-fourth mile from the nearest residence. Under special conditions these distances could possibly be shortened. It is not economical to place the stabilization ponds too great a distance from the community because of the cost of the additional outfall sewer.

The pond site should be located downwind from habitation and where the pond surface will have an unobstructed wind sweep. (Consideration should be given to the soil characteristics; whether gravity flow from the community can be obtained or if a pumpin station should be installed; and the possibility of polluting the ground water aquifer.) From an economical standpoint the cost of the land must also be considered.

Dikes

The structure of the dikes surrounding a stabilization pond will,

in all probability, determine the life expectancy of the pond. Therefore, it is of the greatest importance that initial construction be of sound engineering practice. From the results of this study and from numerous observations made in South Dakota, the following design criteria seems to be of the greatest importance:

1. Good engineering practice should be observed in providing proper soil compaction in the dike construction. If it is deemed advisable to seal the bottom of the pond to prevent seepage losses and to protect the ground water supply then this should be done.

2. If the dikes are composed of sandy loam they should be riprapped with 2 to 3 inch diameter stones one foot above and 1 foot below the maximum operating level.

3. The inside and outside faces of the dike should be planted with blue grass or some other short-rooted grasses to protect the soil from erosion. If no fencing is provided and there is danger of cattle drinking from the ponds, matrimony vines could be planted as this type of vine is a short-rooted, spreading vine containing prickly thorns that cattle will not eat nor walk through. Care should be taken to see that no deep-rooted plants are planted on the dike as this tends to cause erosion.

4. The inside slope of the dike should be approximately four horizontal to one vertical to reduce erosion by wave action. As the size of the pond increases the inside slope should be flatter as larger bodies of water tend to have larger waves and thereby increasing erosion. The free board distance above the high water level should be at least 3 feet to provide for wave action and frost heave.

5. The width of the dike should be such as to allow free movement

of a vehicle around the pond to facilitate maintenance, such as mowing and repairing eroded dikes.

Inlet Structure

The location of the inlet structure to raw sewage stabilization ponds should be a sufficient distance from the shore to insure that wind action will contribute to the dispersion of incoming solids. Most inlets in the Dakotas are on the bottom of the pond; however, a few of them are at the side and the top of the dikes. (See Table II.) In some instances, the end of the inlet pipe terminates in an elbow discharging upward. Insofar as can be determined by observations, this holds no particular advantage over the horizontal discharge, as mixing appears to be the same in either case. There has been no trouble encountered with the clogging of these submerged inlet pipes. Neither has there been any evidence of short circuiting of the pond contents, because the flow is primarily controlled by wind directions.

Multiple inlets could conceivably be considered necessary where large volumes of raw sewage are to be handled by a single pond. Apparently this is not necessarily so, as observations made by the author at Jamestown, North Dakota, having a pond area of 135 acres and receiving the sewage from 12,000 persons, have shown no evidence of solids concentrating around its single center inlet. In areas less affected by winds, however, multiple inlets might well be desirable.

Outlet Structures

In South Dakota installations range from no outlet to elaborate dual spill-way drawdown structures. Other types include valved drain lines, weirs within an outlet manhole, and pipe overflows set at a

permanent level. The weir-manhole structure appears to be very satisfactory especially for areas subject to severe winter temperatures. This device is not subject to clogging by floating objects or ice, and can be designed to maintain flexible drawdown levels.

Method of Operation

The only apparent variable in operation is the flexibility that is offered by multiple cells. With multiple cells there are two possible methods of operation, parallel and series. Parallel operation will result in equal loading of both suspended and dissolved organic matter to each unit. With parallel operation it is possible to divert the entire flow to one pond when first placing the system in service, thereby reducing the lag period commonly experienced in developing a desirable liquid depth to affect weed control. The size of each pond could be reduced with parallel operation thus decreasing the possibilities of wave action and dike erosion.

The operation of the different cells in series will result in practically all of the settleable solids being removed in the first pond, which may overload it to the point that aerobic conditions cannot be maintained. Therefore, the first cell in a series operation would require an area equal to the criteria developed to keep spring recovery to a minimum and aerobic conditions to a maximum.

Design Standards

The South Dakota State Health Department, Division of Sanitary Engineering, has prepared Design Criteria For Sewage Stabilization Ponds which generally gives recommendations for the engineering aspects of the above considerations. In the light of the information gathered during

this study, these standards were reviewed point by point at the end of the cooperative project and thereby constitute the latest design criteria of stabilization ponds.

Because this writer is primarily concerned with the development of these standards as affecting the location, design and construction of ponds in South Dakota, these standards are reproduced, in their entirety, in appendix III.

The Missouri Basin Engineering Health Council, which comprises of the States of Minnesota, South Dakota, North Dakota, Nebraska, Wyoming, Montana, Kansas, Iowa, Missouri and Colorado, met in Deadwood, South Dakota on July 28, 1958 to review the design criteria of waste stabilization ponds of these various states and to formulate a set of standards to be used in the basin. It was expected that a proposed draft of the criteria would be completed in 90 days.[30]

Design standards only provide an engineer with an outline to follow for any design. Local conditions at each proposed pond site requires careful engineering evaluation and consideration to enable the communities to economically construct and utilize a stabilization pond for treating their wastes.

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30. South Dakota State Health Department files.

PUBLIC HEALTH CONSIDERATIONS

During the study it was evident that the ponds frequently were and still are attractive for recreational or other uses. It was reported to this author that boys have waded and used a sailboat in the third cell at Maddock, North Dakota; that a transient family parked a trailer near the pond at Lemmon, South Dakota, and swam in it; that water was pumped from the pond at Wall, South Dakota, and was used for road stabilization; and that at Rolla, North Dakota, pond water was used for washing trucks. Because of these unsanctioned uses, the need for human-proof fencing and signs is advisable.

The possibility that ponds may cause bacterial, viral or chemical contamination of ground water by percolating through the soils and into ground water has long been a question.

The mechanism involved in the removal of bacterial contamination for waters vertically percolating through soil is entirely different from that encountered in water flowing in ground water channels. The vertical distance a polluted liquid must travel to be free from bacterial contamination has been shown to be a function of the soils infiltration rate if there is no limiting clay lens near the surface of the soil. Studies conducted at California on the reclamation of sewage have shown that soils with low water infiltration rates, 0.5 to 1 feet per day, when spread with primary sewage produced an effluent that was relatively free from bacterial contamination after passing through 4 to 6 feet of soil. Soil with high water infiltration rates (those about 10 to 31 feet per day) require a distance of from 10 to 15 feet to produce a relatively

free bacteriological effluent.[31]

Once the polluted water has mixed with the ground water, the horizontal distance required to remove the organisms is greater than that found for vertical movement. It has been reported in the literature that coliform bacteria have been observed from 10 to 400 feet away from the source of contamination and that the pollution front decreases with time.[32]

The rate and extent of travel of chemical pollution in ground waters has been reported to a limited extent. Most observers agree that, in general, chemicals can be expected to travel long distances in both directions. Data that has been obtained shows that chemicals travel from 2 to 30 times as far as bacteria and in some cases pollution has been observed as far as 20 miles from the source of contamination.[33]

Raw sewage ponds are attractive to waterfowl during migration and nesting periods. Several broods of mallards, shovelers, and blue-winged teal were produced at Maddock during the course of this study, and broods were seen at other installations also. Questions have been raised on the hazards of handling such birds when hunting, the danger of pellet driven contaminated feathers in the flesh and the possibility that the ducks distribute pathogens when moving from one area to another.[34]

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31. Investigation of Travel of Pollution, p 19-21

32. Ibid

33. Ibid

34. R. J. Ellison and R. L. Smith, "Evaluating the Use of Sewage Lagoons," Public Works, LXXXV, (March, 1954), 69.

Mosquito breeding on the ponds in the Dakotas have been very minor and insignificant. In August of 1956 the Public Health Service CDC Field Station, Logan, Utah, conducted a special study of the Dakota stabilization ponds to evaluate potential mosquito control problems. They found very few mosquito larvae in the lagoons but recommended that the weeds be controlled so that the mosquito breeding potential can be eliminated.[35]

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35. State Health Department, Division of Sanitary Engineering Files

COSTS

Cost is the major reason for the widespread utilization of sewage stabilization ponds in South Dakota. Prior to the use of stabilization ponds as an accepted method of sewage treatment, the cost of providing both sewers and treatment works was beyond the economic reach of most small communities in this area. The advent of stabilization ponds, however, placed water carried sewerage, including treatment, within the economic range of these communities.

Cost data for 40 of the municipal stabilization ponds in South Dakota appear in table number VII. This data includes only the cost of the pond and its appurtenances and does not include outfall lines and lift stations. The data is divided into actual earthwork costs and total pond construction costs. The difference between earthwork and total costs indicates the cost of fencing, seeding, structures and other necessary items other than earthwork. Also included are columns for land acquired and the cost of land acquired, date of completion, cost per capita and cost per acre. The cost per acre is essentially the same as the cost per 100 design population which may give a truer per capita cost.

The summary of the data shows that the per capita treatment unit cost, exclusive of land, varies from a low of $5.28 to a high of $58.07, and the average cost of the installations listed is $19.96 per capita. Land costs have not been included in determining unit costs since this cost is extremely variable and largely dependent on local conditions. The tabulation, although not conclusive, is considered to be indicative

of prevailing general construction costs.

Comparison Between Conventional and Pond Treatment

Because stabilization ponds are utilized chiefly by smaller communities who employ one man for maintaining streets, the water system, and the sewer system, it is extremely difficult to obtain any operation and maintenance costs for stabilization pond installations. Therefore, a complete cost analysis is practically impossible. However, a few comparisons can be made that pertain mostly to the first cost of construction.

In recent years, since the advent of the adaptation of stabilization ponds, conventional sewage treatment construction in South Dakota has been on the decline. Table number VIII shows the cost per capita of the conventional treatment units constructed in the smaller communities in South Dakota since 1951. The only relative factor that can be compared on an equal basis is the cost per capita.

The cost per capita shown in table number VII does not include the cost of the land and the various outfall sewer lines. When constructing a conventional treatment plant, an outfall sewer line is required as is land. The amount of land required for a pond is much more than that required for a conventional plant. It frequently happens that a municipality buys more land than is actually needed to affect control of the area surrounding a sewage treatment plant, and thereby, in some cases, the amount of land purchased would be the same regardless of the type of sewage unit constructed.

To make a comparison between conventional treatment and a stabilization pond, it is necessary to include the cost of the land with the

construction costs for the pond. The average cost per acre of land (from table VII) is $120.38 and for any stabilization pond extra land is required for dikes to surround the surface area required. Assuming 25 per cent excess for dikes the cost per surface acre of land for a pond would be $150.48. Therefore, the cost per capita of stabilization ponds based on the design population would be one-hundredth that of the cost per acre including land costs and construction costs. Making this adjustment in the cost per capita a comparison can be made with conventional treatment. The average cost for conventional treatment providing secondary treatment (table VIII) is $108.11 while the cost per capita for stabilization ponds, which provide secondary treatment, is $18.30 including land and construction costs. This shows an average decrease of $89.81 per capita in favor of stabilization ponds and indicates partially why they have reached such great popularity with smaller communities. Imhoff tanks and other primary treatment compares closely with stabilization ponds costwise, but at some future date these primary treatment units may be required to be expanded to provide secondary treatment.

Complete cost comparison between conventional and stabilization pond treatment cannot be made because of the absence of operation and maintenance cost records for stabilization ponds. Because only seasonal maintenance is required it can be assumed that stabilization pond operation and maintenance costs are relatively low. Conventional treatment, on the other hand, requires daily and at least semi-weekly maintenance.

Where sewage lift stations are required for ponds, the operation and maintenance costs increase. However, because conventional treatment

requires lift stations in some installations, it can be assumed that this cost would be the same in either case. Actually comparing the treatment devices then would be a comparison between a secondary treatment plant and a stabilization pond, exclusive of lift stations.

The first cost is the controlling factor in the building of a sewage treatment unit. A low first or construction cost combined with low operation and maintenance costs is ideal. Stabilization ponds do provide this ideal cost combination and this is the greatest factor in the wide adoption of stabilization ponds over the more conventional type of sewage treatment.

TABLE VII
SOUTH DAKOTA STABILIZATION PONDS
COST DATA

CITY	DATE OF COMPLETION	LAND	TREATMENT UNIT COSTS			EARTHMOVING		
		ACQUIRED COST	TOTAL $	PER CAPITA $	PER ACRE $	CUBIC YARDS	COST PER YARD $	TOTAL COST $
Beresford	Summer 1955	160 Acres City owned	17,265.00	10.24	1,046.36	95,000	0.14	13,300.00
Bonesteel	Summer 1955	11 Acres $2,300	10,235.00	21.10	1,895.37	30,500	0.20	6,100.00
Bowdle	Summer 1957	160 Acres City owned	10,546.50	13.50	1,226.34	35,175	0.18	6,331.50
Burke	Fall 1953	10 Acres $2,500	7,458.00	8.99	908.54	16,500	0.30	4,950.00
Canton	Spring 1957	City owned	24,582.00	9.72	819.40	70,000	0.17	11,900.00
Castlewood	Winter 1957	25 Acres	18,000.00	36.22	1,125.00		Lump Sum	
Chancellor	Winter 1958	3.89 Acres	11,208.20	58.07	5,604.10	20,000	0.20	4,000.00
Clear Lake	Fall 1953	18.2 Acres $1,366.50	12,571.00	11.37	1,047.58	40,000	0.18	7,200.00
Colton	Summer 1958	12.75 Acres $4,462.50	19,787.00	37.98	3,212.18	23,000	0.21	4,830.00
Eagle Butte	Summer 1957	20.2 Acres $1,012	8,618.00	22.98	1,025.95	Lump Sum		6,834.00

TABLE VII (CONTINUED)

CITY	DATE OF COMPLETION	LAND	TREATMENT UNIT COSTS			EARTHMOVING		
		ACQUIRED / COST	TOTAL $	PER CAPITA $	PER ACRE $	CUBIC YARDS	COST PER YARD $	TOTAL COST $
Edgemont	Winter 1957	40 Acres / $3,000	10,890.00	9.46	533.82	40,500	0.20	8,100.00
Elk Point	Under Construction	58 Acres / $4,105.05	22,368.00	16.37	1,443.10	60,000	0.20	12,000.00
Freeman	Summer 1956	10 Acres / $4,000	8,425.00	8.96	842.50	25,000	0.137	3,425.00
Gettysburg	Fall 1955	40 Acres / $2,000	20,131.00	12.95	1,006.50	82,000	0.18	14,760.00
Hayti	Fall 1953	11 Acres / $1,100	15,670.00	37.94	3,134.00	25,350	0.34	8,619.00
Howard	Summer 1958	35.7 Acres / $4,550.00	15,200.00	12.20	1,013.33	59,000	0.20	11,800.00
Isabel	Summer 1955	5 Acres / City owned	7,000.00	13.70	2,592.59	8,000	0.22	1,760.00
Kadoka	Fall 1953	14 Acres / City owned	11,500.00	19.69	1,402.44	10,000	0.28	2,846.00
Langford	Fall 1956	9.16 Acres / $1,250	3,869.00	8.48	730.00	22,000	0.14	3,080.00

TABLE VII (CONTINUED)

CITY	DATE OF COMPLETION	LAND	TREATMENT UNIT COSTS			EARTHMOVING		
		ACQUIRED COST	TOTAL $	PER CAPITA $	PER ACRE $	CUBIC YARDS	COST PER YARD $	TOTAL COST $
Lemmon	Summer 1951	35 Acres $2,000	31,000.00	11.23	1,143.91	45,572	0.40	19,028.00
Mission	Fall 1957	20 Acres $2,000	11,081.00	28.56	2,702.68	Lump Sum		6,500.00
Murdo	Fall 1955	143 Acres $12,000	12,000.00	16.24	1,290.32	57,700	0.19	10,963.00
New Effington	Spring 1954	2 Acres $1,200	6,524.00	17.78	1,763.24	14,384	0.38	5,465.00
Onida	Spring 1958	City owned	18,368.00	22.51	1,597.22	Lump Sum		13,500.00
Orient	Spring 1958	______	7,876.00	38.42	3,938.00	29,000	0.172	5,000.00
Parkston	Summer 1957	36 Acres $8,500	2[illegible],829.65	21.29	1,659.98	150,000	0.16	24,000.00
Philip	Fall 1953	6 Acres $1,000	4,276.00	5.28	750.18	6,890	0.35	2,412.00
Pollock	Summer 1955	9.5 Acres $950	12,713.50	31.78	2,763.80	24,500	0.23	5,635.00
Redfield	Fall 1955	87 Acres $8,700	26,960.00	10.15	892.72	105,000	0.19	19,950.00

TABLE VII (CONTINUED)

CITY	DATE OF COMPLETION	LAND ACQUIRED / COST	TREATMENT UNIT COSTS TOTAL $	PER CAPITA $	PER ACRE $	EARTHMOVING CUBIC YARDS	COST PER YARD $	TOTAL COST $
Selby	Summer 1958	27 Acres / $1,875	11,514.00	16.45	1,151.40	36,700	0.17	6,239.00
Sisseton	Summer 1955	45 Acres / $12,375	29,764.50	10.37	1,102.39	122,900	0.13	20,360.00
Springfield	Fall 1957	26.5 Acres / $3,710	20,500.00	25.63	1,090.43	Lump Sum		
Tabor	Spring 1956	6.8 Acres / $1,360	2,560.00	6.86	522.45	12,000	0.20	2,400.00
Valley Springs	Fall 1955	15.9 Acres / $3,270	9,750.00	25.06	1,681.03	45,000	0.17	7,650.00
Veblen	Summer 1954	12 Acres / $1,200	5,856.00	12.34	2,342.40	12,600	0.31	3,906.00
Wagner	Under Construction	40 Acres / $7,000	21,117.00	13.91	1,005.57	65,400	0.145	9,483.00
Wall	Fall 1951	25 Acres / City owned	15,000.00	26.98	1,685.39	6,975	0.35	2,411.00
Whitewood	Under Construction	7.8 Acres / $235	6,607.50	21.74	1,573.21	23,000	0.20	4,687.50

TABLE VII (CONTINUED)

CITY	DATE OF COMPLETION	LAND ACQUIRED COST	TREATMENT UNIT COSTS TOTAL $	PER CAPITA $	PER ACRE $	EARTHMOVING CUBIC YARDS	COST PER YARD $	TOTAL COST $
Wilmot	Under Construction	23.7 Acres $1,000	14,577.85	25.00	1,943.71	38,500	0.23	8,855.00

NOTE: Per Capita cost is based on 1950 population.

Per Capita Cost: Range; $58.07 to $5.28 Average; $19.96

Per Acre Cost: Range; $5,604.10 to $522.45 Average; $1,679.98

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35. Ibid.

TABLE VIII
CONVENTIONAL SEWAGE WORKS COSTS IN SOUTH DAKOTA[36]

CITY	POPULATION 1950 CENSUS	TYPE OF TREATMENT UNITS	TREATMENT UNIT PER CAPITA COSTS $	DATE OF COMPLETION
Dupree	438	Imhoff tank, filtration, final tank and lift station	91.32	October 1952
Hill City	361	Primary and final tank, sludge digestion and filter	110.80	Summer 1954
Lake Andes	1,851	Imhoff tank	5.40	May 1954
Pukwana	302	Imhoff tank, filtration and final settling tank.	136.89	Fall 1951
Roscoe	726	Imhoff tank	18.53	Winter 1952
Volga	578	Imhoff tank, filtration, final settling.	93.43	Summer 1953

REMARKS:

The average per capita cost for the treatment unit providing secondary treatment is $100.11. The average per capita cost for the primary treatment is $11.97.

36. *Ibid.*

SUMMARY AND CONCLUSIONS

This thesis gives an account of the author's participation and investigation of a cooperative field study of sewage stabilization ponds during the winter, spring, summer and autumn of 1955. Physical, chemical and biological features and phenomena were observed and correlated with structural design.

The mechanism of the process of stabilization in an open body of water involves a complex biological-chemical relationship between algae and bacteria. Algal activity is almost negligible under snow covered ice; stabilization that is accomplished during the winter months is primarily a result of physical forces and anerobic bacterial activity. Treatment obtained during both open water and ice-cover is very good. Reduction in B.O.D. concentration ranged from 74 to 98 per cent during the open water seasons and from 70 to 96 per cent under ice cover.

Factors which affect the extent of treatment of raw sewage in a stabilization pond include the strength and type of sewage, loading per unit of surface area, sunlight, temperature, wind, depth, inlet and outlet structure and their location, and soil characteristics.

Site selection for locating a stabilization pond must be based on economics (land cost and if a lift station is required due to the relative elevation of the pond), soil characteristics, and wind direction with respect to the community and the outlying residences.

Public health considerations must be fully recognized. The possible contamination of humans, wildfowl, animals and insects and the contamination of ground water by seepage must be considered as potential hazards. Future

studies regarding the public health aspects need to be made to fully evaluate the significance of stabilization ponds.

Stabilization ponds in this area have been developed as a method of sewage treatment principally because of the high cost of constructing and maintaining more conventional types of sewage treatment. The cost of primary treatment such as an Imhoff tank is comparable on a per capita basis. It must be remembered that ponds provide secondary treatment and someday additional facilities may be required to be added to the primary treatment to improve the efficiency of the treatment.

Because of the present great interest shown in stabilization ponds, the 10 States of the Missouri Basin are formulating criteria standards for the location, design, and construction of ponds throughout the Midwest. Undoubtedly, because of lower land costs, sewage treatment ponds will become very commonplace in the western United States during the next few years.

At the present time there are different stabilization pond research projects in progress. The field of investigation is large, because of the lack of specific knowledge as to the maximum allowable loading, pre-treatment of sewage, soil treatment for sealing and erosion control, and practically the whole field of public health significance. It is hoped that some of these questions will be answered in the near future.

Further conclusions drawn from this study are shown, as standards, in Appendix III. These standards were formulated at the end of the period of investigation and are the design criteria developed from this extended engineering evaluation of stabilization ponds.

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APPENDIX I

SUMMARY OF PERTINENT INFORMATION

KADOKA, SOUTH DAKOTA

Sewage and Sewerage

Population Served:	584 (1950 Census)
Sewer System:	Separate - gravity.
Pretreatment:	None
Industrial Wastes:	Abattoir -- slaughters average 300 beef and 50 hogs per year; about 50% during October, November and December.
Sewage: Flow:	21,100 GPD
Strength:	380 ppm B.O.D.
Loading:	68.7 pounds B.O.D. per day, or 22.9 pounds per acre per day.

Pond

Date Completed:	Fall, 1953
Design Engineer:	Fred Brady, Spearfish, South Dakota
Description:	Single cell, irregular shape (ox-bow) and depth. Area: 3.0 acres; Ave. Depth: 4.45 ft.; Volume: 18.1 acre-feet.
Inlet Structure:	Location: at end of peninsula (see sketch); Discharge: horizontal, 1-1/2 feet below operating level.
Outlet Structure:	Location: NW Corner. Depth: Surface.
Dikes:	Top width: 14 feet. Slope: inside: 1:1; to 1:3; outside: 1:1-1/2 to 1:3
	Diversion ditch prevents entry of surface run-off into pond.
Environs:	Nearest residence: 1400 feet North. Community: 1500 feet South

Fenced: yes, but not adequate to keep out cattle.
Posted: no signs.

COSTS:	Land (20 acres at $50.00)	$1000.00
	Excavation (2250 cy. yd. at $0.60)	1350.00
	Fence (100 rods at $3.00)	300.00
		$ 2650.00
	Sewer Cost	$3532.00
	Engineer	890.00
	Misc.	142.00
	Total	$7214.00

($12.35 per capita)

Soil Conditions:
Type: Clay
Mechanical Soil Analyses*: Sand: 25.7%
Silt: 41.5%
Clay: 32.8%

Bottom was not "sealed"

Effluent: Erratic flow due to wind and occasional clogging of outlet pipe. Ave. flow observed during 1955 studies: 13,600 GPG (Spring: 4800 GPD; Summer: 16,8000 GPD; Fall: 19,100 GPD)

Wildfowl: Frequented by shore birds and ducks.

Odors: Yes, during spring, summer and fall.

Operation and Maintenance: None to date. (However, this installation was abandoned in the Spring of 1956, when the raw sewage was diverted to a new pond.)

Weather (1955)**:

Evaporation	Total 71.4"
Precipitation	Total 16.3"
Temperature	Ave. 48.2°F: Max. 106°F; Min. -15°F.

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* Soils Laboratory, Bureau of Reclamation, Bismarck, North Dakota

** Cottonwood Station, Cottonwood, South Dakota

Prevailing winds from NW.

Elevation: 2467 feet above sea level.

Municipal Water Supply.

Source: Well, 2670 feet deep. Constructed in 1951.

Population Served: 580

Daily Consumption: 18,700 Gal. (Ave. for 1954 metered flow).

Treatment: Chlorination.

Chemical analysis:* (ppm)

Total Dissolved Solids	1841
Total Alkalinity (as $CaCO_3$)	150
Total Hardness (as $CaCO_3$)	222
Iron (Fe)	0.0
pH	7.65
Calcium (Ca)	66.5
Magnesium (Mg)	13.5
Sodium (Na)	511
Fluoride (F)	1.4
Chloride (Cl)	72
Sulfate (SO_4)	1038
Bicarbonate (HCO_3)	183
Nitrates (NO_3)	2.0
Carbonates (CO_3)	---
Manganese (Mn)	0.0

Municipal Personnel (1955)

Mayor:	Dr. N. J. Sundet
Auditor:	Wesley Herrman
Water and Sewage Works:	Roy Hedeen
Treasurer:	Mr. Colburn
Other persons contacted:	Mr. Nielsen, meat packer.

* Analysis made by South Dakota Health Department - January 28, 1954

SUMMARY OF PERTINENT INFORMATION

WALL, SOUTH DAKOTA

Sewage and Sewerage

Population Served: 556 (1950 Census)

Sewer System: Separate - gravity

Pretreatment: None

Industrial Wastes: None

Sewage: Flow: 24,900 GPD
Strength: 315 ppm B.O.D.
Loading: 62.2 pounds BOD per day, or 7.0 pounds per acre per day.

Surface run-off does not reach pond.

Pond

Date Completed: Fall, 1951

Design Engineer: Staven, Rapid City, South Dakota

Description: One cell used, although three are available. Shallow, irregular 5-sided polygon. Area: 8.87 acres: Ave. depth: 14 inches; Volume: 10.7 acre-feet.

Inlet Structure: Side discharge from east section of north dike.

Outlet Structure: Shallow ditch connected to next cell. (SE) (Very little flow, depending on wind direction.)

Dikes: Ave. top width: 4 ft.; Ave. height: 6 ft. Slope: inside: 4:1; outside: 2:1.

Environs: Nearest residence: 1000 ft. west. Community: 2000 ft. WSW.

Area is fenced but not posted.

Costs:	Land (City owned 25 acres) Excavation (3700 cu. yds.)	$2400.00
		$12600.00
	Other costs (sewer system, fence, outfall, etc.)	
	Total cost	$15000.00
		($26.98 per capita)

Soil Conditions:

Type: "Gumbo"

Mechanical Soil Analyses*: Sand: 6.3%
Silt: 68.7%
Clay: 25.0%

Effluent: None

Wildfowl: Shorebirds and ducks.

Odors: None noticed during survey

Operation and Maintenance: None to date.

Weather (1955)**

Evaporation	Total 71.4"
Precipitation	Total 13.9"
Temperature	Ave. 47.3°F; Max. 108°F; Min. - 17°F
Ice Cover:	Nov. 15 - April 1 (4-1/2 months)

Elevation: 1934 feet above sea level.

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* Soils Laboratory, Bureau of Reclamation, Bismarck, North Dakota

** Cottonwood Weather Station, Cottonwood, South Dakota

Municipal Water Supply

Source:	Surface, stock dam construction, 1-1/2 miles NW of town.
Population Served:	560
Daily Consumption:	26,000 Gal. (Ave. of 1954 -- 98% metered)
Treatment:	Coagulation -- Filtration--Chlorination.

Chemical Analysis* (PPM)

Total Dissolved Solids	207
Total Alkalinity (as $CaCO_3$)	154
Total Hardness (as $CaCO_3$)	75.5
Iron (Fe)	0.0
pH	8.0
Calcium (Ca)	24.0
Magnesium (Mg)	2.8
Sodium (Na)	55.5
Fluoride (F)	0.6
Chloride (Cl)	11.0
Sulfate (SO_4)	17.4
Bicarbonate (HCO_3)	193
Nitrates (NO_3)	0.0
Carbonates (CO_3)	---
Manganese (Mn)	0.0

Municipal Personnel (1955)

Mayor:	O. S. Soma
Auditor:	Deane Joyce
Water and Sewage Works:	Harold Welsh

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* Analysis performed by South Dakota State Department of Health, Nov. 16, 1953.

SUMMARY OF PERTINENT INFORMATION

LEMMON, SOUTH DAKOTA

Sewage and Sewerage

Population Served:	2760 (1950 Census)
Sewer System:	Combined - gravity.
Pretreatment:	None
Industrial Wastes:	Two abattoirs Ave. no. animals processed annually: 400 beef, 350 hogs, and 200 deer.
Sewage: Flow:	125,500 GPD
Strength:	186 ppm B.O.D.
Loading:	186 pounds B.O.D. per day, or 6.8 pounds per acre per day.
	Combined sewers conduct about 50% of City rain run-off.

Pond

Date Completed:	Summer, 1951
Design Engineer:	Staven, Rapid City, South Dakota
Description:	Single cell, irregular shape and depth. Area: 27.1 acres; Ave. depth: 5.7 feet; Volume: 154 acre-feet.
Inlet Structure:	Submerged, 1000 feet West of outlet. Depth 3 feet.
Outlet Structure:	Surface discharge, SE corner.
Dikes:	Nearest residence: 1/2 mile WSW Community: 1 mile SW. Area is fenced but not posted.

Costs:		
	Land (1/4 section)	$2000.00
	Excavation (47,572 cu. yds @ 0.40)	19029.00
		21029.00
	Other costs (Fees, sewers, etc.,)	12754.00
	Total:	33,783.00
		($12.20 per capita)

Soil Conditions:

Type: Silty Clay

Mechanical Soil Analysis:*

Sand: 34.5%
Silt: 38.5%
Clay: 27.0%

Effluent: Discharges to branch of Cedar Creek. (Ave. summer flow: 14,590 GPD)

Wildfowl: Many ducks and shorebirds.

Odors: Occasionally noticed along feathered shore of SW cove.

Operation and Maintenance: Trash and rocks are dumped along inner dikes to act as rip rap.

Weather (1955)**

Evaporation: Total 58.8"
Precipitation: Total 17.3"
Temperature: Ave. 41.5°F; Max. 101°F; Min. -21°F.

Ice cover: Nov. 1 - April 1 (five months)

Elevation: 2518 feet above sea level.

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* Soils Laboratory, Bureau of Reclamation, Bismarck, North Dakota

** Shadehill Weather Station, Shadehill, South Dakota

Municipal Water Supply

Source:	5 wells, 185-915 feet deep.
Population Served:	2760; no meters.
Daily Consumption:	500,000 GAL. (Estimate based on pump rates.)
Treatment:	None

Chemical Analysis* (ppm) (average of five wells)

Total Dissolved Solids	1498
Total Hardness (as $CaCO_3$)	180
Iron (Fe)	0.5
pH	8.3
Calcium (Ca)	8.4
Magnesium (Mg)	2.5
Sodium (Na)	560
Fluoride (F)	2.8
Chloride (Cl)	91
Sulfate (SO_4)	362
Bicarbonate (HCO_3)	903
Nitrate (NO_3)	0.2
Carbonate (CO_3)	---
Manganese (Mn)	---

Municipal Personnel (1955)

Mayor:	J. C. Jacobsen
Auditor:	E. C. Gustafson
Water and Sewage Works:	Al Robinson "Bud" Dosland
Treasurer:	Mr. Cornish
Other persons contacted:	Mrs. Steward, local weather observer, Mr. Nick Biersbach, meat packer. Mr. George Wenzel, meat packer.

*Analysis by South Dakota State Department of Health.

SUMMARY OF PERTINENT INFORMATION

MADDOCK, NORTH DAKOTA

Sewer and Sewerage

Population Served:	741 (1950 Census)
Sewer System:	Separate -- lift station.
Pretreatment:	None
Industrial Wastes:	Dairy (400 Gal. per day) Meat packer (300 beef, 100 hogs, annually)
Sewage: Flow:	50,200 G.P.D.
Strength:	267 ppm B.O.D.
Loading:	109 pounds B.O.D. per day, or 9.3 pounds per acre per day in first pond.

Pond

Date Completed:	Fall, 1949
Design Engineer:	Lium and Burdick,
Description:	Three rectangular cells in series First: Area, 11.7 acres; Ave. depth, 4.0'; Volume, 46.8 acre-feet. Second: Area, 12.3 Acres; Ave. Depth, 2.8' Volume, 34.4 Acre-feet. Third: Area, 8.0 Acres; Ave. depth, 4.4' Volume, 35.2 Acre-Feet. Total: Area, 32.0 Acres, Volume, 116.4 acre-feet
Inlet Structure:	Submerged (3' depth) in center of first cell
Outlet Structure:	None (no effluent)
Dikes:	Top width: 10' Slope: inside: 1:4; outside 1:2
Environs:	Nearest house: 3000 feet East. Community: 1 mile E.

Costs:	Land (65 acres @ $100.00)		$6500.00
	Excavation:	First cell	5000.00
		Second Cell	600.00
		Third cell	4400.00
			$16500.00
		($22.30 per capita)	
	Lift Station		$9500.00
	Force Main (3000' @ $2.95)		8850.00
			$18350.00
	Total Cost		$34850.00
		($46.90 per capita)	

Soil Conditions:

Type; Clay-Silt

Mechanical Soil Analysis* Sand: 22.8%
Silt: 56.3%
Clay: 20.9%

Was not necessary to seal bottom.

Wildfowl: Many ducks

Odors: From first pond during winter-spring transition.

Operation and Maintenance: Cutting weeds on dikes.

Weather (1955)**

Evaporation: Total 32.9"
Precipitation: Total 17.1"
Temperature: Ave. 38.5°F; Max. 100°F; Min. -32°F.

Elevation: 1604 feet above sea level.

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* Soils Laboratory, Bureau of Reclamation, Bismarck, North Dakota

** Devils Lake Weather Station, Devils Lake, North Dakota

Municipal Water Supply

Source:	2 wells, 60 - 64 feet deep.
Daily Population served:	740 (1950 census)
Daily consumption:	43,000 Gallons (Ave. of 1954)
Treatment:	None

Chemical Analysis* (ppm)

Total Dissolved Solids	915
Total Alkalinity (as $CaCO_3$)	336
Total Hardness (as $CaCO_3$)	260
Iron (Fe)	1.4
pH	7.6
Calcium (Ca)	61.6
Magnesium (Mg)	26
Sodium (Na)	158
Fluoride (F)	Trace
Chloride (Cl)	10
Sulfate (SO_4)	244
Bicarbonate (HCO_3)	410
Nitrates (NO_3)	2.1
Carbonates (CO_3)	---
Manganese (Mn)	---

Municipal Personnel (1955)

Mayor:	P. W. Utgard
Auditor:	A. P. Lysne
Water and Sewage Works:	Fireman Leigrid
Former Water and Sewage Works:	Elmer Larsen
Other persons contacted:	Mr. Jacobsen, Mgr., of Co-op Dairy, Mr. Schmid, local meat packer, Mr. George Sheets, R. R. Section Foreman - furnished ice for sample perservation.

*Analysis by North Dakota State Health Department

SUMMARY OF PERTINENT INFORMATION

WISHEK, NORTH DAKOTA

Sewage and Sewerage

Population Served:	1241 (1950 census)
Sewer System:	Separate -- gravity
Pretreatment:	None
Industrial Wastes:	None
Sewage: Flow:	57,200 GPD
Strength:	207 ppm B.O.D.
Loading:	102 pounds B.O.D. per day, or 13.0 pounds per acre per day

Pond

Date Completed:	October 20, 1952
Design Engineer:	Paul Barnes, Valley City, North Dakota
Description:	Single cell, approximately square shape. Area: 7.8 acres; Depth: (ave) 3.0'; Volume: 22.4 acre-feet
Inlet Structure:	50' from East dike, Horizontal, 8" off bottom.
Outlet Structure:	In West dike, 1 foot off bottom. Valve is opened twice a year, "When high level of liquid in pond backs up sewers."
Dikes:	Top width: 14 feet. Slope: inside: 1:4; outside: 1:3.
Environs:	Nearest residence: 300 yards east. Community: 500 yards east.
Costs:	Land (City owned)
	Total cost of pond $5400.00
	($4.50 per capita)

Soil Conditions:

Type: Silty-clay

Mechanical Soil Analyses:*

Sand:	16.1%
Silt:	59.6%
Clay:	24.3%

Wildfowl: Ducks

Odors: Not noticeable during survey.

Operation and Maintenance: Some rip rapping

Weather (1955)**

Evaporation	Total 43.2"
Precipitation	Total 18.3"
Temperature	Ave. 40.4°F; Max. 100°F; Min.-32°F.

Elevation: 2010 feet above sea level.

Municipal Water Supply

Source: Dug well, 12' diameter, 33' deep.

Population Served: Approximately 1200.

Daily Consumption: 85,000 Gal. (Ave. of year 1952)

Treatment: None

Chemical Analyses:*** (ppm)

Total Dissolved Solids	509
Total Alkalinity (as $CaCO_3$)	260
Total Hardness (as $CaCO_3$)	340
Iron (Fe)	3.1
pH	8.0
Calcium (Ca)	101
Magnesium (Mg)	21
Sodium (Na)	--
Fluoride (F)	--
Chloride (Cl)	14
Sulfate (SO_4)	52
Bicarbonate (HCO_3)	317
Nitrates (NO_3)	---
Carbonates (CO_3)	---
Manganese (Mn)	---

*Soils Laboratory, Bureau of Reclamation, Bismarck, North Dakota

**Weather Bureau, Bismarck, North Dakota

***North Dakota State Health Department.

<u>Municipal Personnel</u>

Mayor:	Elmo Nickisch
Water and Sewage Works:	Carl Eissinger

APPENDIX II

SEASONAL SUMMARIES OF LABORATORY ANALYSES

The data in this appendix comprises the summaries for each season and for each sampling station and depth. Because stabilization pond performance was evaluated on the seasonal summaries, they are included in this thesis rather than each and every result from the three day sampling period during the four seasons.

The complete data, including daily observations for this cooperative study, can be found in Sewage Stabilization Ponds in the Dakotas, Volume II published by the Public Health Service, U. S. Department of Health, Education, and Welfare, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio.

LABORATORY ANALYSIS
Seasonal Summary 1955

KADOKA, SOUTH DAKOTA

STATION	SEASON	DAYS SAMPLED /Depth	TEMP. °C	DISSOLVED OXYGEN ppm	DISSOLVED OXYGEN %Sat.	B.O.D. ppm	pH	ALKALINITY P ppm	ALKALINITY Total ppm	CHLORIDE ppm	SULFIDE ppm	AMMONIA ppm	NITRITE ppm	NITRATE ppm	NITROGEN ppm	PHOSPHATE Total ppm	PHOSPHATE Ortho ppm	TURBIDITY ppm	SOLIDS Suspended ppm	COLIFORM MPN/100 ml. (x 1000)
Raw	Winter	3	-	7.5		560	8.9	17.1	608	126	4.9	76	0.054	0.20	134	105	27	970	1030	23,700
	Spring	1	-	-		422	7.6	0	524	196	0.4	130	0.000	0.00	87.4	97	0	552	300	43,000
	Summer	3	-	0.0	0	463	7.0	0	466	99	25.0	41.8	0.008				38	533	383	101,000
	Fall	1	-	0.0	0	256	7.5	0	560	136	0.0	-	-				-	-	320	46,000
																				Max. - Min.
1-U	Winter	3/2.5'	-	0.0	0	62	8.4	17.3	791	215	35.3	29.0	0.000	0.22	39.7	53	28	240	56	2400 - 110
	Spring	3/0.5'	14	0.6	0	40	8.0	0	683	170	1.2	18.5	0.000	0.02	22.7	55	2.0	215	48	750 - 240
	Summer	3/0.5'	27	0.0	0	33	9.0	122	646	158	20.0	1.6	0.008				5.0	215	140	430 - 110
	Fall	1/0.5'	3	0.0	0	31	8.4	65	925	182	1.5	3.2	-				-	-	132	930
1-L	Winter	3/5.0'	-	0.0	0	70	8.4	19.0	808	218	44.2	30.6	0.000	0.16	40.1	55	28	253	84	1100 - 110
	Spring	3/3.0'	14	0.0	0	41	7.9	0.0	678	152	-	21.7	0.000	-	31.5	52	3.5	210	85	460 - 230
	Summer	3/3.0'	26	0.0	0	34	8.8	87	625	157	0.3	2.1	0.004				7.0	203	151	110 - 43
	Fall	1/3.0'	3	0.0	0	23	8.4	65	930	185	1.5	3.5	-				-	-	156	930
2-U	Winter	3/2.5'	-	0.0	0	38	8.4	24.4	788	219	36.6	26.3	0.000	0.19	31.9	50	28	200	66	930 - 110
	Spring	3/0.5'	14	0.1	0	41	7.9	0	679	158	0.2	18.5	0.000	0.02	26.3	55	2.5	243	71	230 - 43
	Summer	3/0.5'	27	0.0	0	34	8.9	136	620	165	0.06	2.1	0.003				9.0	189	151	460 - 46
	Fall	1/0.5'	3	0.0	0	26	8.5	65	930	182	1.0	3.5	-				-	-	120	930
2-L	Winter	3/5.0'	-	0.0	0	45	8.5	26.0	787	219	36.6	25.6	0.000	0.12	33.1	49	27	213	59	1100 - 430
	Spring	3/5.0'	14	0.0	0	39	8.0	0	680	161	0.9	20.0	0.000	-	24.8	55	3.0	239	90	240 - 230
	Summer	3/5.0'	24	0.0	0	120	7.6	0	918	140	100	8.3	0.005				19.0	243	85	460 - 4
	Fall	1/5.0'	3	0.0	0	50	8.5	70	935	176	1.5	3.7	-				-	-	152	390
3-U	Winter	3/3.0'	-	0.0	0	30	8.5	33.6	791	217	36.0	21.8	0.000	0.16	28.5	41	28	200	61	15 - 3.6
	Spring	3/0.5'	13	0.0	0	39	8.0	0	681	161	1.4	20.7	0.000	-	26.9	56	1.5	217	64	240 - 230
	Summer	3/0.5'	24	0.0	0	23	8.8	129	635	161	0.2	2.4	0.002				7.0	195	129	240 - 46
	Fall	1/0.5'	3	0.0	0	30	8.4	65	950	179	1.5	3.6	-				-	-	140	930
3-L	Winter	3/7.0'	-	0.0	0	36	8.4	30.7	800	217	42.8	21.8	0.000	0.13	28.8	41	28	197	69	240 - 2
	Spring	3/5.0'	14	0.0	0	33	7.9	0	680	155	24.2	21.3	0.000	-	25.1	50	3.5	216	77	460 - 430
	Summer	3/5.0'	25	0.0	0	33	7.6	0	784	150	128	8.1	0.001				20	219	84	240 - 9
	Fall	1/5.0'	3	0.0	0	32	8.4	70	945	176	1.4	3.2	-				-	-	130	430
Effluent	Winter	3	-	0.0	0	22	8.4	27.1	776	219	22.1	21.2	0.000	0.13	38.3	44	26	220	124	24 - 1.1
	Spring	3	13	4.5	46	51	8.2	0	687	149	0.8	10.8	0.000	0.02	34.2	58	4.0	243	107	230 - 120
	Summer	3	26	0.0	0	60	8.8	104	561	161	16.0	2.4	0.002				8.0	146	119	240 - 43
	Fall	1	-	0.0	0	35	8.1	0	932	182	0.0	-	-				-	-	108	430

REMARKS:

Location

No. 1 -- 100 feet North of inlet

No. 2 -- Center of pond at bend; 325 feet from inlet

No. 3 -- Center of pond, 100 feet from outlet, 500 feet from inlet

Effluent -- At outlet structure; 650 feet from inlet

LABORATORY ANALYSES
Seasonal Summary 1955

WALL, SOUTH DAKOTA

STATION	SEASON	DAYS SAMPLED	TEMP. °C	DISSOLVED OXYGEN ppm	DISSOLVED OXYGEN % Sat.	B.O.D. ppm	pH	ALKALINITY P ppm	ALKALINITY Total ppm	CHLORIDE ppm	SULFIDE ppm	AMMONIA ppm	NITRITE ppm	NITRATE ppm	NITROGEN ppm	PHOSPHATE Total ppm	PHOSPHATE Ortho ppm	TURBIDITY ppm	SOLIDS ppm	COLIFORM MPN/100 ml (x 1000)
Raw	Winter	3	7	1.9	17	298	7.7	0	605	97	0.9	84.0	0.002	0.12	115	63	28	367	287	13,420
	Spring	3	-	-	-	410	7.5	0	485	79	0.0	14.0	0.000	-	61.8	65	5.0	408	298	3,170
	Summer	3	15	0.0	0	256	7.0	0	413	75	0.2	45.1	0.005				23	383	287	63,240
	Fall	1	-	-	-	278	8.5	15	465	88	0.5	13.0	-				-	-	200	46,000
																				Max. - Min.
#1	Winter	3	0.3	0.0	0	178	7.6	0	1210	352	80	54.0	0.000	0.12	75.8	66	41	280	43	1500 - 430
	Spring	3	12	11.1	111	53	10.5	177	737	161	0.0	10.5	0.000	0.12	46.9	44	6.5	1270	807	15 - 4.3
	Summer	3	20	0.0	0	36	9.3	142	538	163	0.6	0.9	0.002				4.0	312	210	460 - 43
	Fall	1	0.5	2.8	21	44	9.5	110	495	143	0.0	0.0	-				-	-	680	240
#2	Winter	3	0.4	0.0	0	143	7.9	0	1390	442	52	39.0	0.000	0.19	62.9	72	55	250	66	2100 - 230
	Spring	3	14	10.7	111	60	10.5	179	527	161	0	10.5	0.000	-	75.0	53	5.0	2040	775	7.5 - 2.3
	Summer	3	20	0.2	0	27	9.4	145	543	162	0	0.9	0.002				3.0	335	238	150 - 15
	Fall	1	0	2.2	17	43	9.5	110	490	143	-	-	-				-	-	860	240
#3	Winter	3	0.3	0.0	0	176	7.4	0	687	138	11	87.0	0.000	0.10	106	61	49	350	159	24000 - 1100
	Spring	3	14	11.0	111	51	10.5	173	558	161	0	10.5	0.000	-	49.6	54	7.0	1360	830	9.3 - 9.3
	Summer	3	20	1.2	0	29	9.4	158	595	163	0	0.9	0.003				4.0	331	270	240 - 93
	Fall	1	0	4.4	33	40	9.5	115	500	143	0	0.0	-				-	-	-	
#4	Winter	3	0.2	0.0	0	201	7.3	0	841	204	35	77.0	0.000	0.15	101	79	58	340	149	4600 - 1100
	Spring	3	14	7.7	80	54	10.5	169	471	173	0.4	18.2	0.000	0.10	47.0	49	5.5	1570	820	240 - 43
	Summer	3	20	0.9	0	28	9.4	152	557	165	0	1.1	0.003				4.0	302	240	460 - 43
	Fall	1	0	2.5	18	41	9.6	100	485	143	0	0.0	-				-	-	800	240
#5	Winter	3	0	0.0	0	201	7.5	0	1660	417	89	64.0	0.000	0.11	90.0	98	68	407	59	750 - 210
	Spring	3	15	10.3	110	50	10.4	177	476	162	0	2.6	0.000	-	45.4	52	4.0	1310	730	46 - 9.3
	Summer	3	20	0.5	0	29	9.4	152	551	163	0	1.1	0.004				5.0	331	260	430 - 43
	Fall	1	0	5.1	38	39	9.6	100	485	143	0	0.0	-				-	-	100	460
#6	Winter	3	0	0.0	0	111	7.8	0	1400	458	58	37.0	0.000	0.16	61.2	61	56	287	77	430 - 210
	Spring	3	15	7.7	83	46	10.5	176	493	158	0	4.0	0.000	-	46.8	53	3.0	1385	730	3.9 - 2.3
	Summer	3	20	0.3	0	25	9.3	158	500	160	0	1.0	0.003				5.0	321	250	460 - 39
	Fall	1	0	3.3	24	40	9.6	105	490	143	0	0.0	-				-	-	760	460

REMARKS:
Location
Raw: Manhole at West end of North Dike.
No. 1 : 200 feet East of West dike -- in line with utility pole and island. (500 feet from inlet)
No. 2 : Center of line between utility pole and island. (250 feet from inlet)
No. 3 : 100 feet South of inlet -- in line with No. 2
No. 4 : 200 feet Southeast of inlet -- in line with island.
No. 5 : 100 feet West of outlet -- in line with utility pole. (350 feet from inlet)
No. 6 : 100 feet North of South dike -- in direct line of utility poles. (500 feet from inlet)

LABORATORY ANALYSES
Seasonal Summary 1955

LEMMON, SOUTH DAKOTA

STATION	SEASON	DAYS SAMPLED /Depth	TEMP. °C	DISSOLVED OXYGEN ppm	DISSOLVED OXYGEN % Sat.	B.O.D. ppm	pH	ALKALINITY P ppm	ALKALINITY Total ppm	CHLORIDE ppm	SULFIDE ppm	AMMONIA ppm	NITRITE ppm	NITRATE ppm	NITROGEN ppm	PHOSPHATE Total ppm	PHOSPHATE Ortho ppm	TURBIDITY ppm	SOLIDS Suspended ppm	COLIFORM MPN/100 ml (x 1000)
Raw	Winter	3	10	0.3	-	400	8.2	0	933	214	1.4	51.0	0.204	0.10	82.3	82.3	27.0	473	370	19,000
	Spring	3	11	2.8	-	252	8.0	0	805	233	0.1	23.7	0.137	0.02	50.3	51.6	1.0	650	384	4,580
	Summer	3	-	-	-	142	8.0	0	511	133	0.0	41.8	0.021				22.0	285	228	34,900
	Fall	1	-	-	-	165	8.2	0	860	170	Tr.	4.6	-				20.0	-	316	2,300
#1	Winter	3/1.5'	1	3.3	17	44	8.6	45	857	202	0	10.1	0.011	0.10	17.8	19.3	15.0	130	68	823
	Spring	3/1.5'	10	8.6	84	31	9.3	63	830	233	0	2.2	0.333	0.00	9.8	25.2	1.0	300	120	78
	Summer	3/1.5'	22	4.3	54	16	9.5	150	525	177	0	1.6	0.135				4.0	81	51	163
	Fall	1/1.5'	2	9.9	79	21	9.2	90	790	200	0	0.7	-				0.7	-	104	150
#2	Winter	3/3.0'	1	2.7	21	28	8.6	50	851	201	0	7.9	0.004	0.08	13.6	18.8	13.0	110	65	99
	Spring	2/1.5'	11	8.8	87	28	9.0	100	887	255	0	2.2	0.391	0.02	9.5	20.8	1.5	220	60	29
	Summer	3/1.5'	22	3.2	40	11	9.5	144	485	180	0	2.1	0.151				3.0	77	44	13
	Fall	1/1.5'	2	6.5	52	20	9.1	105	765	188	0	0.7	-				0.7	-	128	93
3-U	Winter	3/3.0'	1	1.0	8	26	8.6	49	854	202	0	7.4	0.002	0.08	12.0	17.4	12.0	107	73	34
	Spring	3/1.5'	10	9.1	88	32	9.0	86	807	218	0	2.2	0.712	-	-	-	1.0	300	140	47
	Summer	3/1.5'	23	7.9	100	13	9.6	140	617	183	0	2.1	0.150	-			4.0	81	57	46
	Fall	1/1.5'	2	7.9	63	18	9.1	140	785	194	0	0.7	-				0.7	-	100	43
3-L	Winter	3/9.0'	2	0.0	0	29	8.5	41	861	207	6.7	9.0	0.005	0.09	13.3	14.6	11.0	143	84	217
	Spring	3/6.0'	10	9.1	88	35	9.0	88	870	237	0	2.2	0.375	0.15	9.4	18.4	1.0	297	83	32
	Summer	3/6.0'	22	2.4	30	9	9.5	456	609	186	0	8.3	0.142				4.0	71	46	20
	Fall	1/6.0'	3	7.8	64	13	9.1	110	790	188	0	0.7	-				0.7	-	96	93
4-U	Winter	3/3.0'	1	2.7	21	27	8.6	53	850	201	0	8.2	0.013	0.13	13.3	16.5	10.0	113	53	37
	Spring	2/1.5'	11	8.4	83	27	9.0	130	840	270	0	2.2	0.529	0.00	9.5	18.8	0.5	226	110	58
	Summer	3/1.5'	23	7.1	90	14	9.6	144	618	183	0	2.4	0.156				3.0	86	69	21
	Fall	1/1.5'	2	8.3	66	15	9.0	120	800	194	0	0.8	-				0.7	-	104	240
4-L	Winter	3/7.5'	2	0.2	2	26	8.6	51	854	206	16.0	7.3	0.008	0.08	11.9	16.8	13.0	110	56	58
	Spring	0/-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Summer	3/6.0'	23	6.6	84	14	9.5	147	619	183	0	8.1	0.163				3.0	83	59	11
	Fall	1/4.0'	2	8.5	67	11	9.0	115	805	194	0	0.7	-				0.7	-	120	150
Effluent	Winter	3/0.1'	1	3.8	30	35	8.6	57	843	200	0	7.7	0.005	0.11	13.7	16.0	10.0	117	39	36
	Spring	3/0.1'	11	8.7	86	29	9.2	90	850	197	0	2.2	0.500	0.00	9.5	18.8	0.7	348	145	36
	Summer	3/0.1'	-	-	-	10	9.6	145	621	184	0	2.4	0.233				4.0	72	58	67
	Fall	1/0.1'	2	7.6	60	12	9.1	140	725	176	0	0.7	-				0.7	-	104	930

REMARKS:

Location :

No. 1 : 200 feet from inlet on line between inlet and outlet.
No. 2 : 500 feet from inlet on line between inlet and outlet.
No. 3 : 200 feet Northwest from outlet.
No. 4 : 600 feet Northwest from outlet.
Effluent: At outlet structure.

LABORATORY ANALYSES
Seasonal Summary 1955

MADDOCK, NORTH DAKOTA

STATION	SEASON	DAYS SAMPLED /Depth	TEMP. °C	DISSOLVED OXYGEN ppm	DISSOLVED OXYGEN % Sat.	B.O.D. ppm	pH	ALKALINITY P ppm	ALKALINITY Total ppm	CHLORIDE ppm	SULFIDE ppm	AMMONIA ppm	NITRITE ppm	NITRATE ppm	NITROGEN ppm	PHOSPHATE Total ppm	PHOSPHATE Ortho ppm	TURBIDITY ppm	SOLIDS Suspended ppm	COLIFORM MPN/100 ml (x 1000)
Raw	Winter	2	-	3.0	-	357	7.9	0.0	605	105	2.7	44.5	0.331	0.12	73.6	53.4	36	425	394	32,000
	Spring	3	-	6.0	-	137	7.8	0.0	627	182	0.0	7.0	0.306	0.00	41.4	32.8	1.0	186	297	2,580
	Summer	3	-	-	-	390	7.7	-	580	106	0.0	15.3	0.207				30	304	270	32,200
	Fall	1	-	-	-	185	8.1	0.0	590	130	0.5	50.0	0.330				45	310	197	930
#1	Winter	3/2.5'	0.0	0.0	0.0	77	8.1	-	912	295	118	19.6	0.004	0.09	20.9	26.2	25	220	45	310
	Spring	3/1.5'	9	13.1	120	20	9.0	137	595	188	0.0	4.5	0.012	0.00	11.8	21.2	1.0	234	137	28
	Summer	3/0.5'	21	0.7	8	10	8.8	95	602	187	0.0	1.3	0.003				8	91	45	138
	Fall	1/0.5'	0.0	9.9	72	4.0	8.4	50	670	199	0.0	23.5	0.160				19.4	180	77	23
#2	Winter	3/2.5'	1	0.0	0.0	88	8.1	-	869	269	114	19.5	0.018	0.08	21.0	26.1	28	230	49	1,800
	Spring	3/1.5'	10	12.6	116	15	8.9	135	585	160	0.0	4.45	0.015	0.02	11.5	20.0	1.0	239	137	20
	Summer	3/0.5'	21	0.5	6	11	9.0	100	618	183	0.0	1.3	0.004				8	83	43	280
	Fall	1/0.5'	0.0	10.1	74	2.6	8.4	60	675	198	0.0	21.8	0.150				20	190	65	43
#3	Winter	3/2.5'	1.0	0.0	0.0	83	8.1	-	918	291	119	20.9	0.002	0.10	21.1	25.9	29	217	54	1,400
	Spring	3/1.5'	10	12.7	116	13	9.0	120	575	164	0.0	3.0	0.015	0.00	11.2	22.0	0.5	246	140	21
	Summer	3/0.5'	21	0.5	6	12	9.1	100	613	180	0.0	1.2	0.004				8	91	48	207
	Fall	1/0.5'	0.0	9.4	69	1.0	8.5	55	660	197	0.0	21.8	0.185				21	170	108	23
#4	Winter	3/2.5'	0.0	0.0	0.0	16	8.2	-	1060	449	42	1.7	0.006	0.10	-	16.3	18	98	27	23
	Spring	3/1.5'	9	9.6	88	3.1	8.7	97	520	200	0.0	1.0	0.006	0.00	0.0	7.8	0.5	26	30	0.620
	Summer	3/0.5'	22	1.7	20	3.4	9.0	90	627	255	0.0	0.8	0.003				5	17	22	0.820
	Fall	1/0.5'	0.0	12.1	88	2.3	9.2	132	520	314	0.0	0.7	0.086				5	29	22	0.036
#5	Winter	3/2.5'	0.0	11.4	83	2.9	8.6	59.6	731	354	0.0	0.7	0.002	0.10	1.3	4.6	4	12	12	0.030
	Spring	3/1.5'	9	9.8	90	2.1	8.7	87	478	224	0.0	0.7	0.009	0.00	0.0	4.0	1.0	15	29	0.050
	Summer	3/0.5'	21	6.9	81	4.3	9.5	88	435	256	0.0	0.5	0.002				5	12	30	0.030
	Fall	1/0.5'	0.0	12.1	88	1.7	9.5	145	445	288	0.0	0.7	0.060				1.2	25	10	0.036
#6	Winter	3/2.5'	0.0	11.4	83	3.7	8.6	65.7	721	348	0.0	0.5	0.004	0.13	-	4.6	4	12	14	0.030
	Spring	3/1.5'	9	9.9	91	1.7	8.8	75	488	194	0.0	1.2	0.026	0.00	0.0	4.0	0.5	17	32	0.030
	Summer	3/0.5'	22	5.7	68	5.8	9.3	103	418	237	0.0	0.4	0.002				5	7	7	0.110
	Fall	1/0.5'	0.0	12.2	69	1.7	9.5	135	422	287	0.0	0.7	0.050				1.2	25	6	0.000

REMARKS

Location :

Raw : At lift station. Sample collected as flow entered wet well.
No. 1 : 125 feet from North and East dike (in first Pond)
No. 2 : First Pond; Directly over inlet.
No. 3 : First Pond; Approximately 25 feet North of outlet.
No. 4 : Second Pond; 200 feet South of inlet and 300 feet from East dike.
No. 5 : Third Pond ; 50 feet East of inlet.
No. 6 : Third Pond ; 125 feet from North and West dikes.

LABORATORY ANALYSES
Seasonal Summary 1955

WISHEK, NORTH DAKOTA

STATION	SEASON	DAYS SAMPLED /Depth	TEMP. °C	DISSOLVED OXYGEN ppm	DISSOLVED OXYGEN % Sat.	B.O.D. ppm	pH	ALKALINITY P ppm	ALKALINITY Total ppm	CHLORIDES ppm	SULFIDE ppm	AMMONIA ppm	NITRITE ppm	NITRATE ppm	NITROGEN ppm	PHOSPHATE Total ppm	PHOSPHATE Ortho ppm	TURBIDITY ppm	SOLIDS Suspended ppm	COLIFORM MPN/100 ml (x 1000)
	Winter	3	6	2.6	-	499	8.1	0	560	68	1.3	59	0.306	0.18	140	62.7	65	717	885	60,300
Raw	Spring	3	19	5.7	-	195	8.1	0	443	55	0.05	44.5	0.155	0.00	186	31.2	2	218	277	19,950
	Summer	3	-	-	-	219	7.6	0	430	54	0.0	24.0	0.172				19	196	137	42,000
	Winter	3/1.5'	-	0.0	0	132	7.7	0	631	98	125	60	0.221	0.11	65	48.3	48	202	87	2,230
#1	Spring	3/1.5'	15	8.9	95	51	9.4	80	343	82	0.0	44.5	0.060	0.00	28.9	26.8	2	485	248	99
	Summer	3/0.5'	22	0.4	5	24	8.8	32	291	74	0.4	1.5	0.014				6	149	75	-
	Winter	3/1.5'	0	0.0	0	157	7.5	0	779	126	47	62	0.000	0.09	68	63.9	55	293	85	2,600
#2	Spring	3/1.5'	15	8.7	93	51	9.5	78	402	76	0.0	26.8	0.057	0.00	29.9	24.8	1	489	237	244
	Summer	3/0.5'	22	3.8	46	28.4	9.1	38	282	74	0.0	1.2	0.007				4	141	67	-
	Winter	3/2.0'	-	0.0	0	144	7.6	0	925	157	59	63	0.001	0.10	62	60.1	60	317	66	2,243
#3	Spring	3/1.5'	15	9.0	96	50	9.5	73	413	79	0.0	25.2	0.062	0.00	29.4	25.2	1.5	440	237	112
	Summer	3/0.5'	22	3.3	40	19.1	9.2	38	287	75	0.0	1.5	0.003				5	143	75	-

REMARKS

Location :

Raw : M.H. Northeast of Imhoff Tank building.
No. 1 : 100 feet West of inlet.
No. 2 : Center of line between outlet and island.
No. 3 : 100 feet from outlet on line between outlet and island.

Fall Samples:

No samples were taken in the Fall because the operator at Wishek had drained the pond just prior to the Fall survey.

APPENDIX III

SOUTH DAKOTA DEPARTMENT OF HEALTH

DESIGN CRITERIA FOR SEWAGE STABILIZATION PONDS

A. General

1. A preliminary report for proposed sewage stabilization pond installations should be submitted for review prior to preparation of final plans. This report shall include the shape of the cell(s) (B-4), a description of soil characteristics as revealed by test borings (E-3), size, location, and other such proposed design features.

2. The review of proposed stabilization pond installations will be carried out on an individual basis with local conditions taken into consideration.

3. All plans and specifications shall be submitted at least 30 days prior to date upon which action by the approving authority is desired.

4. Construction as early as is possible during the construction season is encouraged to permit some initial summer operation.

B. Design

1. Original construction should provide at least one surface acre per one-hundred (100) population plus the industrial waste population equivalent, if significant. In terms of B.O.D., a loading of 20 pounds per surface acre should not be exceeded. Due consideration should be given possible future municipal expansion and/or additional sources of wastes when the original land acquisition is made.

2. The choice between the use of single cell and multiple cell ponds will be dictated on the basis of local conditions and downstream water use. Where a greater degree of treatment is necessary or desirable, one or more cells in series may be added to the primary cell; provided, however, that the primary cell should have a surface area equal to that set forth in B-1.

3. Where ponds of one or more cells follow some type of conventional treatment device, the requirements in B-1 may be reduced to compensate for the B.O.D. reduction in the pre-treatment unit(s). However, the area of the first or primary cell following the pretreatment unit(s) should be not less than 75% of B-1.

4. The shape of all cells should be such that a uniform perimiter results. No islands or peninsulas will be permitted.

C. Location

1. Ponds should be located at a practical distance away from built-up areas with due respect given to possible future expansion of the city.

2. Locating ponds in watersheds receiving significant amounts of runoff water is discouraged unless adequate provisions are made for storm water to by-pass the ponds.

3. In locating ponds, preference should be given sites which will permit an unobstructed wind sweep across the ponds, especially in the direction of the local prevailing winds.

4. Proximity of ponds to water supplies and other facilities subject to contamination should be critically evaluated to avoid creation of health hazards or other undesirable conditions.

D. Embankments and Dikes

1. Compacted embankments of impervious materials should be constructed.

2. Minimum embankment top width should be 8 feet. Lesser top width will be considered for very small installations.

3. Maximum embankment slopes should not be steeper than:

   a. Inner - 3 horizontal to 1 vertical (preferably 4 or 5 to 1).

   b. Outer - 3 horizontal to 1 vertical.

4. Minimum embankment slopes should not be flatter than:

   a. Inner - 6 horizontal to 1 vertical.

   b. Outer - not applicable, except that significant volumes of surface water should not enter the ponds.

5. Minimum free board should be 3 feet plus frost heave.

6. Minimum normal liquid depth should be 3 feet.

7. Maximum normal liquid depth should be not more than 5 feet. For ponds with surface areas of more than 10 acres, special consideration will be given to maximum liquid depths greater than 5 feet provided such depths are minimal in area.

8. Embankments should be seeded, except below the water line. Alfalfa should not be included in seed mixtures since the long roots of this plant are apt to impair the water-holding efficiency of the dikes. Additional protection for embankments (rip-rap) may be necessary as soil conditions and pond size warrant.

E. Pond Bottom

1. The pond bottom should be as level as possible at all points. Shallow or feathering fringe areas usually result in locally unsatisfactory conditions.

2. The bottom should be cleared of vegetation and debris. Organic material thus removed should not be used in embankment construction.

3. Soil formations should be relatively tight to avoid undue liquid losses through percolation or seepage. Soil borings to determine soil characteristics shall be made a part of preliminary surveys to select pond sites.

F. Influent Lines

1. Any generally accepted material for pond piping will be given consideration but the material selected should be adapted to local conditions. Special consideration should be given to the character of the wastes, possibilities of septicity, exceptionally heavy external loadings, abrasion, the necessity of reducing the number of joints, soft foundations, and similar problems.

2. The influent line into single-celled ponds should be essentially center-discharging. Influent lines into the primary section of multiple-celled ponds should be essentially center-discharging, but this does not apply to those cells following the primary cell in series operation.

3. Either vertical or horizontal discharging influent lines may be used. When vertical discharging lines are used the discharge end of the pipe should be located approximately one foot above the bottom of the pond and should not extend to such elevation that ice will damage the terminal structure during winter operations.

4. The end of the discharge line should rest on a suitable concrete apron with a minimum size of two feet square. Larger aprons and influent piping supports are suggested in cases where the soil is unstable. Flow splitters or dispersing devices are also desirable where a horizontal type of influent line terminal structure is utilized.

5. Influent and effluent piping should be located to minimize short circuiting within the pond.

6. Manholes or clean-outs are recommended where pipes pass through the embankment.

7. Influent lines should be placed in or near the bottom. The use of exposed dikes carrying influent lines to the center of the pond will not be approved.

G. Interconnecting Piping and Overflows

1. Interconnecting piping and overflows should be of cast iron pipe or corrugated metal pipe of ample size. The use of frost proof overflow manholes or valve boxes for controlling liquid levels in the pond is recommended. Multiple influent lines to such structures should be provided and arranged so that overflows will ordinarily come from, at, or near the surface of the pond. The lowest of the multiple influent lines to such manholes or structures should be at least twelve inches off the bottom to control eroding velocities and to avoid pickup of bottom deposits.

2. Overflow lines should discharge into anchored concrete slabs. These lines should be vented if siphoning may be developed.

H. Miscellaneous

1. The pond area should be adequately fenced with a stock-tight fence.

2. Appropriate signs should be provided to designate the nature of the facility.

3. Provisions for flow measurement should be provided. Facilities for installation of a weir would be adequate for most installations.

I. Industrial Wastes

1. Ponds for industrial waste require special planning and study, and these suggested minimum standards do not apply. The South Dakota Department of Health should be consulted on such problems before the design phase is completed.