Wastewater: Is Muskegon County's Solution Your Solution?

This booklet was written by John M. Walker, Office of Research and Development, U.S. Environmental Protection Agency, Region V with the assistance of the Office of Public Information and Intergovernmental Relations, the Office of the Great Lakes Coordinator, the Construction Grants Branch, and other groups within Region V. Their important contributions along with the cooperation of Muskegon County, the Michigan Water Resources Commission, Michigan State University, and the University of Michigan are gratefully acknowledged. Much of the data on the Muskegon County System was obtained from the Draft Muskegon County Report for the period 1968-1975 prepared by Y.A. Demirjian and his staff.

Second Printing, by the Office of Water Programs Operations in Washington, D.C., March 1977.

Foreword

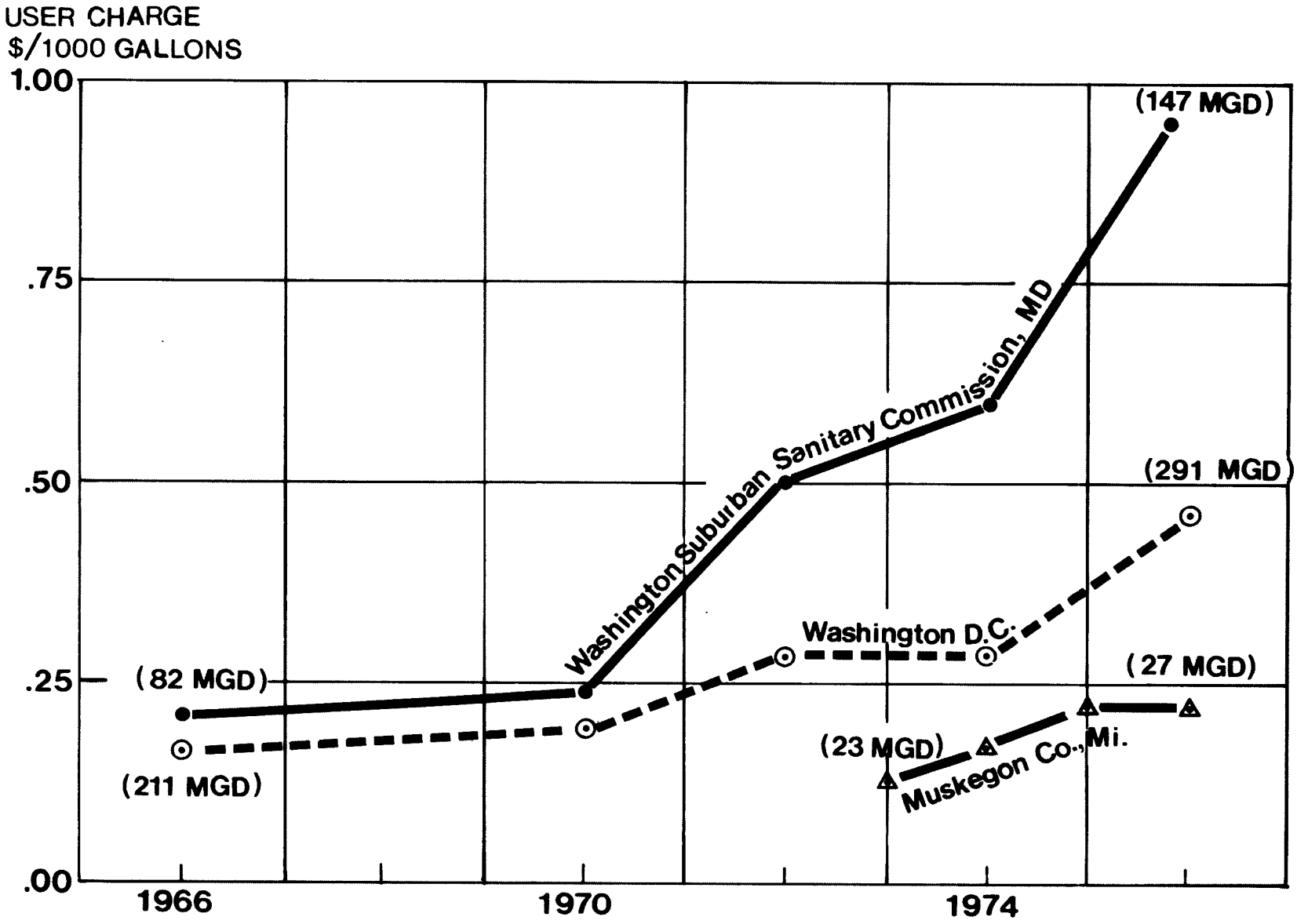
Muskegon County has innovatively transformed a comprehensive idea for utilizing and renovating wastewater by land treatment into a very cost effective operational system. Their land treatment system has nearly eliminated industrial and municipal pollutants from the 27 million gallons of wastewater treated each day, thereby protecting the County's lakes and streams as well as Lake Michigan. It has utilized wastewater as water and fertilizer to grow over a quarter million bushels of corn in 1975 on previously unproductive land, thereby reducing operating costs. This successful wastewater system is also serving as a focal point in the County's efforts to revitalize their economy. This booklet has been prepared for both urban and industrial communities that face wastewater and economic problems and that might benefit from the Muskegon County experience.

The citizens, industries, consultants, and leaders of Muskegon, along with officials and groups throughout the state of Michigan have to be extremely proud of their cooperative accomplishments. Their efforts to achieve these difficult goals have required great courage, patience, and skill. The U.S. Environmental Protection Agency is very happy that it has been able to contribute.

We hope that Muskegon's success with wastewater utilization, renovation,and community revitalization will continue and that it will serve as a valuable example and information base for other communities in dealing with their wastewater problems. The Environmental Protection Agency is continuing its support of evaluational and operational studies on the Muskegon County System to gain essential information for planning, implementing, and operating other proposed systems.

George Alexander, Jr.
Regional Administrator
USEPA Region V
September 1976

SKYROCKETING WASTEWATER TREATMENT COSTS



Your Problem

Nearly every community is faced with the problem of cleaning its dirty water. Surface and ground waters are being polluted by discharges of poorly treated wastewater. Communities without sewers are finding that their individual septic tanks and cesspool systems are causing groundwater pollution. Communities with sewers are finding that their existing wastewater treatment systems are overloaded and inadequate to meet the requirements of Public Law 92-500, the Federal Water Pollution Control Act Amendments of 1972, for providing increasingly greater degrees of wastewater treatment. Needed residential, commercial, and industrial development is being restricted because existing treatment systems lack the capacity to handle the additional volumes and because traditional treatment processes cannot cope with the increasingly complex character of the wastes of modern urban-industrial activity.

Costs for wastewater treatment are skyrocketing. While appreciable fractions of the capital costs for local wastewater treatment facilities can be funded with federal dollars through the Environmental Protection Agency, it is your income tax that increases to pay the bills. In addition, your local taxes and sewer user charges increase to pay all of the operating costs and your local share of the capital costs. Sewer user charges have routinely increased between 200 and 500% over the past 10 years.

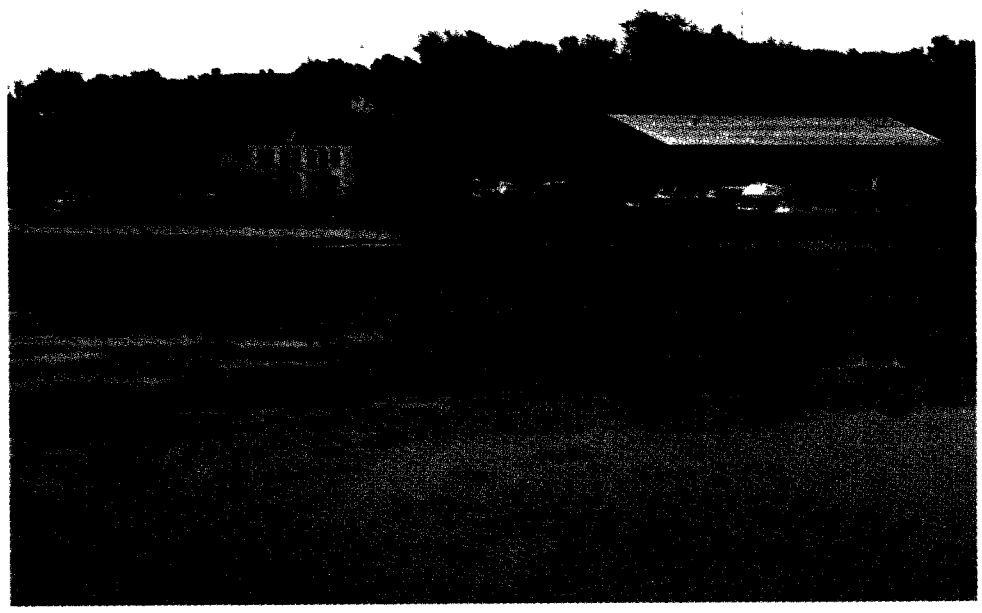
Many of the complex new advanced waste treatment systems being built today consume large amounts of both energy and resources and in some instances are just too costly to operate.

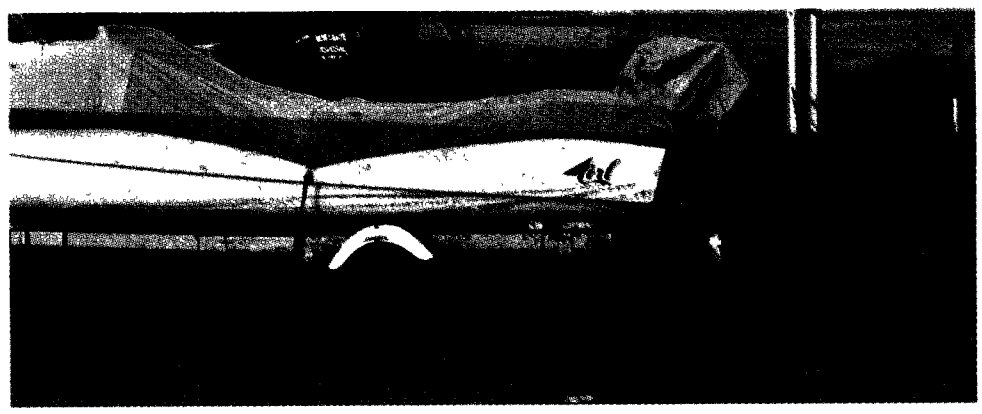
Muskegon County's Problem

Before the Wastewater System

S.D. Warren, a division of Scott Paper Company in Muskegon County, recognized the need to overcome this environmentally objectionable discharge of partially treated wastewater into Muskegon Lake. Faced also with several other difficulties in the late 1960's, the deciding factor in the plant's remaining in operation was the promise of joining Muskegon County in obtaining an environmentally acceptable, cost attractive, land treatment solution.

(see also page 34).





Weeds in White Lake Adversely Affected Recreation

Near the end of the 1960's, citizens and community leaders in Muskegon County were becoming increasingly aware of very serious problems in their community. Each of the many independent communities in Muskegon County were trying to deal separately with their own municipal and industrial wastewaters in small overburdened treatment facilities. Several of the main industries and principal communities in Muskegon County were discharging their wastewater directly into the lakes with inadequate treatment. The County's three main recreational lakes were being polluted. Depending upon the specific lake, there was visible direct pollution, periods of foul odor, severe algal blooms, and/or loss of open water surface to weeds. Swimming and boating in the lakes was unpleasant and becoming unsafe.

Along with their surface and wastewater problems, older industries were leaving or closing rather than rebuilding. New industries and businesses were not coming to Muskegon. The frustrations and strains of these complex overlapping problems were causing residents to lose hope and pride in their communities.

Muskegon County's Solution

Community leaders and their planners in Muskegon County began to come to grips with the seriousness of their many problems in 1969. Interestingly, a common denominator of most problems was dirty water - sewage and dirty streams, rivers, and lakes.

This very important step of recognizing and defining the problem was the first of many difficult tasks in implementing a solution. Enormous political difficulties were involved in uniting the many independent communities within the County toward development of a common wastewater treatment system. Authorities, including those at the State level and in the Federal Water Quality Administration (a predecessor of EPA) had to be convinced that their idea for wastewater utilization and renovation by spray irrigation and crop production on sandy, unproductive soil was worthy of funding and support. There were no adequately studied large scale similar operations in the world to use as a basis for predicting possible success. This made the task of designing and building a spray irrigation system that would reliably handle over 43 million gallons per day (MGD) of wastewater and provide efficient treatment while conserving the integrity and developing the quality of the soil, very difficult.

Planning and Coordination Among Cooperating Governmental Units

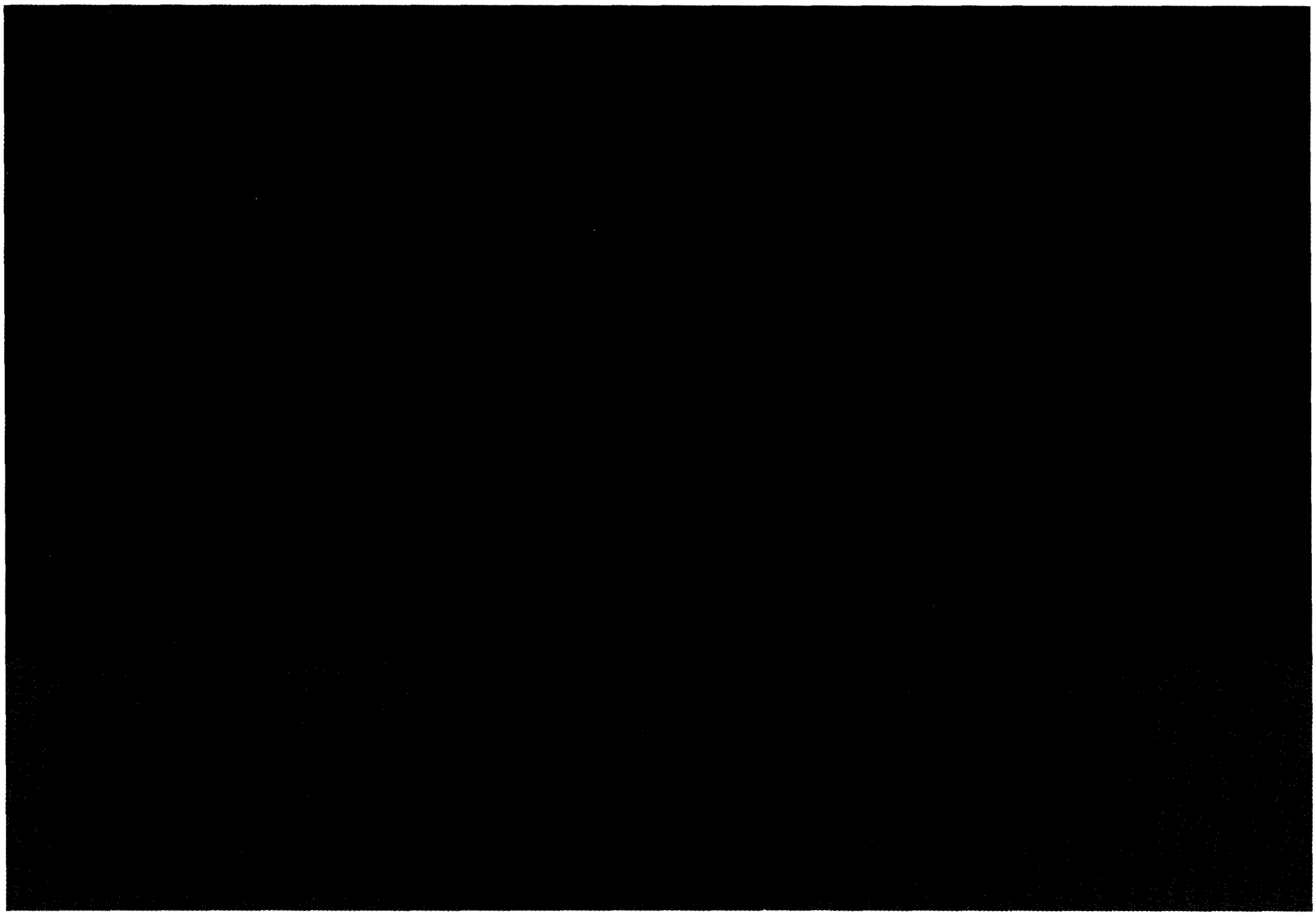
Congressman Guy Vander Jagt R Michigan at Groundbreaking

Muskegon County's Solution

The Costs.. Their combined efforts have resulted in a land treatment system which is yielding very cost effective treatment and utilization of wastewater. Construction costs were approximately $44 million with approximately 45% of the funding from Federal sources (See Detail A).

The 1975 total cost for treatment, including collection, transmission, aeration, land treatment, depreciation, amortization, and debt retirement, was 24¢/1000 gallons of wastewater. This cost is charged to users via a 17¢/1000 gallon operational and a 4.5¢/1000 gallon debt retirment fee (22¢/1000 gallon user charge) and acreage charges. A detailed presentation of operating costs is given in Detail B.

Muskegon County's 22¢/1000 gallon sewer user charge is the lowest of any of the several systems surveyed regardless of the level of treatment given to the wastewater, with the exception of the large Detroit system. The Detroit system charges 16¢/1000 gallons and provides only primary treatment to a majority of its wastewater.



SEWER USER CHARGES, 1976*

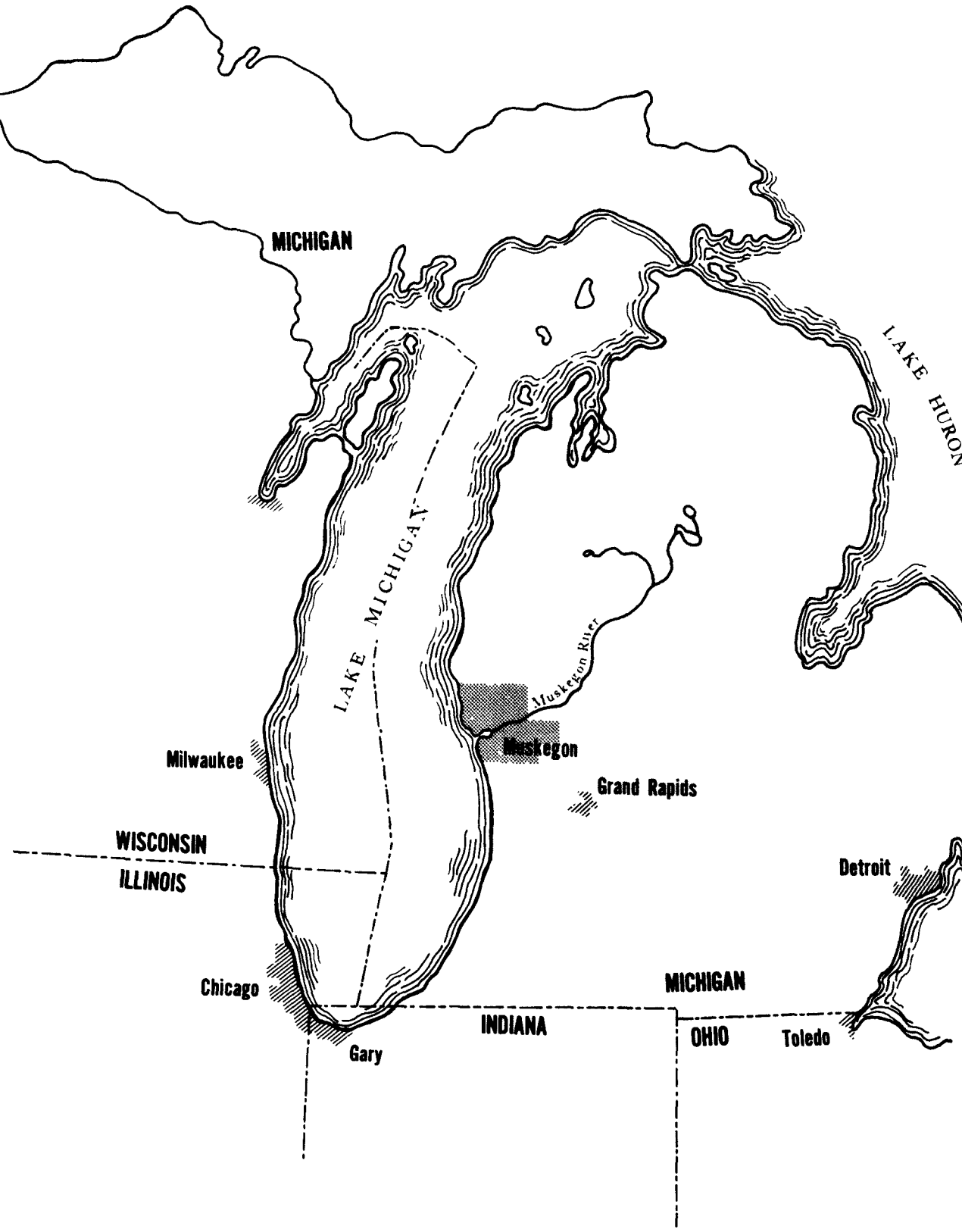
Wastewater Treatment Plants	User Charge $/1000 G	Water Treated MGD	Level of Treatment
Detroit, MI	0.16	930	P + [S]
Grand Rapids, MI	0.29-0.48	45	P + S + [CP]
Lansing, MI	0.41-0.53	25 [36]	P + S + [CP + SF]
Washington, D.C.	0.36-0.56	291 [308]	P + S + CP + [N, etc.]
Suburban D.C. in MD.	0.95	147**	P + S + CP + [N, etc.]
East Lansing, MI	0.85	12 (19)	P + S + CP + SF
Belding, MI	0.40-1.00	0.5	Oxidation lagoons + [SI]
Muskegon Co., MI	0.22+	27 (43)	Aeration + SI

[ ] = Under construction, not yet in service or only in partial service
( ) = Capacity available but not yet utilized
P = Primary
S = Secondary
CP = Chemical precipitation of phosphate
SF = Sand filter
N = Nitrogen treatment
SI = Spray Irrigation

Sewer user charges are calculated on a different basis by every wastewater treatment authority. The charges in this table do not reflect acreage, front foot, or drainage fees; taxes; or any other sewer related charge unless levied as a fraction of water used or sewage treated. The user charges may or may not include capital debt repayment. These charges are also from cities or regions with different wastewater treatment capacity and level. While an absolute comparison of charges cannot then be made, the relative differences in charges still reflect the favorable cost effectiveness of the Muskegon land tertiary treatment system, even when compared with systems providing only primary treatment.

**Part of the Suburban D.C. flow in M D. is a part of the Washington, D.C. flow.*

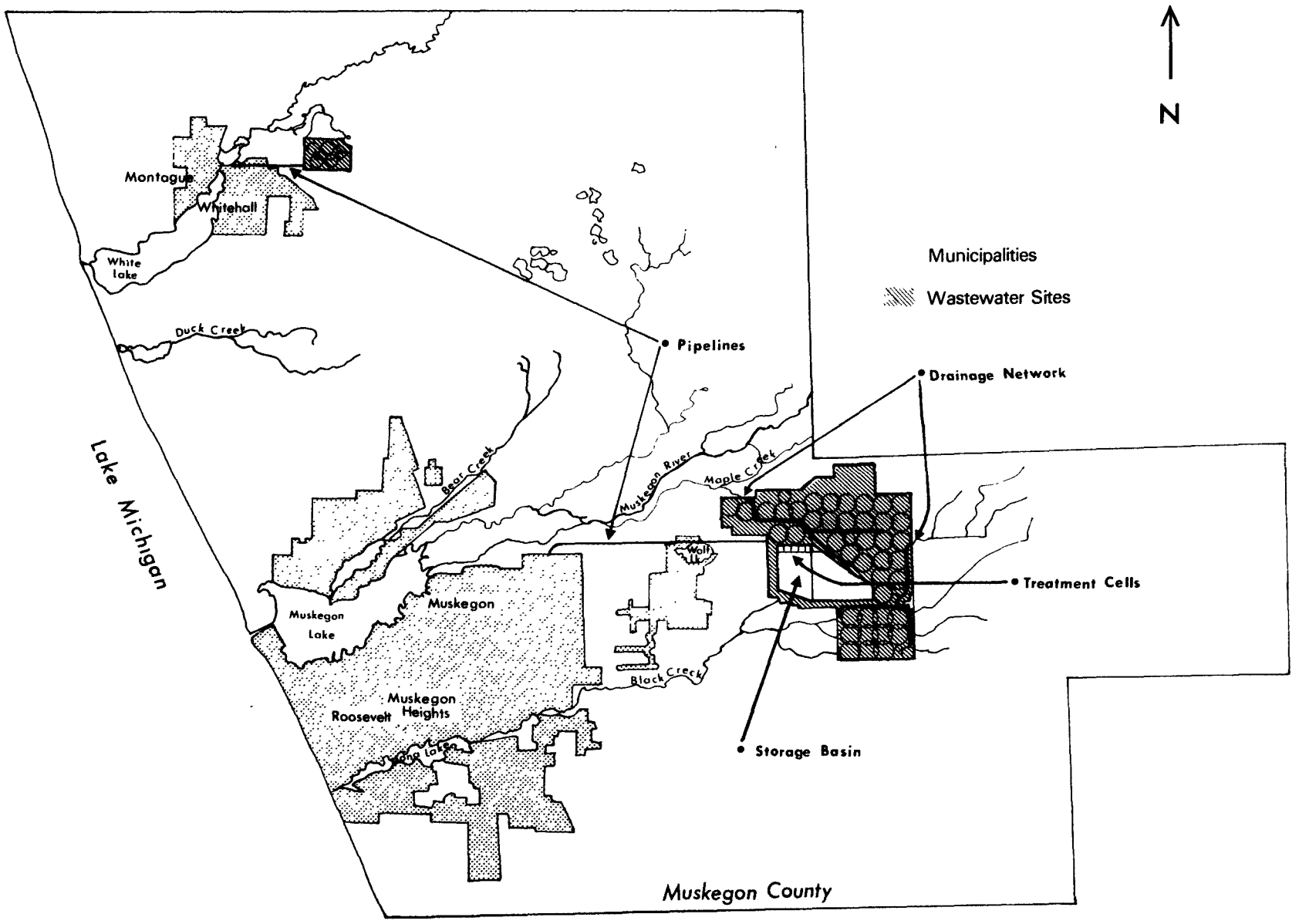
+ *The wastewater system contract fee to communities and major industries in Muskegon County. Local communities levy their own user charges to cover maintenance of their local sewer collection systems and their administrative costs.*

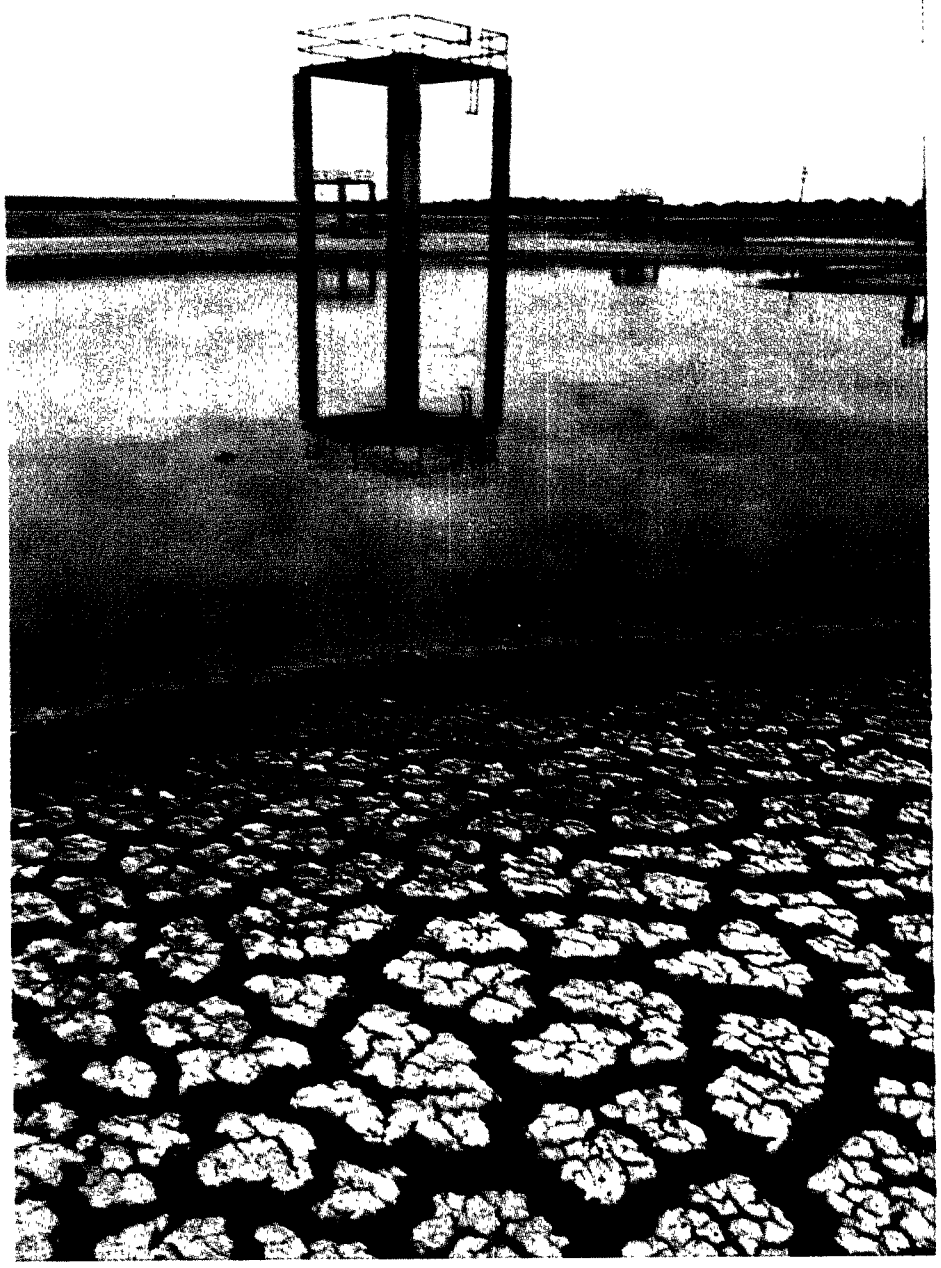


Michigan is one of the Great Lakes States. Under Section 208 of Public Law 92-500 the Great Lakes States are planning management of their watershed basins. Watershed management is planned at sub-state regional levels. Taking each regional management plan together the water quality of the overall Great Lakes basin is affected.

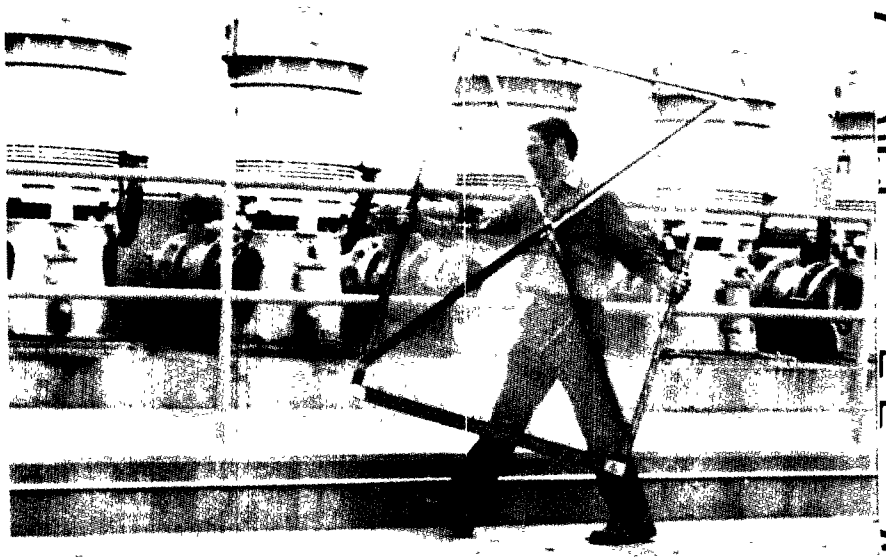
Muskegon County, Michigan (population 160,000), which lies directly along the Lake Michigan Coast, began its plan prior to PL 92-500. Data on its experiences are needed for section 208 planning activities in the Great Lakes States and elsewhere in the country.

The County Wide system has two separate wastewater treatment areas, a 10,500 acre site near Muskegon and a 600 acre site near Whitehall. Renovated water from the Whitehall site goes through the White River on its way to White Lake and Lake Michigan. Renovated water from the main Muskegon site goes in part through Mosquito Creek into Muskegon Lake and in part through Big Black Creek into Mona Lake before emptying into Lake Michigan.

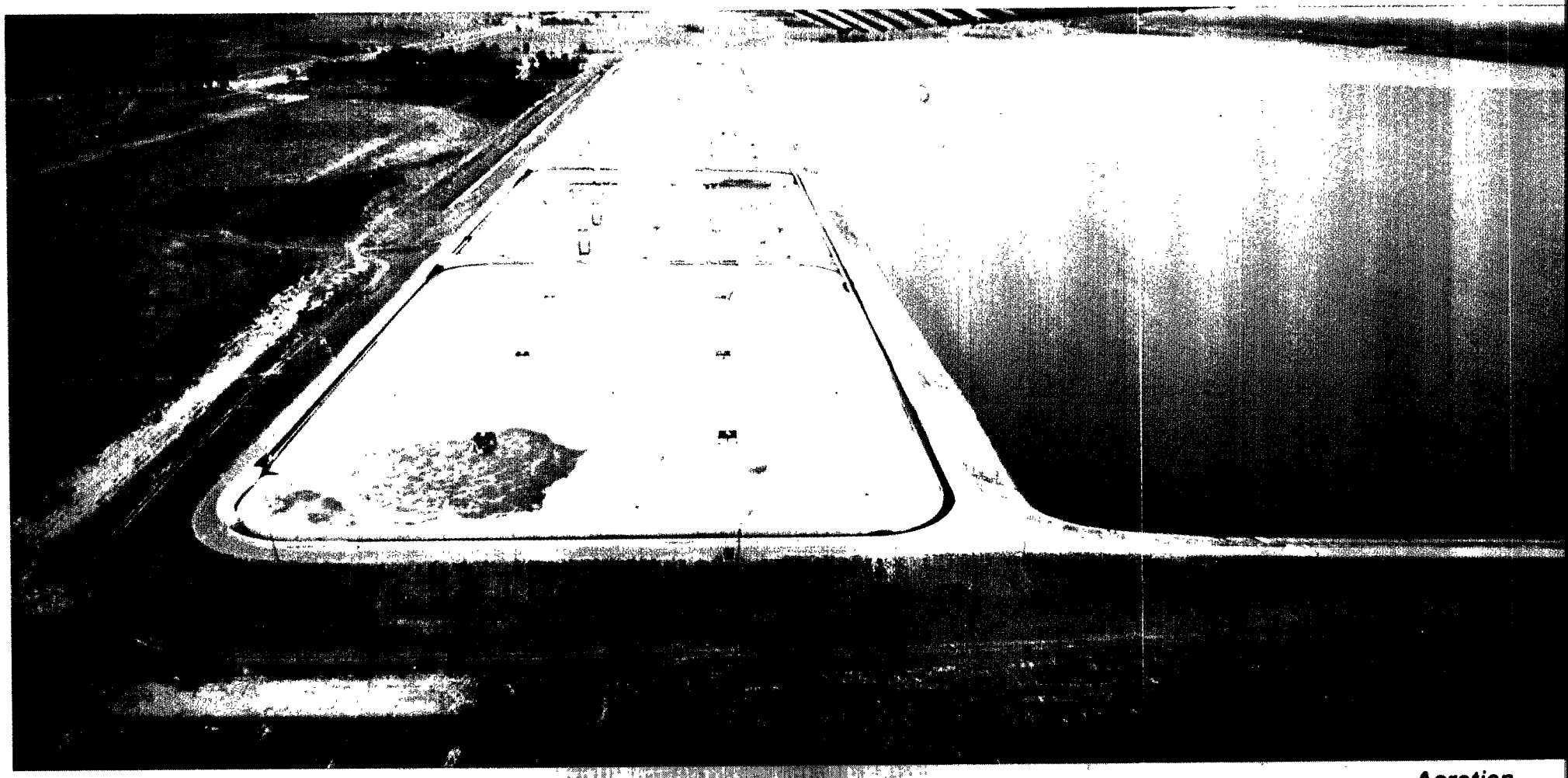




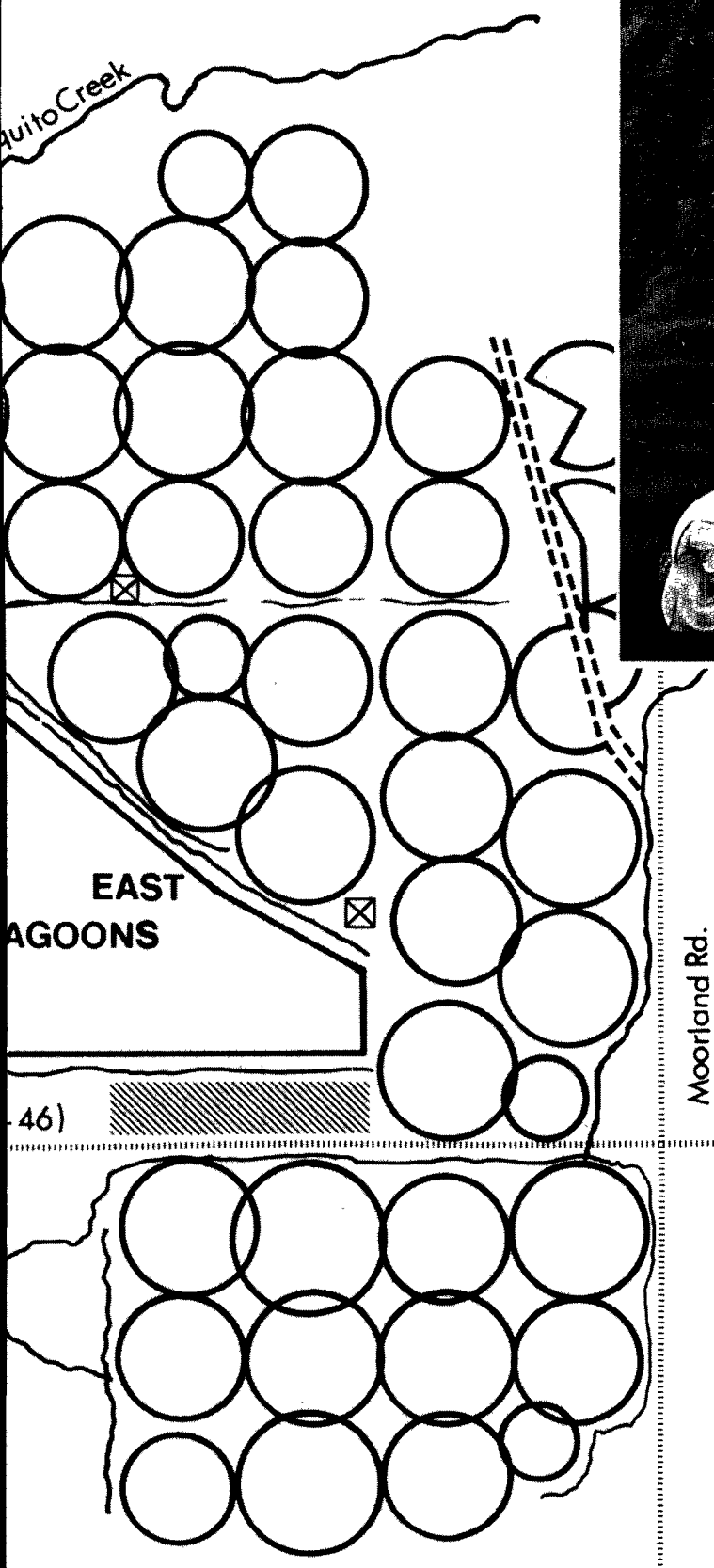
Sludge in Aeration Cell

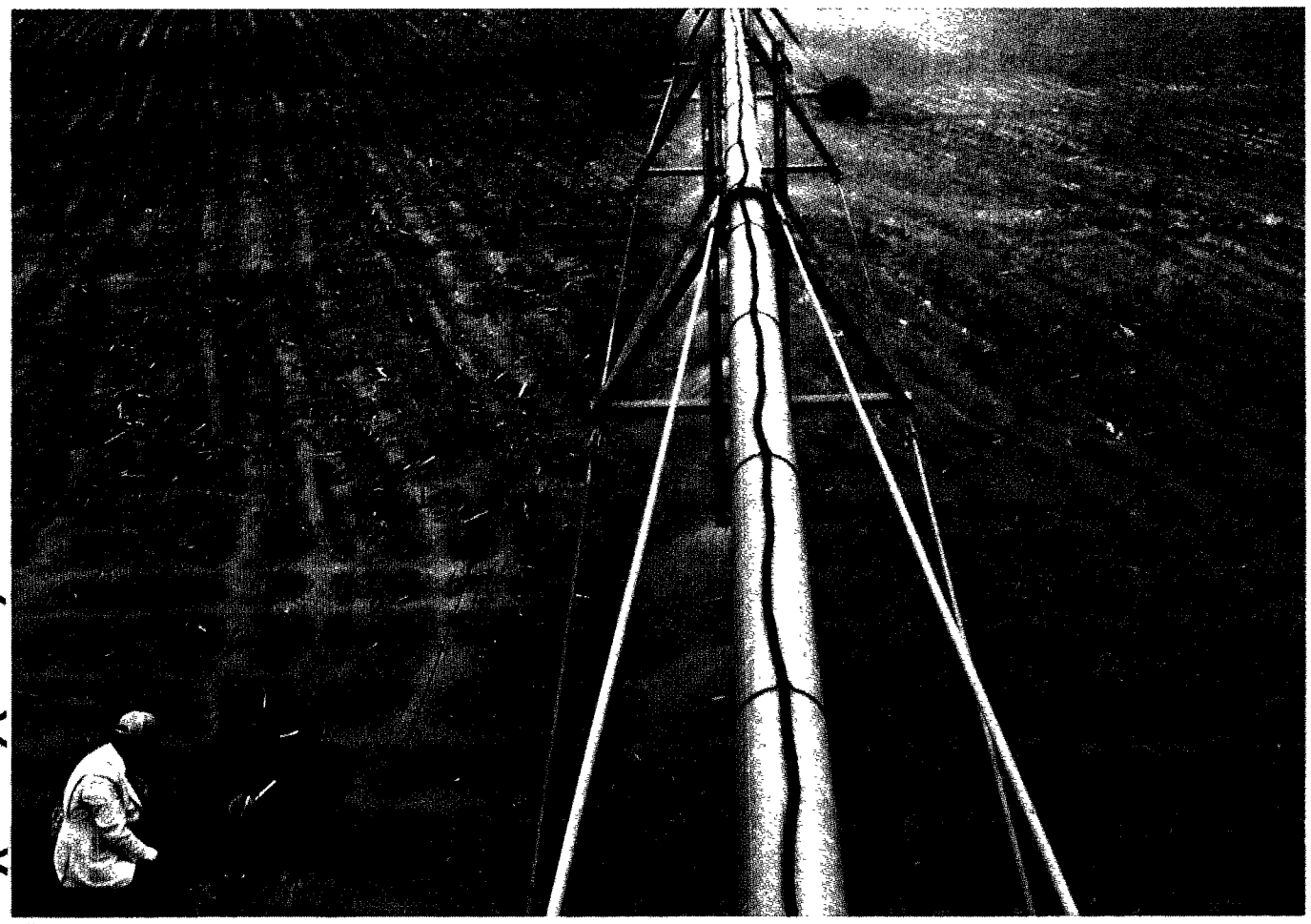


Screening Wastewater Before Irrigation



Aeration





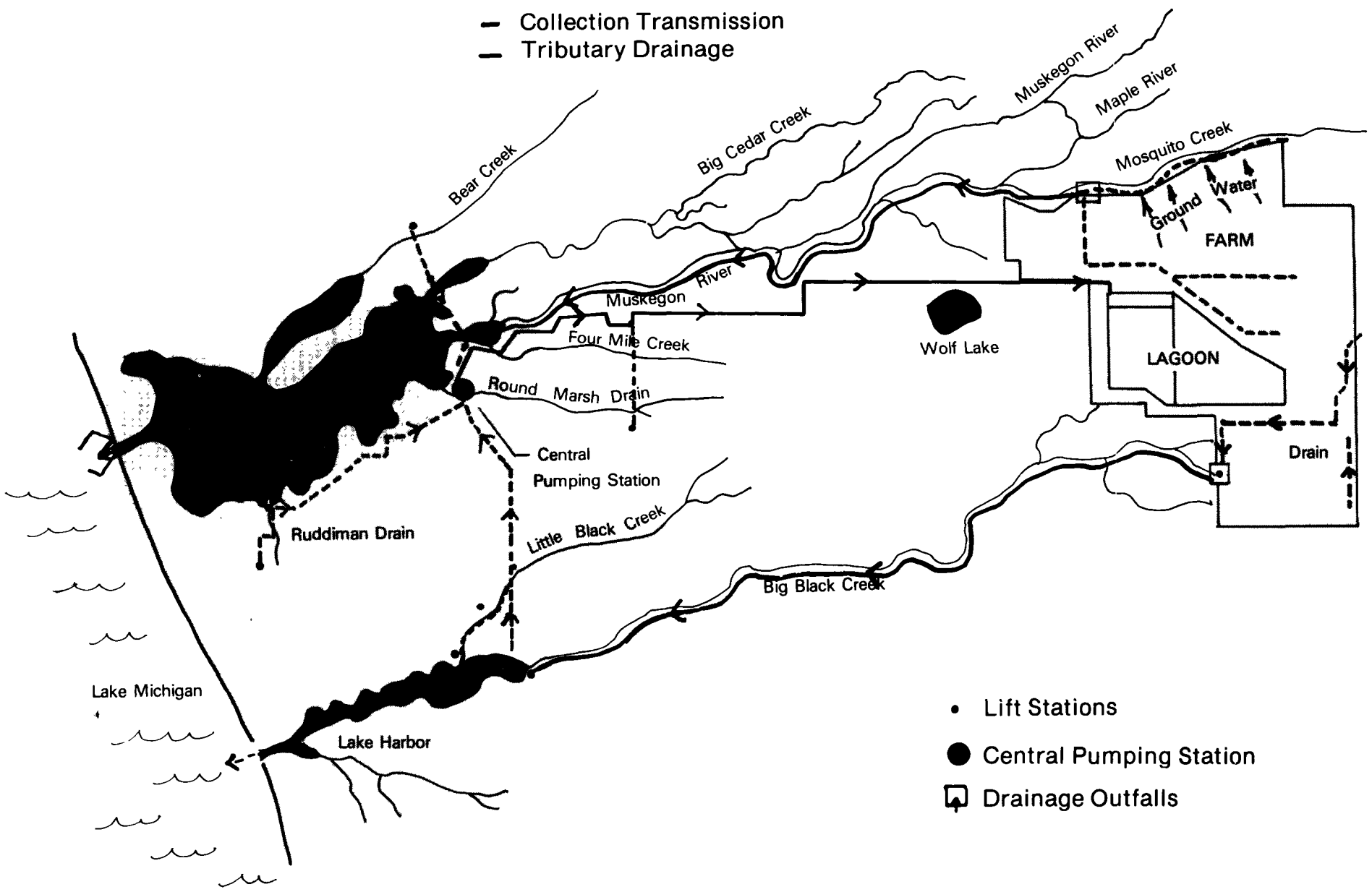
Wastewater Irrigation on Corn

Renovated Wastewater - by Crop and Soil

The System. The Muskegon County Wastewater Management System is comprised of two separate systems of similar design. One system is large (42 MGD wastewater treatment design capacity) and one is small (1.4 MGD). The small separate system was built as an economical alternative to a long expensive sewer connection. This booklet describes only the large system.

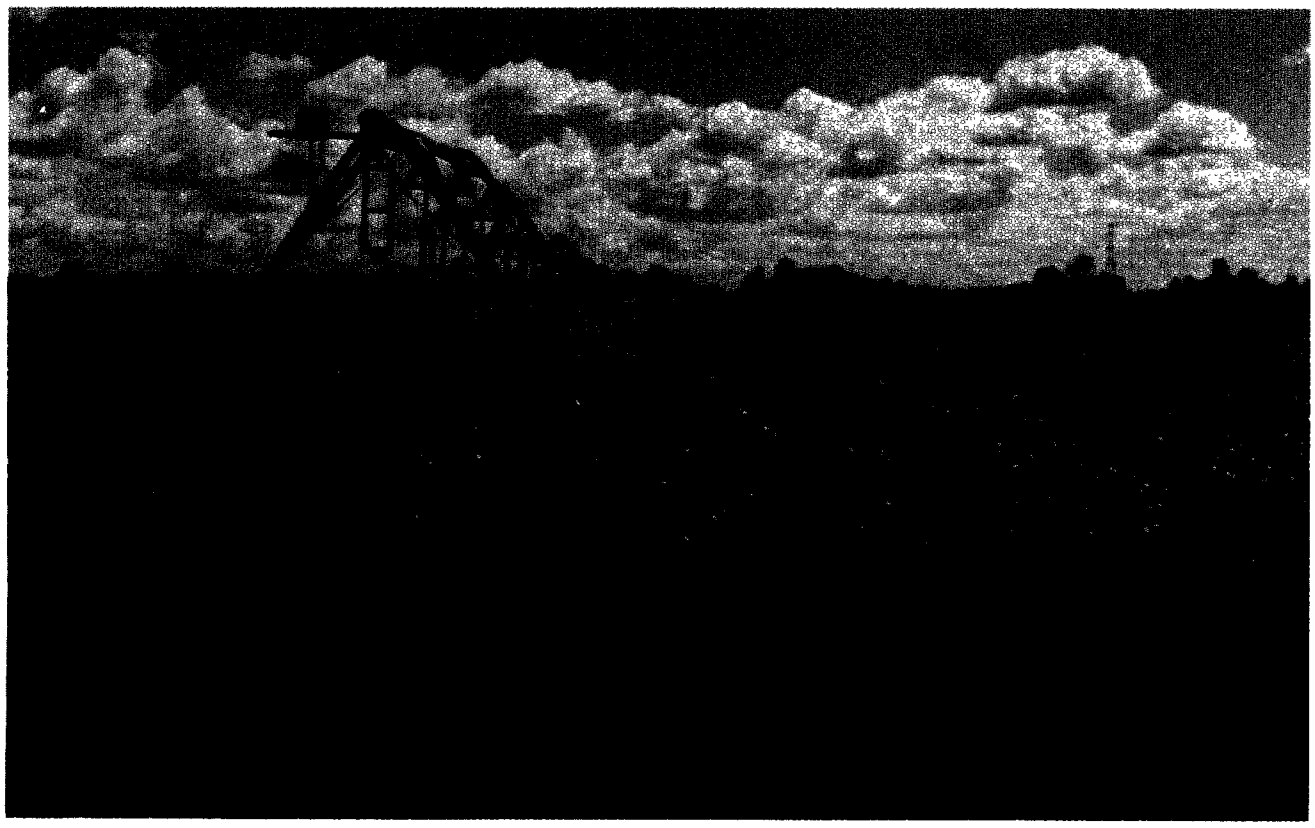
The system consists of collection, transmission, aeration, storage, irrigation, soil, crop, and drainage components. The system treated 27 MGD of wastewater in 1975, 60% of which was industrial flow, leaving a reserve capacity of 15 MGD for serving additional residential and industrial development. (Acreage requirements of various portions of the system are shown in Detail C.)

Wastewater Collection and Transmission. Wastewater is collected via connector sewers and ten lift stations which deliver wastewater to a central pumping station. The wastewater is pumped from the central lift station, eleven miles, through a 66-inch diameter pipe line to the land treatment site.



Aeration and Storage. After reaching the treatment site, wastewater can be aerated in each of three 8-acre 42-million-gallon capacity aeration cells. There are six 50-horsepower mixers and twelve 60-horsepower aerators in each cell. Research and operating experience justified reducing the amount of aeration needed and cut electrical energy used drastically. The aeration mode most often used at this time is treatment with 8 aerators in cell 1 followed by treatment with 4 aerators in cell 2. With the current 27 MGD flow, the average retention time is about 1.5 days in each cell. After aeration in winter, the water flows into the storage lagoons. During the summer, the aerated water may either be sent into storage or retained briefly in an 8-acre solids settling cell before application on land through the irrigation system. There are two storage lagoons, each 850 acres in size, with a combined storage capacity of 5 billion gallons.

Final Disinfection. Before water is irrigated onto the land, it enters a discharge cell. Prior to entering irrigation ditches that supply the water to pumping stations, the water is chlorinated as necessary to meet health standards.



Irrigation and Farming. The pretreated wastewater is distributed to center pivot irrigation rigs via buried asbestos cement pipes (Detail D). The operating pressure is from 30 to 70 psi depending upon location in the system. The rigs were especially designed for spraying wastewater with downward pointing low pressure nozzles. There are 54 center pivot irrigation rigs located in circular fields of 35 to 140 acres. The soils are mostly sandy (Detail D).

During the 1975 season, 4500 of the 5400 irrigated acres were planted with corn and irrigated with up to 4 inches per week of wastewater. The other 900 acres were fallow or in rye grass. Total wastewater applied to the 5400 acres varied from none to over 100 inches per field during 1975 (Detail D). Irrigation was performed from mid-April to mid-November with time out for cultivating, planting, and harvesting the corn crop. Thus far corn has been the main crop. Corn planted in 1975 yielded an average 60 bushels per acre (31 to 90 bushels per acre, Detail E), which was nearly equal to the 65 bushel per acre average corn grain yield in Muskegon County on operating farmland. The average corn grain yield on 4700 acres in 1974 (the initial year of operation) was 28 bushels/acre. The corn has been marketed through normal channels.

The 1974 and 1975 average grain yields of 28 and 60 bushels per acre are indeed remarkable considering the following: (1) the Muskegon system was new and untried; (2) the primary purpose of the system is wastewater renovation; (3) incomplete installation of irrigation equipment and many operational difficulties with the new irrigation system have caused interruptions particularly in 1974 (Detail F); and, (4) most soils at the site are very poor, will not yield more than a few bushels per acre of corn grain without irrigation and nutrients, and normally only support scrub oak and other forest species.

Recycling-Resource Recovery. The irrigation - soil - cropping phase of the wastewater treatment system is providing not only what is often called tertiary or advanced wastewater treatment (AWT), but also utilized nutrients in the wastewater for growing a corn crop. The sale of corn reduced the 1.9 million dollar operating cost for wastewater treatment during 1975 by about one-third (Detail B). Over $100,000 worth of nitrogen, phosphorus, and potassium from the wastewater was utilized in 1975 to improve the soil and grow food.

Calculations and experience has shown that if, for example, 3 inches of wastewater were applied each week over a 6-month season, an adequate amount of phosphorus and potassium is available for the corn crop (Detail G). However, the level of nitrogen would not be adequate because of the low nitrogen level present in the wastewater and because soils do not retain much nitrogen. In addition the nitrogen is utilized by corn primarily only during 2 months of the 6-month irrigation period. The nitrogen fertilizer, therefore, was injected into the wastewater daily during the active part of the corn growing season to increase corn growth and yield and to stimulate increased removal of phosphorus, potassium, and other wastewater nutrients. From 0-89 pounds per acre of nitrogen fertilizer was added to the different irrigated fields, depending upon the amount of wastewater applied and corn crop's needs (Detail E).

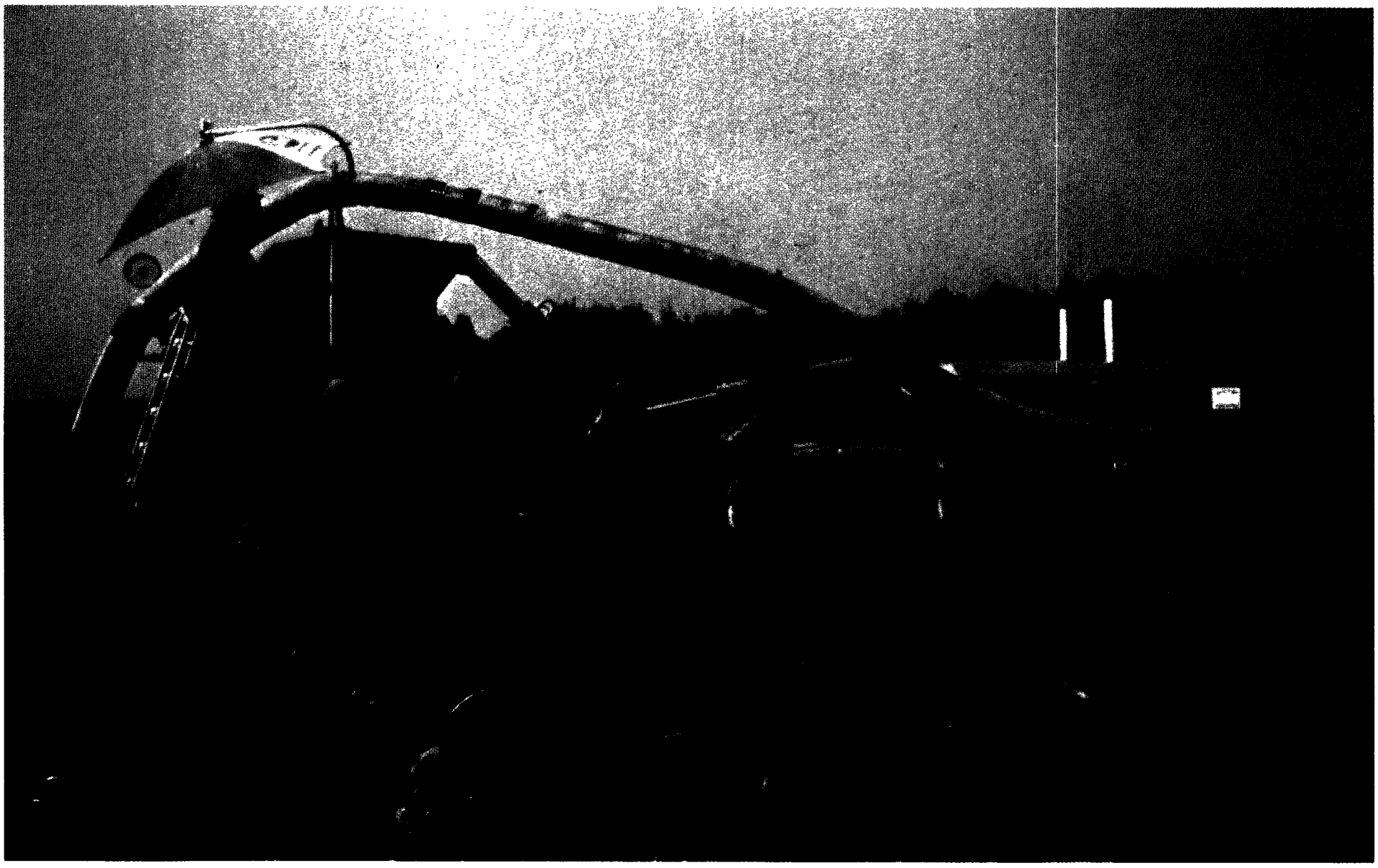
VALUE OF MUSKEGON COUNTY WASTEWATER POLLUTANT—RESOURCES RECOVERED IN 1975

Wastewater Resource	Pounds* Removed	Value** as Fertilizer	
		Percent	Value
Phosphorus (P)	200,000	60	$66,000
Nitrogen (N)	500,000	30	$24,000
Potassium (K)	550,000	40	$22,000

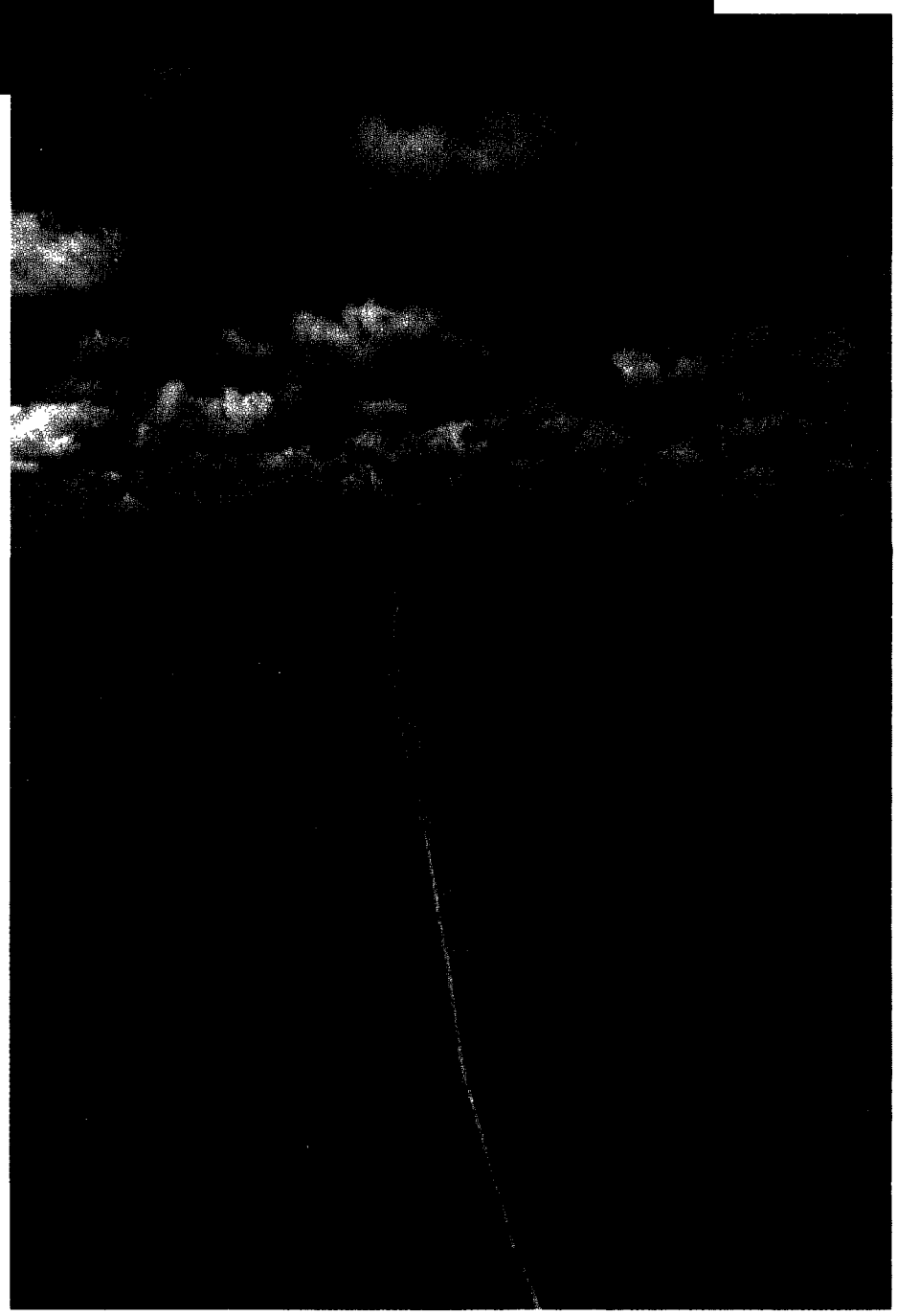
**The pounds removed are based on a 9782 MG flow of wastewater in 1975.*

***An average elemental fertilizer value in the U.S. in Spring 1975 was assumed to be $0.553, 0.162 and 0.102, respectively, per pound of P, N, and K.*

Drainage. Before construction, the groundwater table was very close to the soil surface in many of the fields. Tile drainage or drainage wells were installed and the water table lowered. The drainage network (Detail D) now collects the sprayed renovated wastewater after it has percolated through the crop soil filter and discharges it into the receiving stream. The drainage network, along with interception ditches around the storage lagoon, is designed to protect the quality of the groundwater. Another interesting aspect of the design of the site drainage system was the bypassing of all drainage from lands upstream, and construction of berms to prevent storm water run-off from the site.

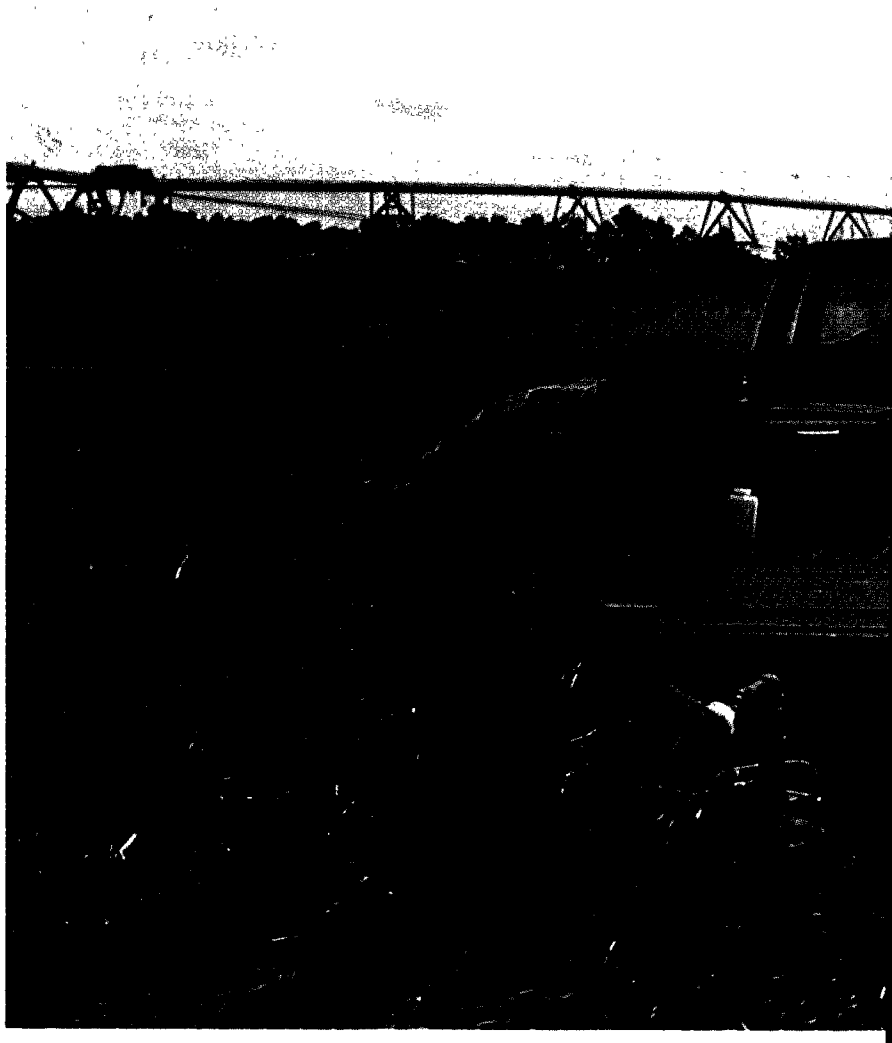


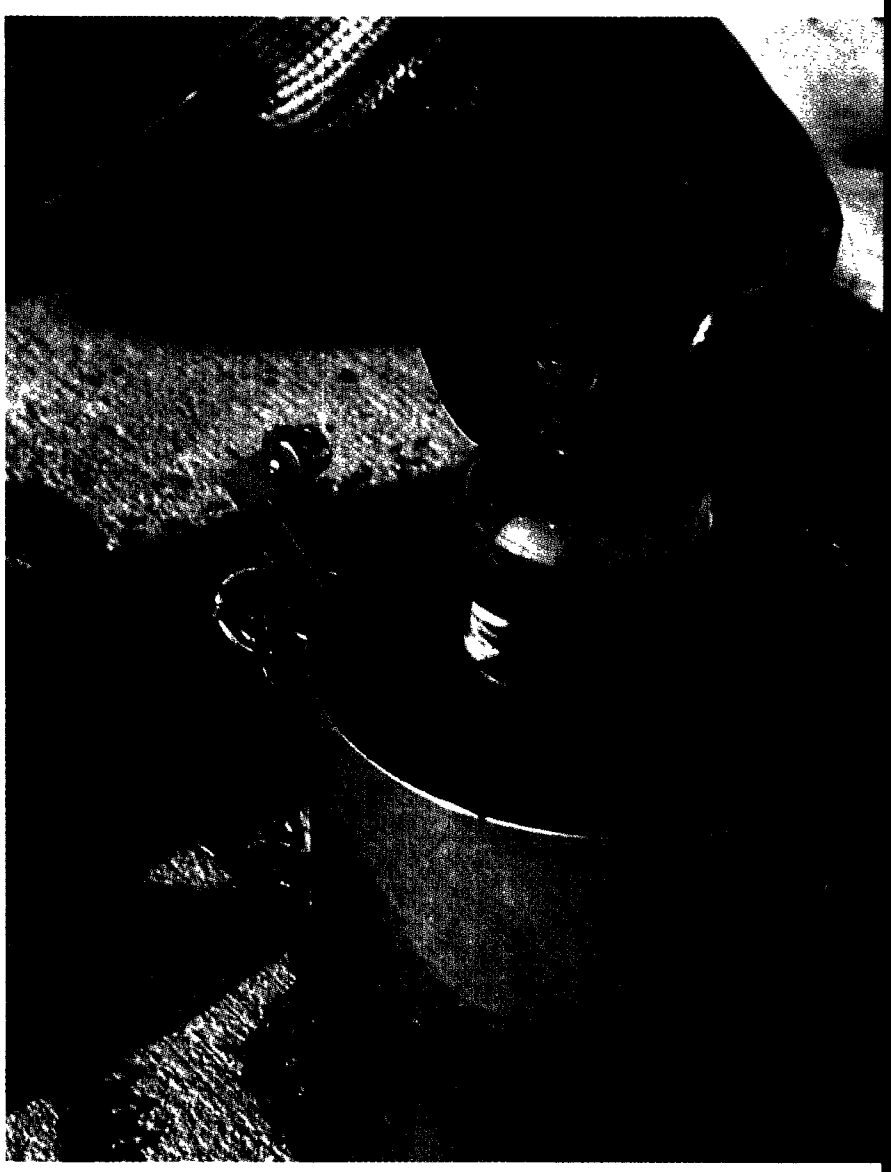
Installation-Note nylon sand screen wrapping.

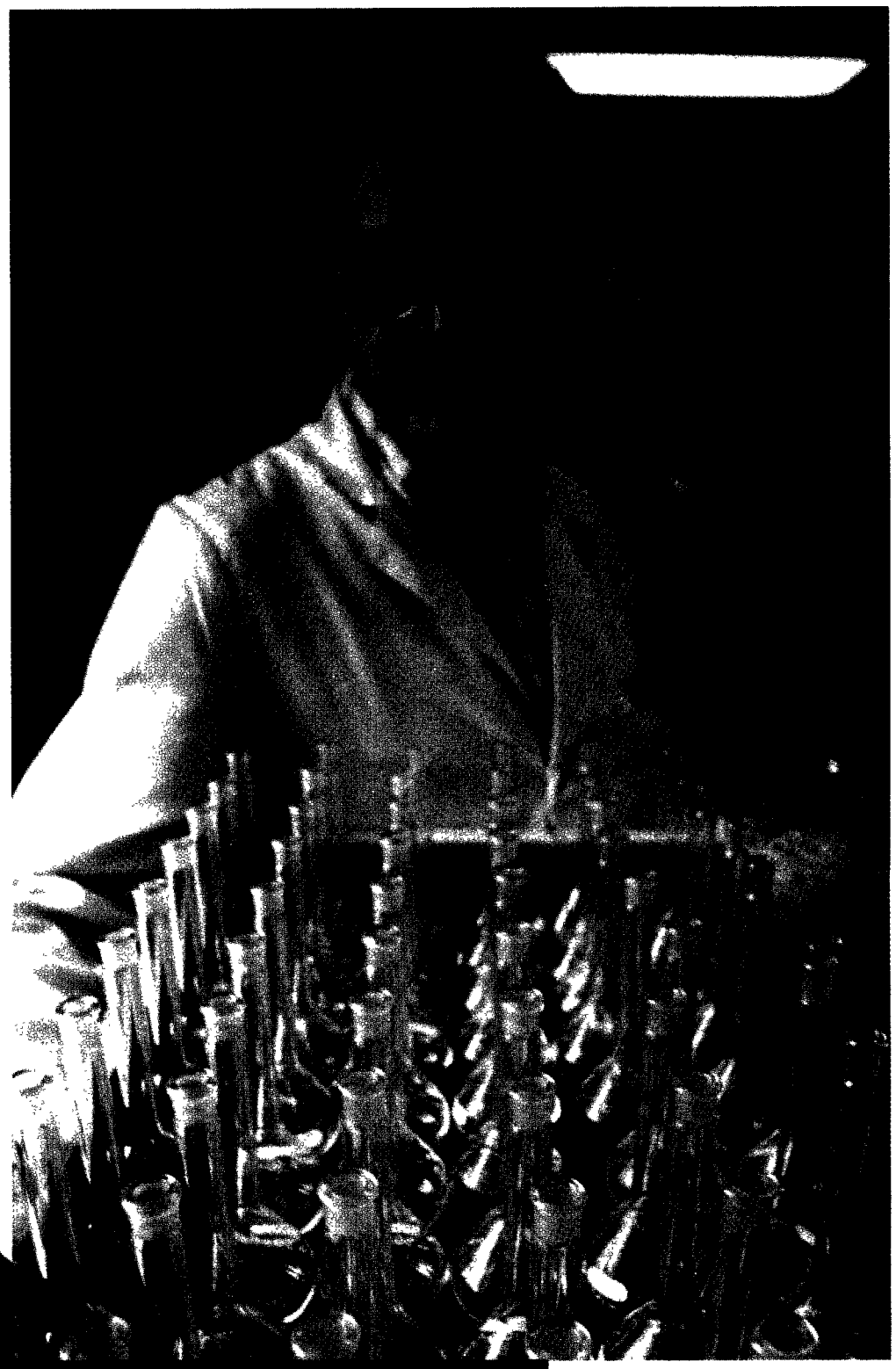


Drainage Tile

Monitoring. There is an extensive monitoring system. Monitoring results are used to determine the efficiency of treatment and to assure operation that avoids the degradation of ground and surface water. Samples are taken for chemical and biological analyses once or twice daily at each step of the treatment process. Groundwater is sampled monthly to twice yearly from the over 300 wells for analysis. Finally, the surface water quality is examined in lakes and streams at some distance from the treatment site, but still under the influence of the wastewater treatment system. Monitoring has shown no significant effect on the ground and surface waters of the area.







Monitoring Effectiveness of Aeration Cells and Soil-Crop Filter

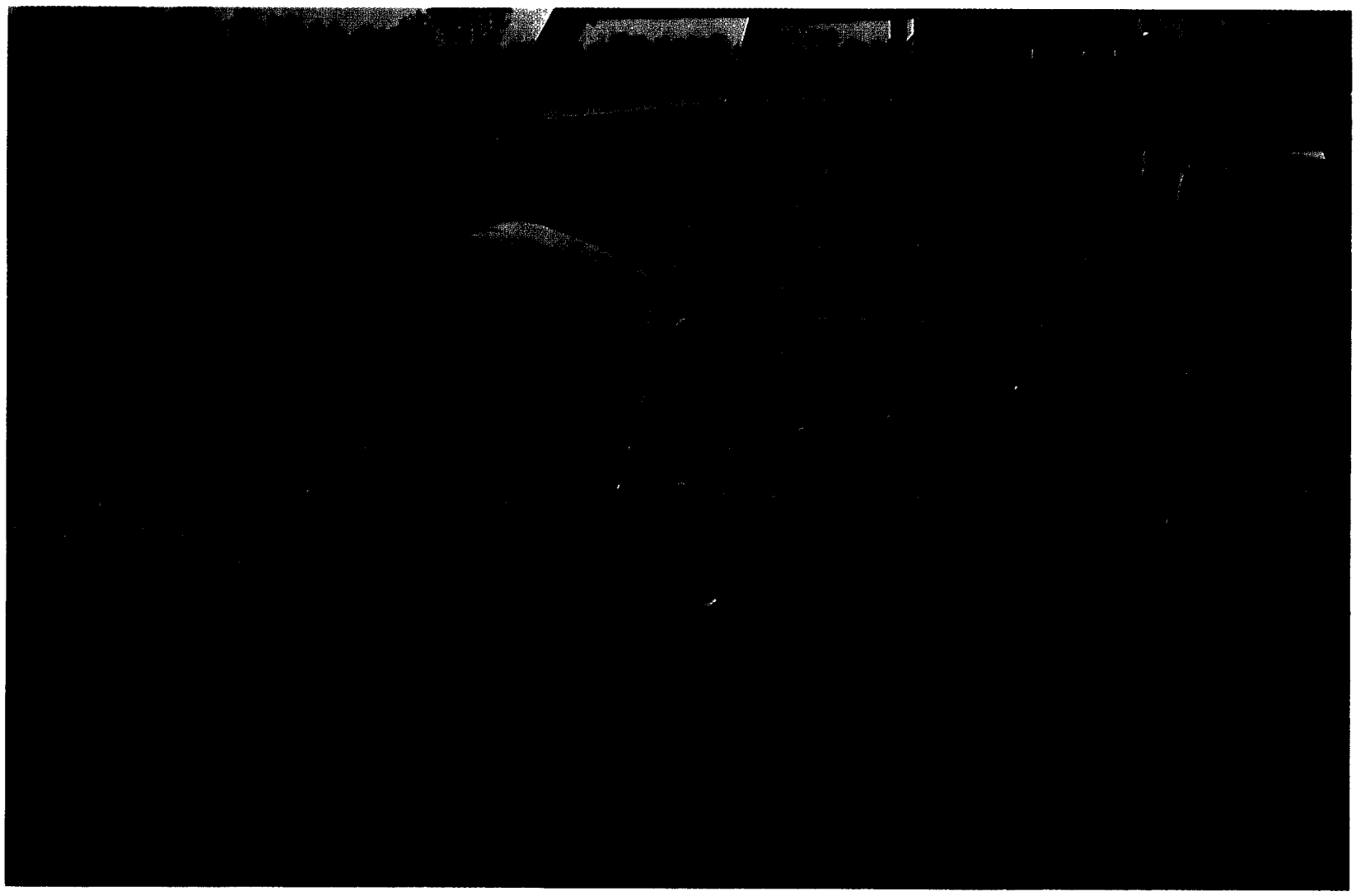
Determining Effects of Wastewater System on Lake Quality

Operations, Management, and Research and Development. The entire system is being operated by 40 full-time persons and an additional part-time labor force of up to 10 workers (Detail H). Some of their job activity is associated with the Muskegon EPA Research and Development Grant. It is essential for large operations of this nature to have laboratory and development study capabilities.

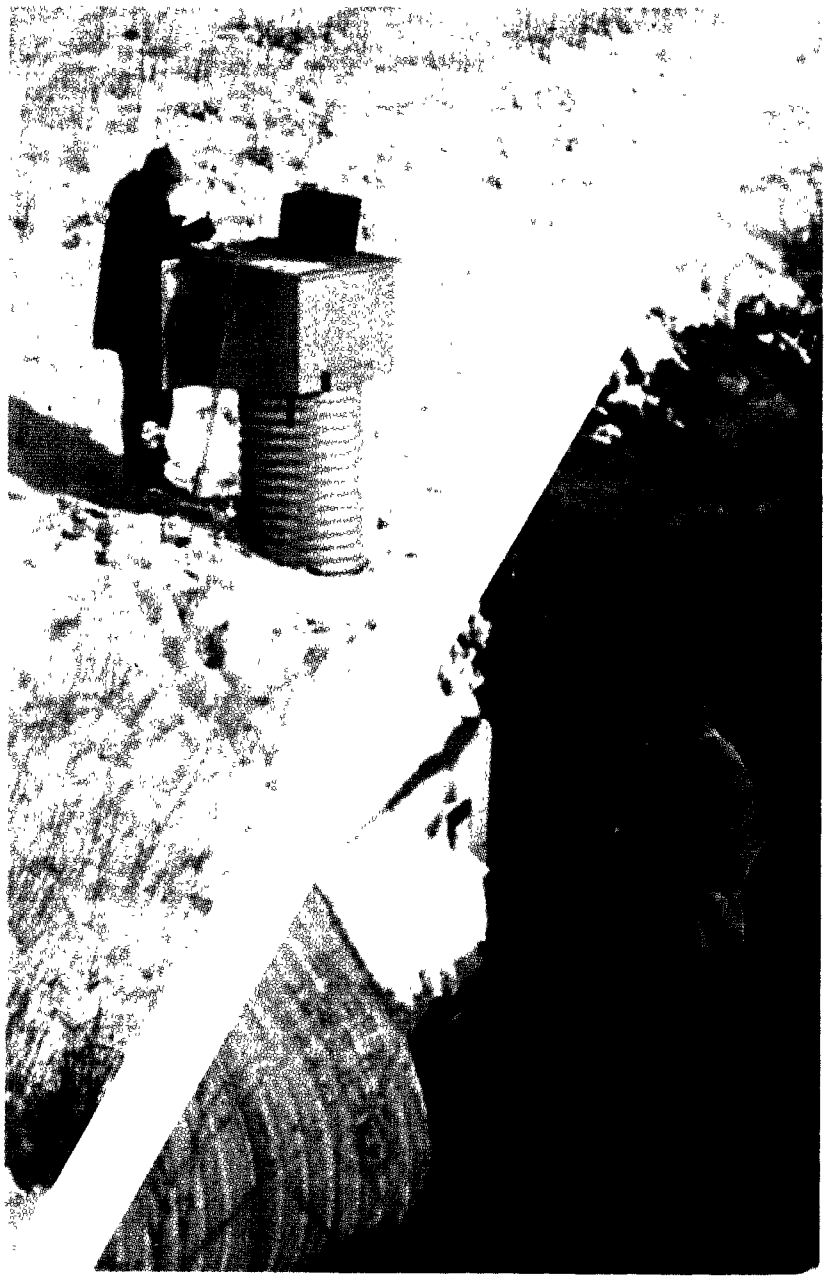
The success of this operation has depended and will continue to depend heavily on expert management which in turn is based on sound business, farming, engineering, and scientific skills.

Management has benefited from the creation of a Farm Advisory Board made up of Agricultural Experts from Michigan State University and from a Research Advisory Board made up of experts within EPA. As a direct result of good management, directly assisted by research and development efforts, progressive improvements have been achieved and operational problems (inherent not only in any system, but also in a large previously untried system of this nature) have been overcome at very modest cost.

Measuring Stream Elevation

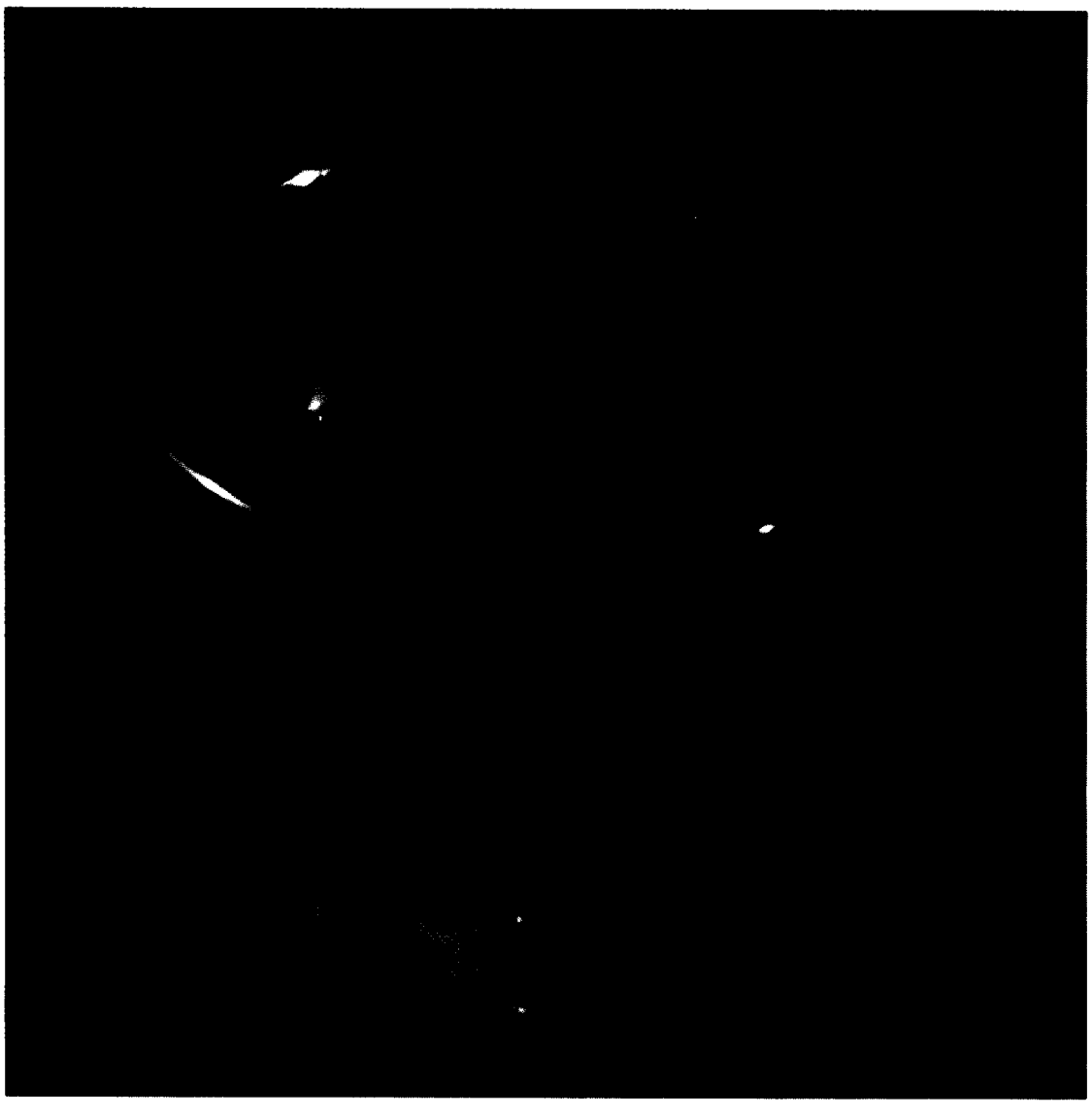


Irrigation Rig Adjustment



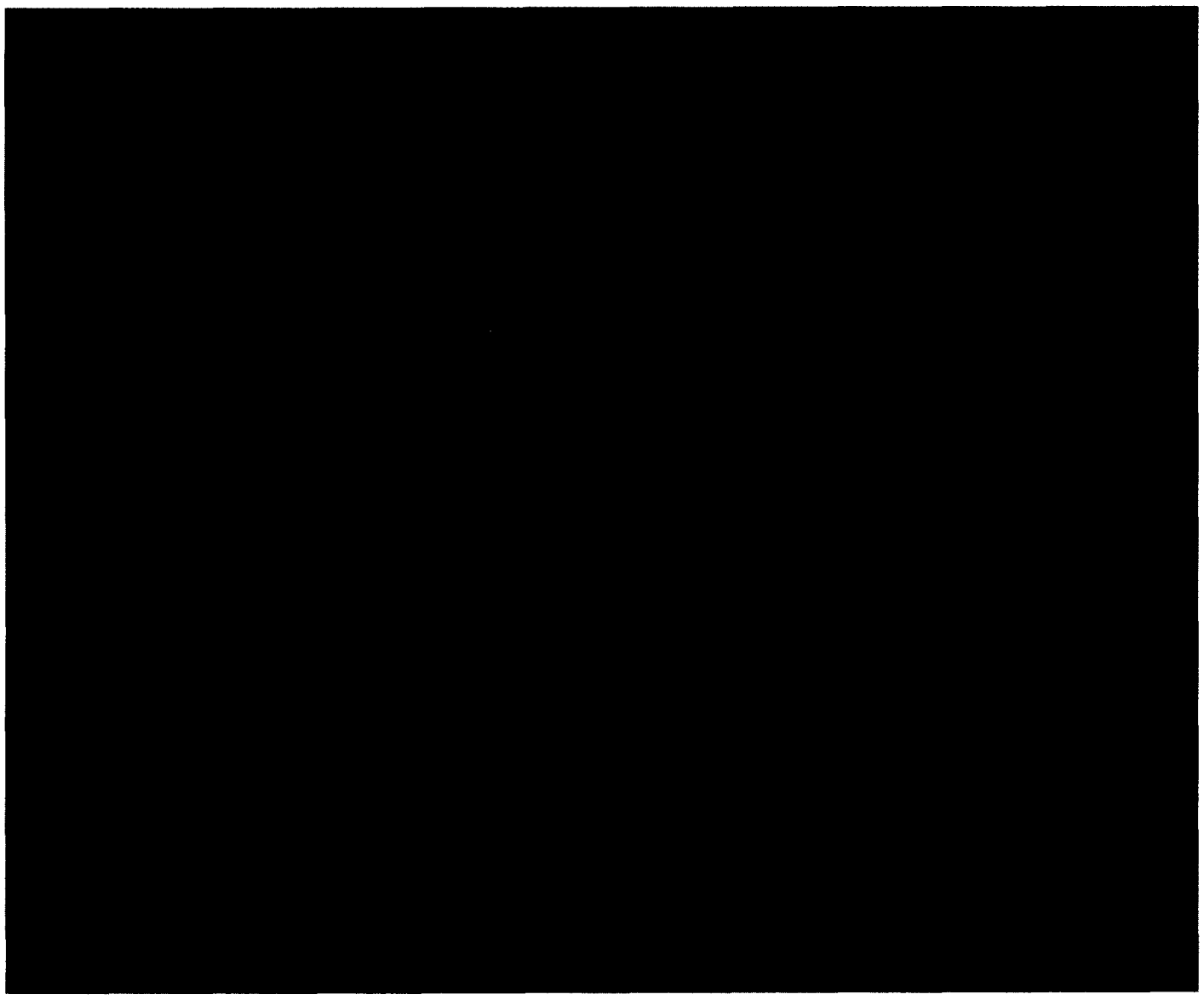
Gauging Stream Volume and Flow

Examples of these coopertive management-research efforts are: (1) Studies and steps undertaken to eliminate problems with underground electrical cable and irrigation mains to irrigation rigs; (2) Economic stepwise modifications of the system to reduce problems with irrigation rig nozzle plugging and to overcome occasional odor problems from industrially discharged flows at the site; (3) Studies and steps undertaken to improve drainage in a number of inadequately drained fields; and (4) Significant reduction in energy consumption based on studies of aeration cell operation. Other examples of improvements, resulting from good management, are: Reduction in the full-time labor force from over 60 to 40; acquisition and updating of equipment for more efficient farming and self-maintenance of nearly every phase of the system; and hedging to insure and improve cash revenues from the 1975 corn crop.

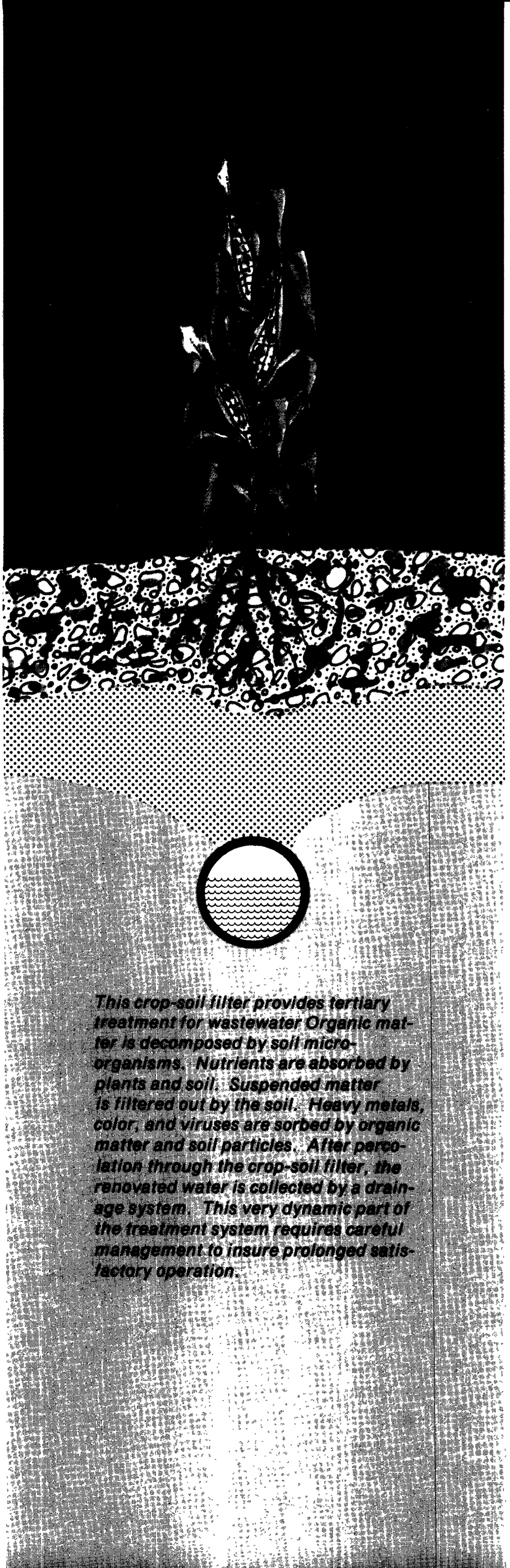


Raw Sewage Influent

Crop - Soil Renovated Effluent



Treatment Performance. Wastewater is being renovated to the degree shown in the adjacent table and figure and in Detail I. Examination of this information shows that the goal of providing clean, high quality renovated water is being met by the Muskegon County Wastewater System, and the goal of capturing and utilizing valuable plant nutrients is being accomplished.



This crop-soil filter provides tertiary treatment for wastewater Organic matter is decomposed by soil micro-organisms. Nutrients are absorbed by plants and soil. Suspended matter is filtered out by the soil. Heavy metals, color, and viruses are sorbed by organic matter and soil particles. After percolation through the crop-soil filter, the renovated water is collected by a drainage system. This very dynamic part of the treatment system requires careful management to insure prolonged satisfactory operation.

Outlook and Life Expectancy. The corn yield is expected to improve as the remaining debris from land clearing is removed, nozzle plugging is reduced, nitrogen fertilizer injection is made more timely, and other improvements are made (again based on research and development,as well as good management).

In view of the very favorable cost experiences at Muskegon and the Clean Water Act (PL 92-500) requirements, a careful reexamination of the comparative economics of land treatment versus other wastewater treatment systems is needed. Economic studies on system management alternatives are needed for still more favorable operation of the land treatment system at Muskegon.

Any wastewater treatment system has limitations and the Muskegon County Wastewater System is no exception. Operated, however, in it's present mode (with adequately pre-treated wastewater of similar composition and irrigated with similar quantities and rates) most of the cropped soils at Muskegon are expected to adequately remove wastewater contaminants like phosphorus for at least 50 years. If after 50 years, the land were saturated with phosphorus and would no longer be able to provide adequate phosphorus removal, many other uses for the land will be possible. Additional research and development activity should more clearly be able to predict the life expectancy of all parts of the system for handling and treating all wastewater constituents , not only under the current mode of operation but also under different modes of operation using wastewater of different characteristics.

After the wastewater system

Establishment of the cost effective land treatment system in Muskegon County has permitted a complete diversion of S.D. Warren's wastewater from Muskegon Lake, purification of the wastewater, improvement of the lake for recreation, and helped retain this needed industry in the County (see also page 6).

Your Solution

The solution to your community's dirty water problem will not be easy. The successful Muskegon County Wastewater Management System is an important treatment alternative for your community's consideration. Since the soils, climate, land availability, wastewater characteristics, and economic situation differ in each locality, your community must carefully assess the potential benefits of utilizing this system or related types of land treatment for solving your wastewater problem. Expert assistance in making this assessment is available in your State government's Departments of Environment and Agriculture, and Federal agencies such as the U.S. Department of Agriculture, the U.S. Geological Survey, and the U.S. Environmental Protection Agency.

Funds for assisting in planning and building appropriate systems for treating your community's wastewater are available through your state from the U.S. Environmental Protection Agency. Implementing cost effective wastewater treatment is a very difficult but rewarding task, as Muskegon County's treatment system experience so clearly has emphasized. This task can only be accomplished by the cooperative efforts of all parties.

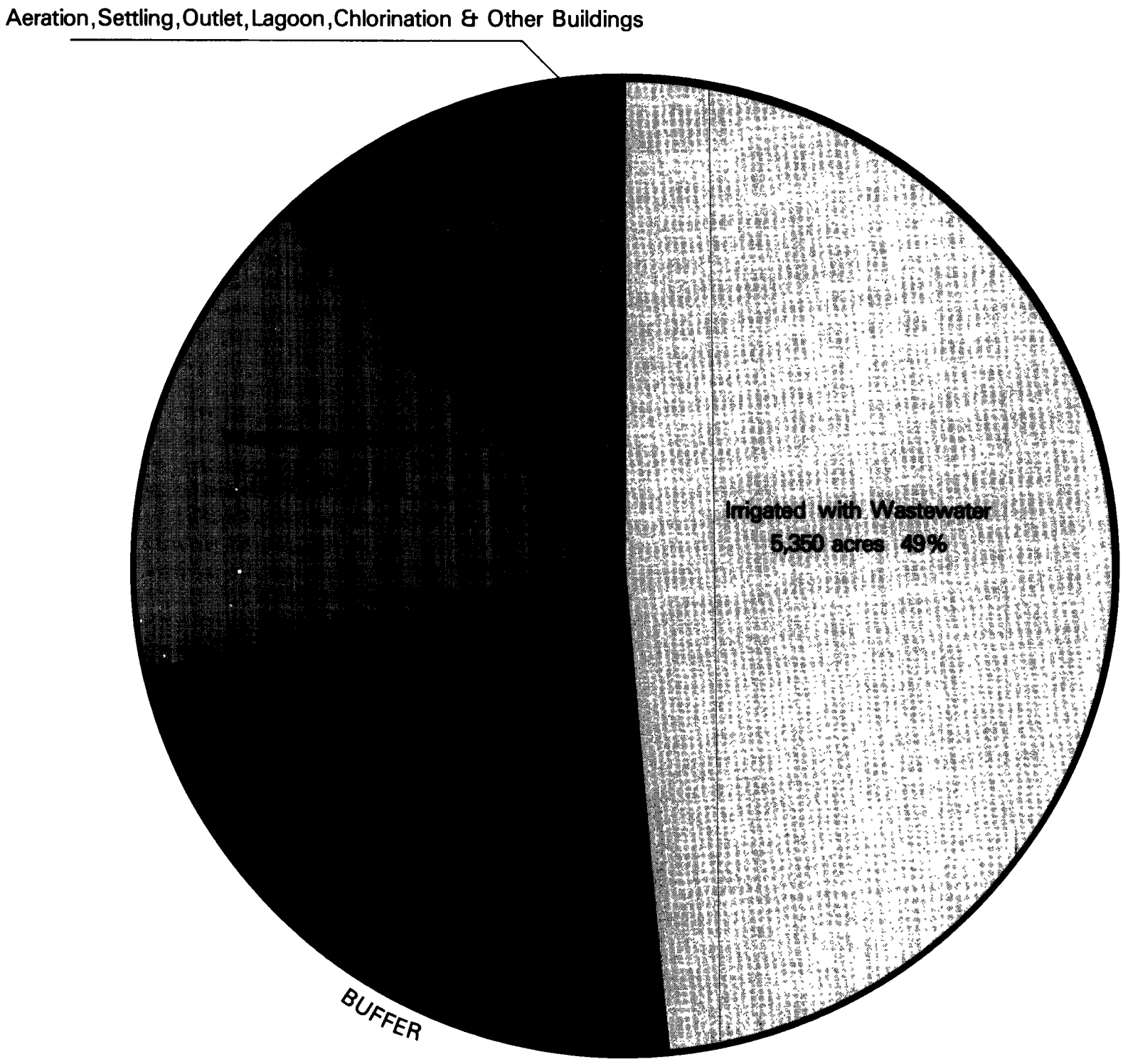
Thousands of Migratory Waterfowl are Attracted to the Storage Lagoons - Whistling Swans

Technical and Economic Detail

This section contains information in greater detail on the Muskegon system including:

A. Capital Costs
B. Operating Costs
C. Land Usage
D. 1. Irrigation System
   2. Soils
   3. Wastewater Application
   4. Drainage System
E. Crop Yields
F. Planning and Construction Timetable
G. Wastewater Nutrient Application
H. Labor
I. Treatment Performance

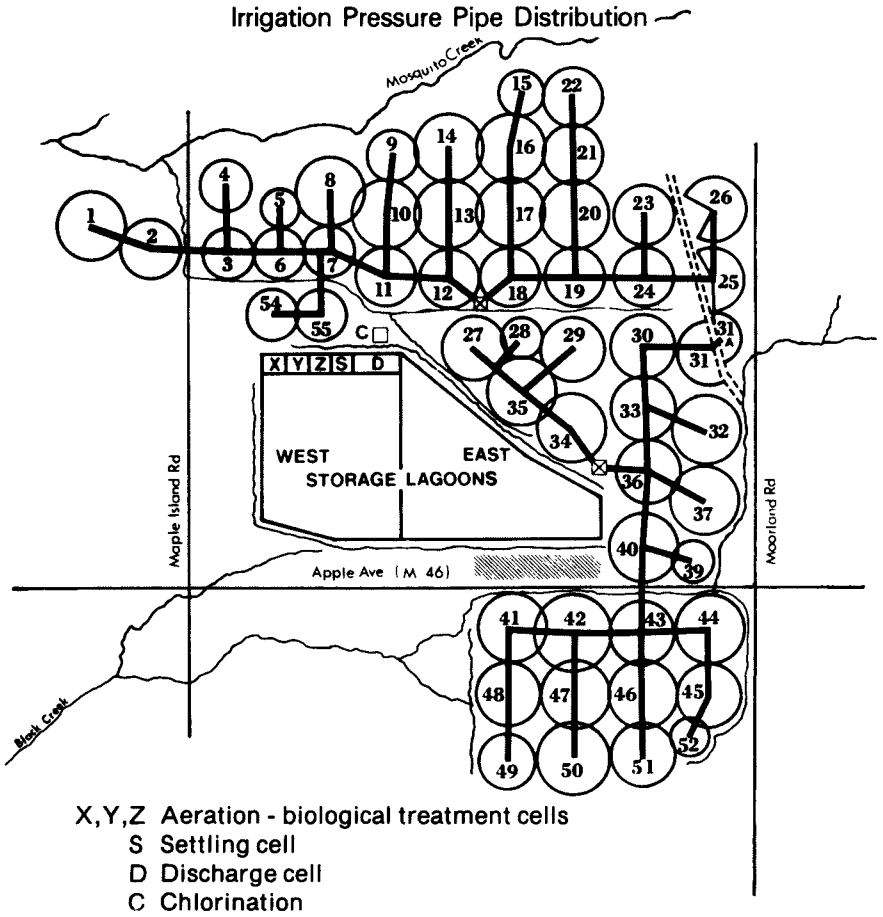
MUSKEGON SITE LAND USES (10,850 acres)



MUSKEGON WASTEWATER TREATMENT SITE

1

Irrigation Pressure Pipe Distribution

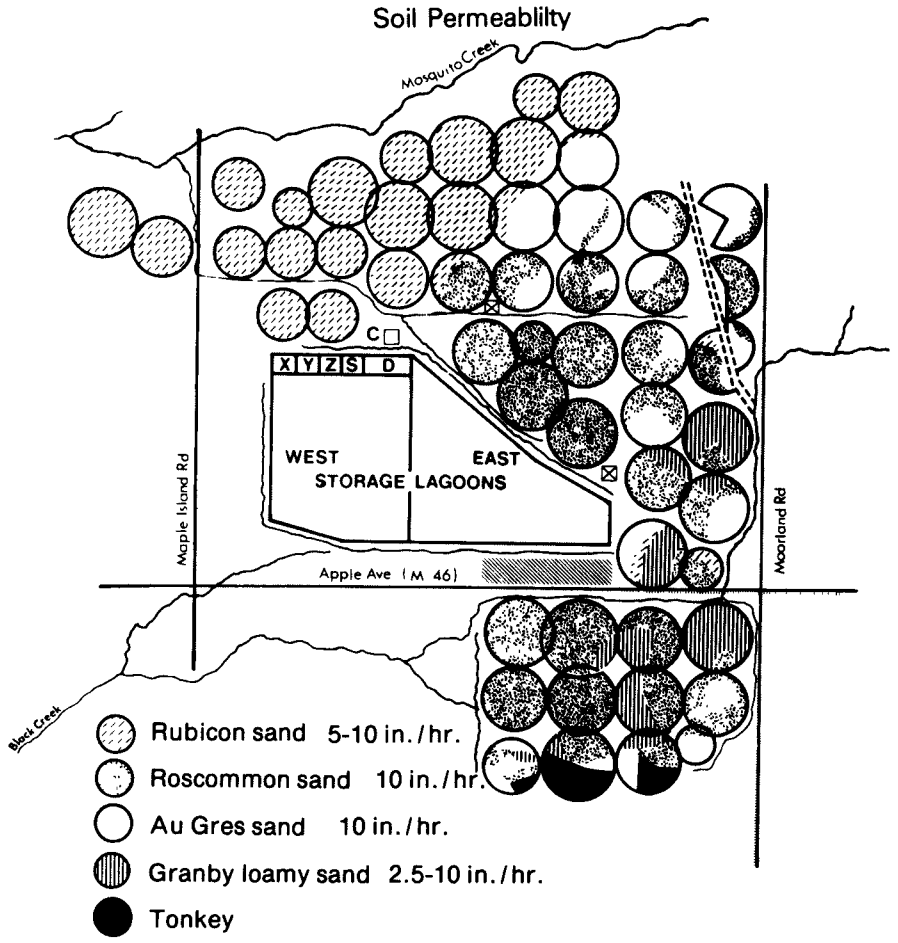


X,Y,Z Aeration - biological treatment cells
S Settling cell
D Discharge cell
C Chlorination
⊠ Irrigation pumping stations
1-55 ○ Center pivot irrigated fields
Solid waste landfill.

N 1 mile

2

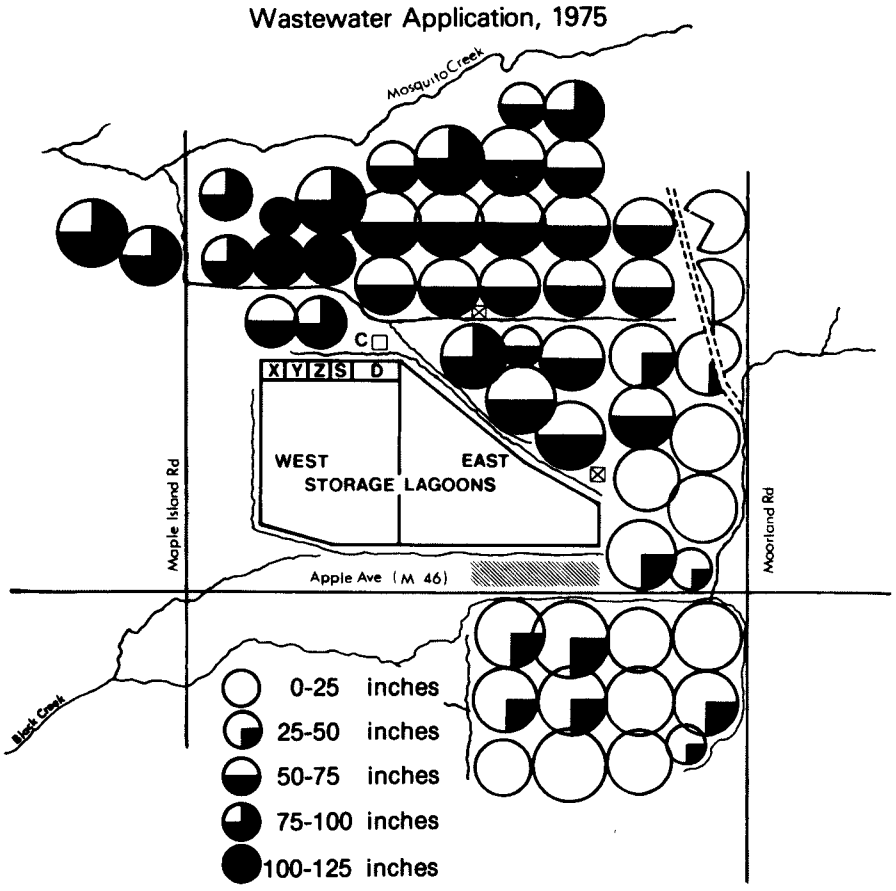
Soil Permeablilty



Rubicon sand 5-10 in./hr.
Roscommon sand 10 in./hr.
Au Gres sand 10 in./hr.
Granby loamy sand 2.5-10 in./hr.
Tonkey

3

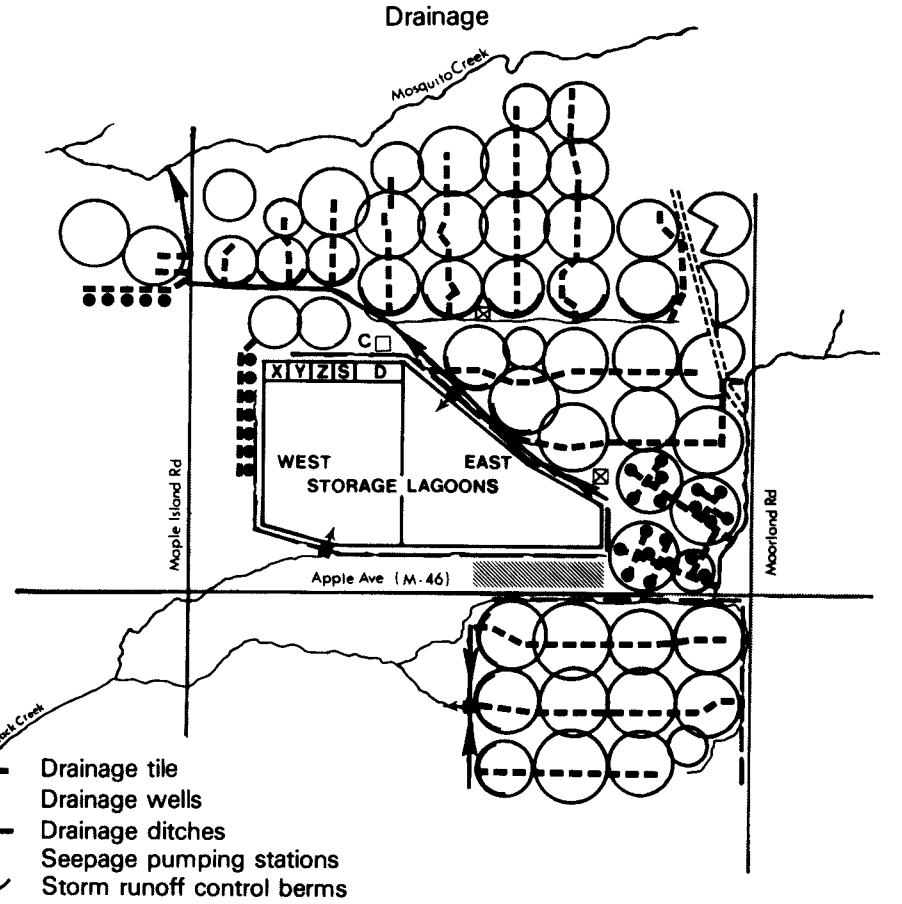
Wastewater Application, 1975



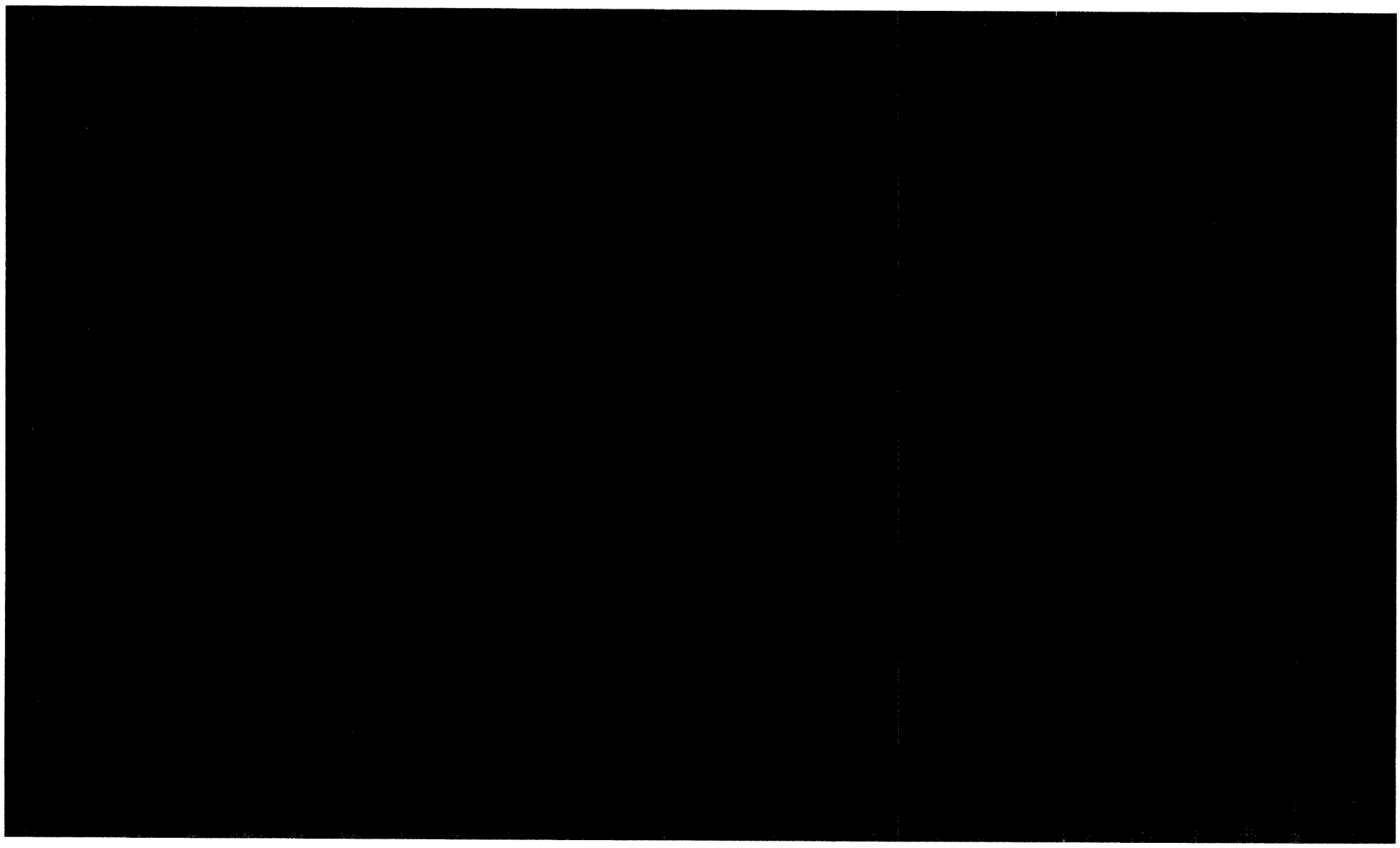
0-25 inches
25-50 inches
50-75 inches
75-100 inches
100-125 inches

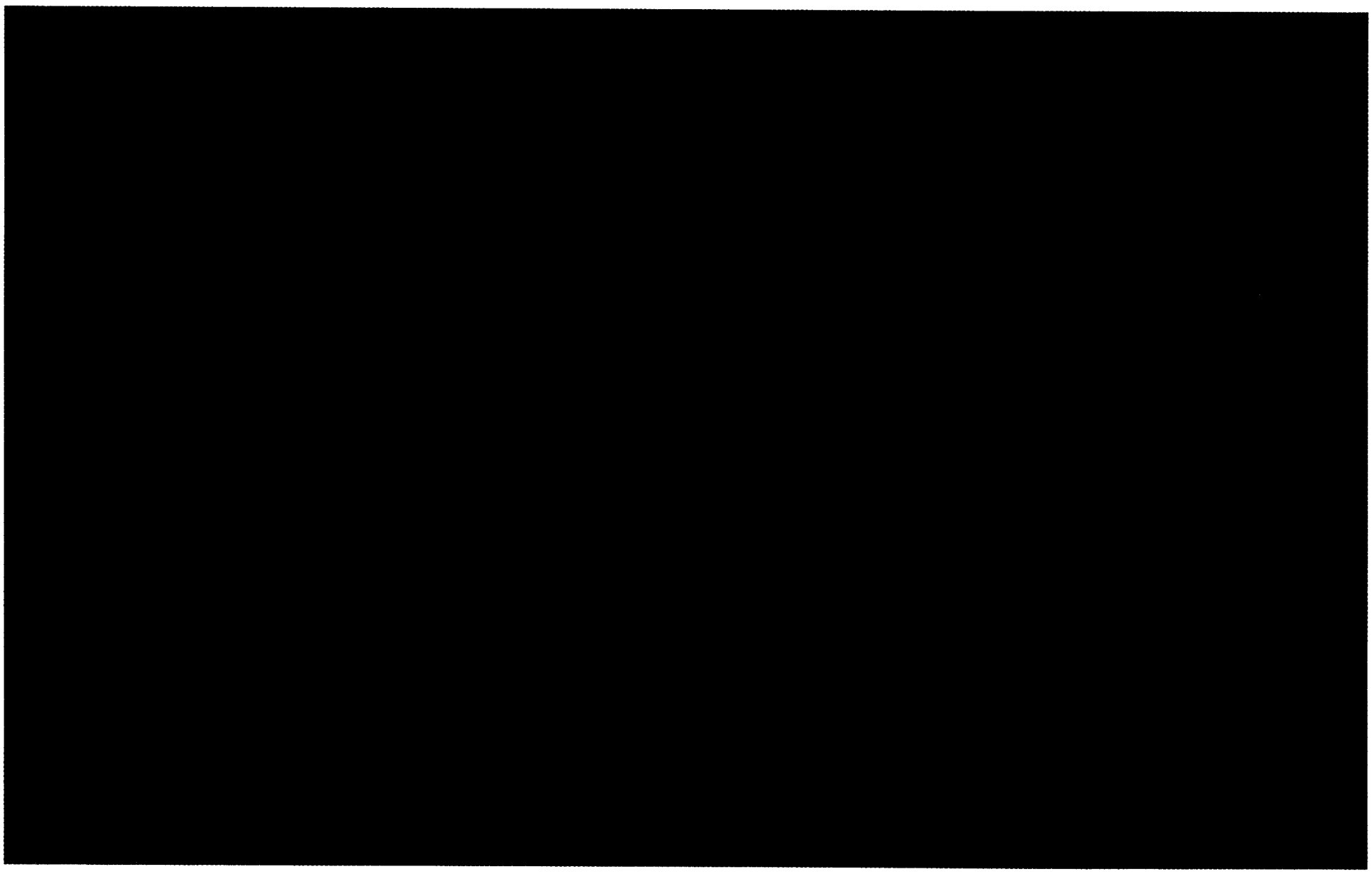
4

Drainage



Drainage tile
Drainage wells
Drainage ditches
Seepage pumping stations
Storm runoff control berms
Creek by-pass ditch
Lagoon seepage ditch





DETAIL G

WASTEWATER NUTRIENTS ADDED TO SOILS

Element	Sprayed Wastewater conc. ppm	Nutrients in 75-inch (season) effluent sprayed lbs/acre	Nutrients for 100 bu/acre corn grain lbs/acre
N	4-7	68-119	85*
P**	1-3	17-51	15
K+	6-11	102-187	20
Na+	140	2400	
Ca+	60	1000	

**In addition to wastewater nitrogen (N), supplemental liquid N fertilizer was injected into the wastewater as needed during the active corn growing season.*

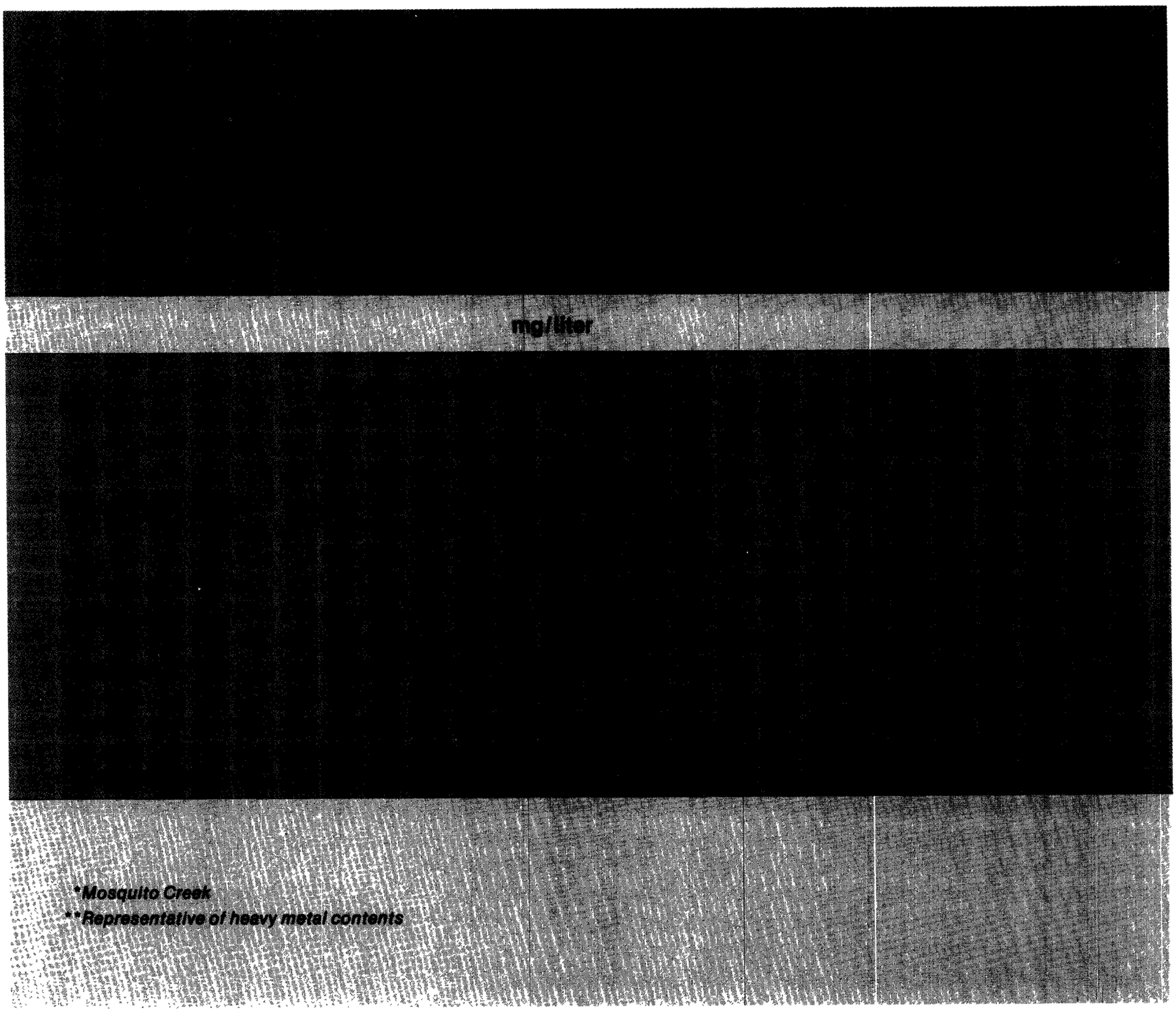
***The phosphorus (P) concentration in the land sprayed wastewater has been just over 1 ppm. At the indicated level of wastewater application the P applied is about equal to crop needs and therefore will not accumulate in the soil. If the total P level is 3 ppm, a majority of soil at the wastewater site should be able to remove the excess P and prevent leaching with the renovated wastewater for at least 50 years. This assumes that wastewater is sprayed uniformly on the soil under the conditions shown.*

+ The quantities of potassium (K), sodium (Na), and calcium (Ca), in excess of crop needs are not causing problems on the sandy soils at Muskegon. Soil monitoring studies by Michigan State University indicate that these wastewater elements are reaching an equilibrium with the soil sorptive surface and will be passing through into the renovated wastewater with little change in concentration but at acceptable levels. Studies on other inorganic and organic constituents in the wastewater do not indicate any anticipated problems under the current mode of operation and with the wastewater as it now exists.

DETAIL H

LABOR MUSKEGON SYSTEM, 1975

Category	Manpower
Full-Time	
Collection & Tranmission	9
Aeration & Storage	3
Irrigation & Drainage	7
Farming	8
Laboratory & Monitoring	9
Administrative	4
TOTAL	40
Part-Time	
Janitorial	2
Seasonal	up to 8
TOTAL	10



*Mosquito Creek

**Representative of heavy metal contents

Studies and Reports

For greater detail on all phases of the Muskegon County operations a series of comprehensive reports have been prepared by the different groups having contributed to the planning and constructing of the system and by groups conducting research there. The major funding for these research and development studies, conducted by Muskegon County, have come from the Municipal Environmental Research Center in Cincinnati, Ohio, and the Robert S. Kerr Environmental Research Laboratory in Ada, Oklahoma. The research reports are currently under review and/or are being prepared for printing. Copies of the research reports should be available from the Region V EPA office and Ada, Oklahoma, later in 1976.

Other studies, in addition to those being conducted by Muskegon County for EPA, are continuing. A five-year study on socio-economics, funded by EPA and Muskegon County, is being conducted by Kiefer and Associates and should be completed by early 1978. This study is aimed at determining attitudes of people about the system before and after it operated, comparing these attitudes with actual performance, and attempting to determine effects on the area unique to the land treatment system. Soil monitoring and soil and crop management studies are being conducted by Michigan State University. EPA Region V is supplying a major part of this funding with grants of PL 92-500 Section 108 Great Lakes funds through the Michigan Water Resources Commission. These studies should permit a more adequate prediction of the life of the system under its current operational mode. In addition, the studies will aid in the development of improved operational modes for wastewater renovation. Possible continuation of monitoring and modeling studies on lakes draining the Muskegon Basin should provide a reliable explanation of the effect of the wastewater treatment system on the area's water quality. EPA Region V also provided a grant with Section 108 Great Lakes Funds for initial lake studies by the University of Michigan and the Michigan Water Resources Commission. These studies, if continued, should provide a valuable information base for PL 92-500 Section 208 planning studies which attempt to examine and predict effects of alternative management of diffuse and point source pollutant inputs into regional watersheds and ultimately into the Great Lakes.

A multi-year study is nearing completion on the hydraulics of the Muskegon County System. This study is being conducted by the U.S. Geological Survey in cooperation with the Michigan Geological Survey.

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1976 UPDATE

The Muskegon County Land Treatment System in 1976 continued its successful operation by producing highly renovated wastewater while at the same time, using water and recycling nutrients to produce an even greater tonnage of corn than in 1975. Pollutant removal remained the same: 98% for BOD, suspended solids and phosphorus, and about 40% for nitrogen. Average yields on 5,000 acres of corn irrigated with wastewater increased from 60 bushels per acre in 1975 to 81 bushels in 1976. This increase occurred in spite of dry weather in 1976 which reduced the county average from 65 to less than 50 bushels per acre. The estimated increase in income from sale of corn kept pace with dramatically higher energy costs, so that operating costs in 1976 (excluding debt retirement) remained about equal to the 1975 treatment cost of 24¢ per thousand gallons of wastewater.

A careful examination of data from a three year study has shown that diversion and treatment of wastewater flows have brought about significant improvements in water quality in Mona and Muskegon Lakes. Such improvements and the likelihood that pollutant levels in surface streams and lakes will decline further with time have important implications for new recreational and industrial developments in the area. Muskegon County has established an office for planning and developing these new potentials. In 1976, several industries have selected Muskegon as the site for new operations. The County's effort to provide cost-effective and environmentally safe treatment for wastewaters was an important factor in their decision.

INCREASED AGRICULTURAL PRODUCTIVITY BY RENOVATION/REUSE OF WASTEWATER IN MUSKEGON

	CORN YIELD AND INCOME		
	1974	1975	1976
	bu/acre		
Wastewater Site	28	60	81
County Average	55	65	45/50
	millions of dollars		
Gross crop revenue	0.35	0.7	1.0 (est.)