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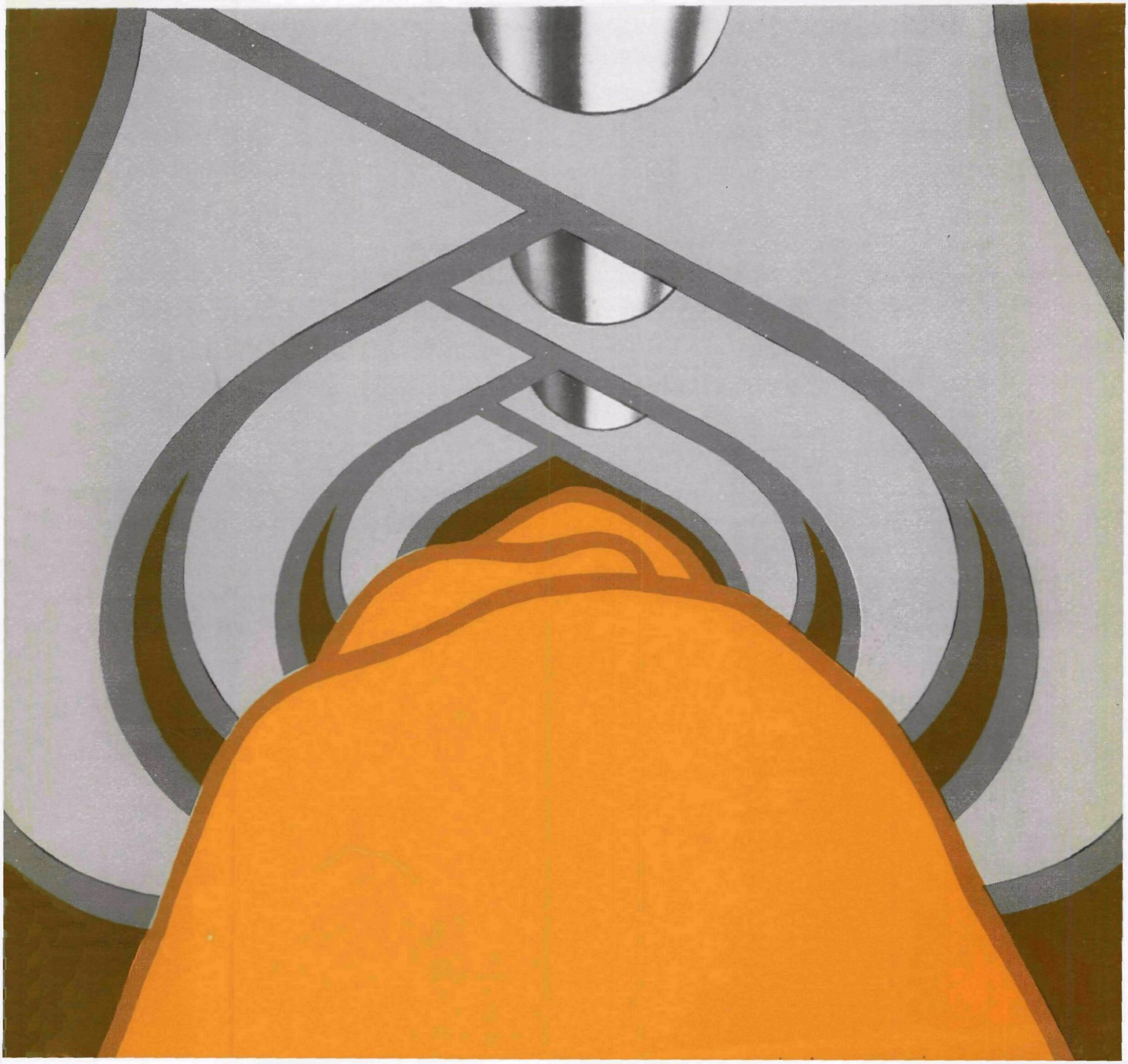
Waste Treatment

Upgrading Meat Packing Facilities to Reduce Pollution

EPA Technology Transfer Seminar Publication



WASTE TREATMENT

Upgrading Meat Packing Facilities to Reduce Pollution

ENVIRONMENTAL PROTECTION AGENCY • Technology Transfer

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NOTICE

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Chapter I

INTRODUCTION

THE NEED FOR WASTEWATER TREATMENT

The discharge of industrial wastewater recently has become a significant area of concern as public regulating bodies have become increasingly involved with the establishment of water quality criteria. Many types of substances, when discharged into a receiving body of water, degrade the water quality to such an extent that beneficial uses of the stream are no longer attainable. While no one industry will pollute a stream with all types of damaging substances, sufficient quantities or combinations of even a few pollutants can cause irreparable harm.

The major components present in industrial waste discharges that have a pollution potential are solids (floating, suspended, settleable, and dissolved), organic matter, nutrients, temperature change, toxic substances, and acids and alkalis.

Floating solids, including grease and scum, are not only unsightly; they may adversely affect natural aquatic characteristics, such as oxygen transfer and light penetration. Settleable solids may have an adverse effect on stream organisms by covering up the stream bed and forming sludge blankets that will decompose anaerobically with the formation of odorous gases. Settleable solids may also prevent fish hatching on the stream bed, and may create an anaerobic environment that will hamper bottom dwelling microscopic animals. Suspended solids will give the water a turbid complexion limiting light penetration, which in turn hampers aquatic vegetation relying on photosynthetic reactions for survival. Large amounts of suspended solids will also increase the requirements for treatment if the water is to be used for domestic supply.

Organic matter discharged into a watercourse will decompose, depleting the dissolved oxygen (DO) supply available in the water. When such oxygen depletion occurs, definite changes will occur in the composition of the organisms that inhabit that particular reach of stream. The more desirable species of fish (trout, bass, etc.), which require DO levels near 5 mg/l or greater, will disappear to be replaced by the coarser types (such as carp and bullheads), which can survive DO levels near 2 mg/l. Below the 2-mg/l level, however, fish life will cease to exist. Other forms of life react in a similar manner to decreasing levels of DO, and a shift toward anaerobic species eventually will occur in the affected area. Only physical processes, such as the natural reaeration of flowing water, will help the stream to recover from its oxygen-depleted state.

Nutrient-rich waste flows are causing increasing concern as excessive algae growths become unacceptable. The two major nutrients commonly found in many types of industrial discharge are nitrogen and phosphorus. Presence of these nutrients may cause excessive growth of algae. When these heavy algae growths die, they exert an oxygen demand that, in turn, may cause fish kills, unpleasant odors, and an undesirable taste. The effective use of a body of water for recreational and domestic purposes is diminished greatly by algae growth.

Temperature changes in water may cause adverse changes in the organisms and affect stream reaeration. Fish and other forms of aquatic life have preferred temperatures at which their life processes are at an optimum. When temperatures deviate from the optimums, the organisms will not flourish and may disappear entirely. In addition to long-term alteration of temperatures, rapid changes in temperature are harmful. Moreover, deviation to higher than normal temperatures lowers the stream's ability to reaerate itself by limiting the amount of DO at saturation.

Toxic chemicals are common constituents of some types of industrial processes, and, therefore, find their way into the waste stream. Such toxic substances may be harmful to both plant and animal life, and may leave the water unsuitable for recreation and human consumption.

Acidity and alkalinity, as measured by pH, are also a factor to be considered in stream quality. Because the pH of most industrial discharges varies from neutral, effluents must be checked and often adjusted before being discharged into a stream.

To avoid degradation of water quality, industrial waste treatment must be practiced in some form. This form may be complete treatment at the industrial plant or partial treatment before discharge to a municipal sewer system. The degree of treatment required is contingent upon Federal and local requirements, which establish effluent standards for a particular receiving body of water.

MICRO-ORGANISMS AND THEIR ROLE IN WASTE TREATMENT

Treatment of industrial wastes is accomplished by living systems. The waste flow furnishes food and environment to a mixed culture of micro-organisms that break down the organic constituents of the waste and remove it from solution. The basis of adequate treatment is the proper control of the biological environment to make it possible for the organisms to function at the desired level.

The most important organisms in waste treatment are bacteria—the simplest form of living matter. Bacteria may be heterotrophic (using organic compounds as a carbon source) or autotrophic (using carbon dioxide as a carbon source). Heterotrophs may be aerobic, requiring free DO; facultative, functioning with or without free oxygen; or anaerobic, requiring complete absence of oxygen. Other organisms of importance are fungi, protozoa, and rotifers (higher level animals that feed on bacteria and play an important part in activated sludge). Algae, which are important in some waste-treatment systems, are autotrophic, photosynthetic plants, relying on carbon dioxide and sunlight to carry out their biochemical reactions.

The breakdown of organic wastes is a complex process involving complicated biochemical reactions. The process by which cells remain viable and obtain energy for synthesis and respiration is called metabolism. For heterotrophic aerobic bacteria, the large molecules that make up the food supply must first be hydrolyzed, with carbohydrates going to sugars, protein to amino acids, and fats to fatty acids. These products then can be used by the cells for assimilation.

Anaerobic reaction involves the breakdown of organics to intermediate products (chiefly organic acids) by one set of bacteria, and the use of these products as food by methane-forming bacteria that further break down the waste. These bacteria require higher temperatures to live than do aerobic bacteria, and are called thermophilic. Compared to aerobic processes, anaerobic reactions will not yield as much energy and breakdown will be incomplete.

Metabolism to insure growth is important because the maximum rate of metabolism results in the maximum growth rate for the organisms. That is to say, the greatest removal of organics occurs at the time of greatest growth.

In summary, aerobic processes are characterized by complete metabolism and large biological growth, while anaerobic processes are characterized by small growth, incomplete metabolism, and creation of high-energy end products.

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Chapter II

WASTE LOADS FROM THE MEAT PACKING INDUSTRY

A definite analysis of the waste characteristics of the meat packing industry is not a simple matter. It is difficult to characterize a typical plant and its associated wastes, owing to the many procedures and facets of meat-processing operations. A given plant may perform many or only a few of these procedures. For all practical purposes, however, the industry may be divided into three categories, as follows:

- Slaughterhouses (killing and dressing)
- Packinghouses (killing, dressing, curing, cooking, etc.)
- Processing plants (processing with no killing operation)

Typical slaughterhouse and packinghouse wastes are generally high in 5-day biochemical oxygen demand (BOD_5), total suspended solids, floatable material, and grease. Furthermore, the waste is generally at an elevated temperature and contains blood, bits of flesh, fat, manure, dirt, and viscera. Important processes such as blood recovery, grease recovery, separate paunch manure handling, and efficient rendering operations can reduce waste loads substantially and may also produce salable by-products. In addition, a well-managed program of in-plant housekeeping practices is desirable, both from a sanitary and waste-load standpoint.

Table II-1 gives waste loads that have been found, through extensive study and research of records, to be typical of various types of meat packing plants. A widespread sampling program currently is being conducted for the Environmental Protection Agency by the North Star Research and Development Institute, for the purpose of supplementing and updating these data.

Table II-1.–*Standard raw waste loads*

Type	Flow, gallons	BOD_5, pounds	SS, pounds	Grease, pounds
Slaughterhouse, per 1,000 pounds LWK[1]	696	5.8	4.7	2.5
Packinghouse, per 1,000 pounds LWK[1]	1,046	12.1	8.7	6.0
Processing plant, per 1,000 pounds product	1,265	5.7	2.7	2.1

[1] LWK indicates live weight kill.

SOURCE: Industrial waste study by the North Star Research and Development Institute for the Environmental Protection Agency.

Table II-2.—*Unit waste loadings for meat packing plants*

Type of animal slaughtered	BOD_5	Suspended solids	Nitrogen	Grease
	Pounds per 1,000 pounds of live weight			
Hogs	18.0	12.0	2.67	0.90
Hogs	15.0	9.1	1.29	2.30
Mixed	12.7	4.6	2.02	1.44
Hogs	13.1	9.8	1.25	2.83
Cattle	20.8	14.8	2.24	.68
Hogs	15.7	14.8	2.01	1.79
Hogs	10.5	10.0	1.02	1.00
Mixed	19.7	9.4	2.59	.60
Hogs	9.8	7.2	1.46	.27
Mixed	16.7	15.0	2.18	2.00
Cattle	10.0	11.0	1.08	.55
Mixed	14.7	13.2	1.70	1.5
Mixed	6.5	6.2	.79	.5
Mixed	19.2	11.2	2.10	2.1
Mixed	8.9	10.8	.89	([1])
Mixed	21.6	21.7	1.82	6.0
Average	14.6	12.0	1.70	1.63

[1] Data missing.

SOURCE: "An Industrial Waste Guide to the Meat Industry," U.S. Department of Health, Education, and Welfare, Washington, D.C., 1965.

The values listed for slaughterhouses apply only to medium-sized plants that slaughter from 95,000 to 750,000 pounds per day and do very little or no processing of edible by-products, perform dry inedible rendering and do no blood processing, or dry blood in such a manner as to produce no blood water. The values listed for packinghouses apply to most medium or large plants that carry out all processes associated with slaughtering, cutting, rendering, and processing. Values for processing plants represent plants that cut and process meat, but do no slaughtering or rendering.

The values given are in general agreement with other values found in the literature, although the variations may have a wider range. Table II-2 shows the characteristics of the waste flow from 16 cattle and hog packing plants, illustrating a typically wide variation from plant to plant.

In general, the processes undertaken at a packing plant have a much greater effect on the waste-load factors than the size of the plant.

A limited number of studies have attempted to analyze the component parts of the process. Because such wide variations in raw waste loads do exist, data obtained from actual sampling of wastes similar to those anticipated are extremely useful and often economically beneficial in designing waste-treatment facilities.

Table II-3 presents a typical source breakdown of hog packinghouse wastes. Packing-plant wastes are of an organic nature, and treatment may be accomplished by many different systems of biological treatment.

Table II-3.—*Analyses of major components of waste from hog packinghouses*

Source of flow	Concentration, mg/l						pH
	Solids		Nitrogen		Cl as NaCl	BOD_5	
	Total	Suspended	Organic	NH_3			
Killing department	1,840	220	134	6	435	825	6.6
Blood and tank water	44,640	3,690	5,400	205	6,670	32,000	9.0
Scalding tub	13,560	8,360	1,290	40	640	4,600	9.0
Hog dehairing	1,540	560	158	10	290	650	6.7
Hair cook water	4,680	80	586	30	290	3,400	([1])
Hair wash water	7,680	6,780	822	18	230	2,200	6.9
Meatcutting	2,840	610	33	2.5	1,620	520	7.4
Gut washer	22,600	15,120	643	43	360	13,200	6.0
Curing room	26,480	1,800	83	12	19,700	2,040	7.3
Curing room showers	34,100	1,720	255	25	29,600	460	6.7
Cured meat wash	9,560	920	109	17.5	6,200	1,960	7.3
Pickle	140,000	([1])	2,750	37	77,800	18,000	5.6
Sausage and miscellaneous	11,380	560	136	4	880	800	7.3
Lard department	820	180	84	25	230	180	7.3
By-products	4,000	1,380	186	50	1,330	2,200	6.7
Laundry	18,620	4,120	56	5	([1])	1,300	9.6

[1] Data missing.

SOURCE: "An Industrial Waste Guide to the Meat Industry," U.S. Department of Health, Education, and Welfare, Washington, D.C., 1965.

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Chapter III

PROCEDURES IN THE PLANNING, DESIGN, AND CONSTRUCTION OF A WASTEWATER-TREATMENT SYSTEM

SAMPLING THE WASTE

When a meat packing plant undertakes the task of providing treatment for its wastewater, one of the first steps is to determine the characteristics of the waste flow. As mentioned earlier, meat packing wastes vary considerably from plant to plant. Consequently, it is important to set up a sampling program to determine the specific nature of the flow for which the treatment facilities are to be designed.

Sampling stations should be established at all accessible points of waste discharge, and samples should be taken at half-hour intervals continuously for 3 days, and preferably 1 week. These samples should be combined for every 24-hour period to provide an accurate composite of the waste. A weir, or similar measuring device, should be installed at each sampling station to provide a means of determining the rate of flow when each sample is taken. The sampling bottle must be kept chilled during the sampling period, and should be delivered to the testing laboratory as quickly as possible at the end of each 24-hour interval.

It is important that the laboratory selected to perform the tests be experienced in analyzing wastewater samples. The most frequently performed determinations are 5-day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), settleable solids, suspended solids, volatile suspended solids, grease, Kjeldahl nitrogen, and pH.

DEVELOPMENT OF DESIGN CRITERIA

Once the results of the sampling program have been reviewed and analyzed fully, the design engineer can establish the design criteria. These factors are usually determined on the basis of 1,000 pounds of live weight kill or per head. Any anticipated change in slaughtering or processing operations must be considered, as current waste characteristics will be affected. If flows and BOD appear to be excessively high as sampled, a conscientious review of waste conservation and in-plant housekeeping programs should be made, with the goal of reducing these values to more generally acceptable values.

The following design factors are determined from sampling data:

- Design average flow, gallons per 1,000 pounds of live weight per day
- Design maximum flow, gallons per day
- Design BOD, pounds per 1,000 pounds live weight kill

- Design suspended solids, pounds per 1,000 pounds live weight kill
- Design workweek, days per week

EFFLUENT REQUIREMENTS

Environmental Protection Agency Guidelines

As required by Public Law 92-500,[a] the U.S. Environmental Protection Agency is preparing effluent guidelines for discharges by the meat-processing industry. The guidelines are based upon the application of the "best practicable control technology currently available." These guidelines are to be promulgated by October 18, 1973, 1 year from the date of enactment of the law. As guidance until that date, interim guidelines have been prepared by the EPA Permit Program. These values are listed in table III-1.

State Requirements

Public Law 92-500 allows the State to establish standards that are more stringent than the Federal guidelines. State effluent requirements may therefore vary considerably throughout the country and within an individual State, depending on the water quality standards for the receiving stream into which the treated wastewater will be discharged. In some States, tertiary treatment is already required on some streams and lakes, with BOD_5 and suspended solids limitations of 5 mg/l or less.

Municipal Requirements

Most municipalities have ordinances that place limitations on the characteristics of the wastewater that may be discharged into the municipal sewer system. These limitations are set to prevent operational problems at the municipal waste-treatment facility and to prevent the plant from becoming overloaded. Any industry failing to meet this limiting value must pay a surcharge. Because of the high flows and concentrated wastes discharged from a meat packing plant, it is generally necessary to pretreat these wastes to a degree that will permit the municipality to handle them. Also, further

Table III-1.—*EPA interim guidelines for meat-processing discharges*

Meat processing	BOD_5 [1]	Suspended solids[1]
Slaughterhouse	0.17	0.23
Packinghouse	.26	.35
Processing plant only	.26	.26

[1] Values expressed in terms of pounds per 1,000 pounds of live weight killed.

SOURCE: "Effluent Limitation Guidance for the Refuse Act Permit Program," Washington, D.C., Environmental Protection Agency, July 27, 1972.

[a] 92d Cong., Oct. 18, 1972.

reduction of BOD and suspended solids would be economically advantageous. Screening, grease skimming, and solids removal are perhaps the most important initial types of pretreatment. In some cases, waste flow must also be treated biologically in order to meet BOD limitations.

When a municipality builds or expands its waste-treatment facility, the industries are expected to pay their share of the construction and operational costs. These costs can become high, particularly in smaller communities where the industrial flow is a substantial percentage of the total. In these cases, the economics of extensive pretreatment, partial treatment, or completely separate and industry-owned waste-treatment facilities must be studied carefully.

DEVELOPMENT OF ALTERNATIVE TREATMENT METHODS

Once design criteria and effluent requirements have been established, various methods of waste treatment that will provide an effluent meeting those standards are investigated by the design engineer. Several additional factors must be considered in making a choice. These factors include land availability, proximity to residential or commercial areas, initial construction cost, operation and maintenance costs, and ease of operation. Meat packing plants located in a built-up area will have fewer options to consider, since available space will be at a minimum. It is wise to be in contact with State regulatory agencies at this stage of the design. Preliminary submittal of the selected treatment scheme for approval of design criteria and layout will facilitate later review by these agencies.

DESIGN OF THE TREATMENT SYSTEM

The design engineer begins preparation of final plans and specifications for construction once the selection of the treatment system is made. At this stage, it is important to obtain reliable topographical information that provides ground elevations, location of existing property lines, building, and sewers, sewer invert elevations, and a benchmark elevation on which to base proposed construction. Where a large area is involved, an aerial survey is often the most efficient way to obtain this information. The design engineer must also check the availability of utilities and electrical service at the site, as well as the power characteristics that should be used in specifying equipment.

Once the treatment units have been sized an overall site layout can be developed, leaving adequate room between structures for access and maintenance. This layout will include utilities and wastewater piping, site grading, and other site improvements. It is essential that future expansion and upgrading of the system be considered in making the layout, permitting additions to be made to the facilities with minimum disruption of the existing treatment system. Sewer outfall lines can often be designed with extra available capacity at little additional cost.

Final plans and specifications will include all structural, electrical, and mechanical work required to complete the project. Equipment drawings and specifications generally are prepared in such a manner as to permit various manufacturers to bid on the units, and installation details are provided with shop drawings furnished after award of contract.

When the plans and specifications are complete, the design engineer prepares for the owner an estimate of the construction cost. The final design documents are then submitted to the State environmental regulatory agency for review and approval leading to issuance of a permit for construction.

CONSTRUCTION

As soon as a permit has been granted by the State, the project can be advertised for bids. A notice describing the project is made available to qualified contractors in the vicinity, and plans and specifications are issued to any of these contractors, upon request, for a period of 3 weeks to a month. Sealed bids are then opened by the owner or his representative on a specified letting date. Award of contract is usually made to the low bidder, contingent upon the recommendation of the engineer.

The construction phase of the project should be subject to periodic inspection by the design engineer or other qualified personnel hired by the owner. Careful conformance of construction with plans and specifications is essential for correct and reliable functioning of the system. Any deviation from the contract documents should be made only with the approval of the design engineer. Equipment shop drawings should also be routed to the engineer for review and approval.

When construction has been completed, the contractor should put the facility into operation for a brief period of observation, during which time the owner and the design engineer should inspect the project for final acceptance.

Chapter IV

WASTEWATER-TREATMENT METHODS FOR THE MEAT PACKING INDUSTRY

The secondary treatment methods commonly used for the biological treatment of meat-processing waste flows include the following:

- Anaerobic processes
- Aerobic lagoon systems
- Variations of the activated-sludge process
- High-rate trickling filters
- Rotating biological disks

All of these treatment processes are capable of providing complete treatment and can achieve BOD reductions of 70-95 percent and suspended solids reductions of 80-95 percent. Each system has advantages and disadvantages; generally, the degree of treatment required, together with site location and limitation, capital costs, and operational costs, will dictate the selection of the treatment system. There follows a discussion of each system describing the treatment process and equipment used, as well as advantages and drawbacks. In addition, disposal of treated wastewater by irrigation methods is discussed as an alternative to tertiary treatment.

ANAEROBIC PROCESSES

Treatment by the anaerobic process is often used for wastes originating from meat-processing plants, because the nature of the waste lends itself to this type of biological activity. Elevated temperatures (85°-95° F) and high concentrations of BOD and suspended solids—typical characteristics of the waste flow from a meat packing plant—are necessary for successful anaerobic treatment. As discussed earlier, anaerobic bacteria, which function in the absence of free oxygen, break down organic waste into gases (primarily methane and carbon dioxide) through production of intermediate acids. When compared to aerobic processes, the rate of removal and sludge yield are small. Nevertheless, anaerobic treatment often proves to be a highly economical method for removing substantial amounts of BOD and suspended solids.

Two types of anaerobic treatment are commonly used, anaerobic lagoons and anaerobic contact units.

Anaerobic Lagoons

Anaerobic lagoons are used widely for treatment of meat packing wastes, and function extremely well when the wastes have the desired characteristics. Typically, meat packing wastes have a high quantity of fats and proteins, high concentrations of nutrients, and an elevated temperature—all of these are essential for good anaerobic biological treatment.

Such lagoons are designed with a low surface-to-volume ratio to conserve heat in the pond. Depths are much greater than for aerobic ponds, ranging from 12 to 17 feet. Loadings range from 12 to 25 pounds BOD per 1,000 ft^3, with 15 to 20 pounds BOD per 1,000 ft^3 frequently used in meat-processing waste applications. A typical anaerobic lagoon system consists of one or more square or rectangular ponds with a depth of 15 feet and an inlet near the bottom. A layer of sludge on the bottom of the lagoon, containing active micro-organisms, comes in contact with the incoming waste. Excess grease floats to the surface and forms a scum layer or grease cover, which serves to both retain heat and restrict odors. Recirculation generally is not considered necessary, although it has been used in some installations.

The following site conditions must be evaluated when considering anaerobic lagoons:

- Proximity to residential or commercial areas where potential odors may cause a nuisance—one-quarter mile distance from any single-family dwelling is usually considered minimum, and at least 1/2 to 1 mile from any residential area, preferably downwind

- Soil conditions—i.e., location of the ground water table and nature of the soil with respect to workability and impermeability

It is essential that a natural cover be developed as soon as possible after the lagoon is placed in operation, particularly in northern climates. The cover will minimize odors and assure adequate heat retention. Recently, concern with air pollution has resulted in consideration of artificial covers for odor control.

A natural cover will usually form if enough grease is present in the waste. To accelerate development of a cover, paunch manure or normally recovered grease may be bypassed to the lagoon for a short period. Because high winds may disturb the scum layer and result in heat loss and odor problems, a windbreak, such as a board fence sheltering the lagoon from high prevailing winds, may be advisable to keep the natural cover intact. Low pH may affect adversely the formation of a natural cover, and the influent may require some pH adjustment.

Styrofoam, polyvinyl chloride, and nylon-reinforced Hypalon have been used as artificial covers, and other materials currently are being investigated. An adequate gas collection system to trap the methane gases that rise to the surface is a major consideration in constructing a cover. Also, sunlight and wind action on the cover will affect the life of the cover, depending upon the material selected.

Properly designed inlet and outlet structures are important to successful functions of the anaerobic lagoon system. Good operation has been achieved with a feed inlet near, but not on, the bottom. The effluent piping should be near the surface, and should be designed to prevent short circuiting and disturbance of the grease cover.

Studies have indicated that solids do not accumulate to any significant extent in anaerobic lagoons, but reach a state of equilibrium. Consequently, solids removal is not a maintenance problem.

Advantages of an anaerobic lagoon system are low initial cost, ease of operation, ability to accept shock loads while continuing to provide a consistent quality effluent, and ability to handle large amounts of grease. Problems may arise if a sufficient cover cannot be maintained and odors result.

Where water used for meat processing is high in sulfates, waste flows cannot be treated in anaerobic lagoons. Oxygen is stripped from sulfates by anaerobic bacteria, and hydrogen sulfide is produced, causing severe odor problems as the gas is released to the atmosphere.

It should also be noted that the effluent from an anaerobic lagoon system generally contains up to 100 mg/l of ammonia nitrogen. The presence of ammonia nitrogen is toxic to fish in concentrations of 3-5 mg/l, depending upon pH, and water quality standards in most States limit the concentration to 2-5 mg/l. Consequently, the secondary treatment method selected to follow the anaerobic lagoon system should provide for nitrification of the ammonia nitrogen where water quality standards place this limitation.

The anaerobic lagoon system will not produce an effluent suitable for discharge into a stream without further treatment. It is highly efficient as a first-stage treatment unit and generally is followed by some form of aerobic system. Some States, however, will not permit the use of anaerobic lagoons or are requiring that they be provided with a cover.

Figures IV-1 to IV-3 show anaerobic lagoon facilities for three waste-treatment facilities.

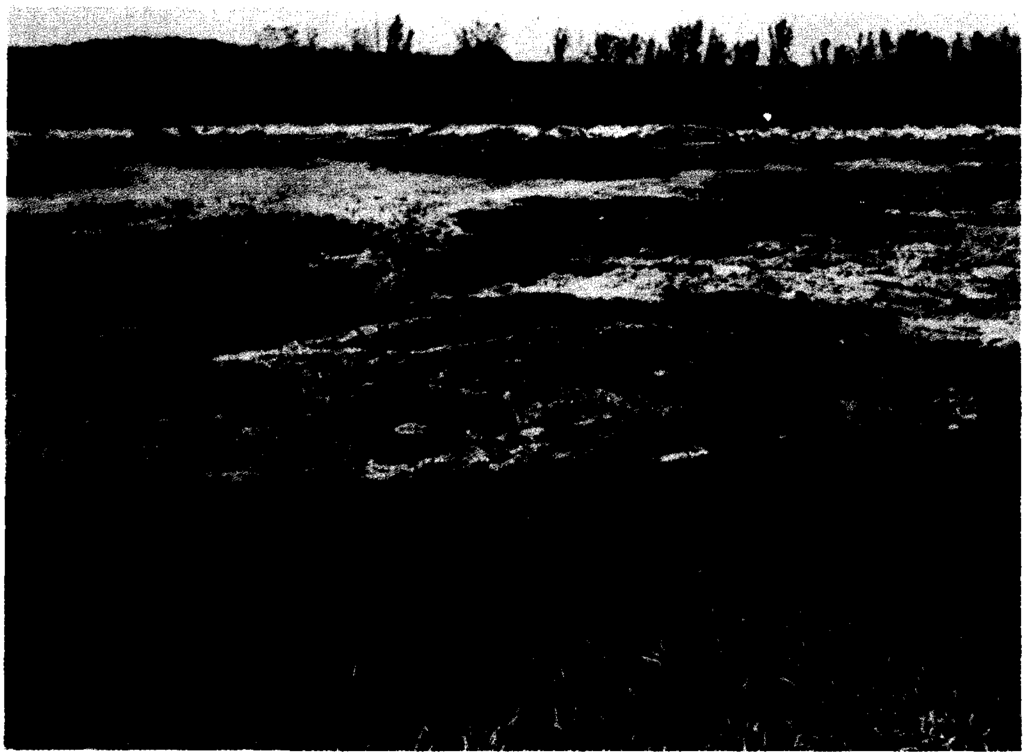

Figure IV-1. Anaerobic lagoon, Iowa Beef Processors, Inc., Denison.

Figure IV-2. Anaerobic lagoon, Farmland Foods.

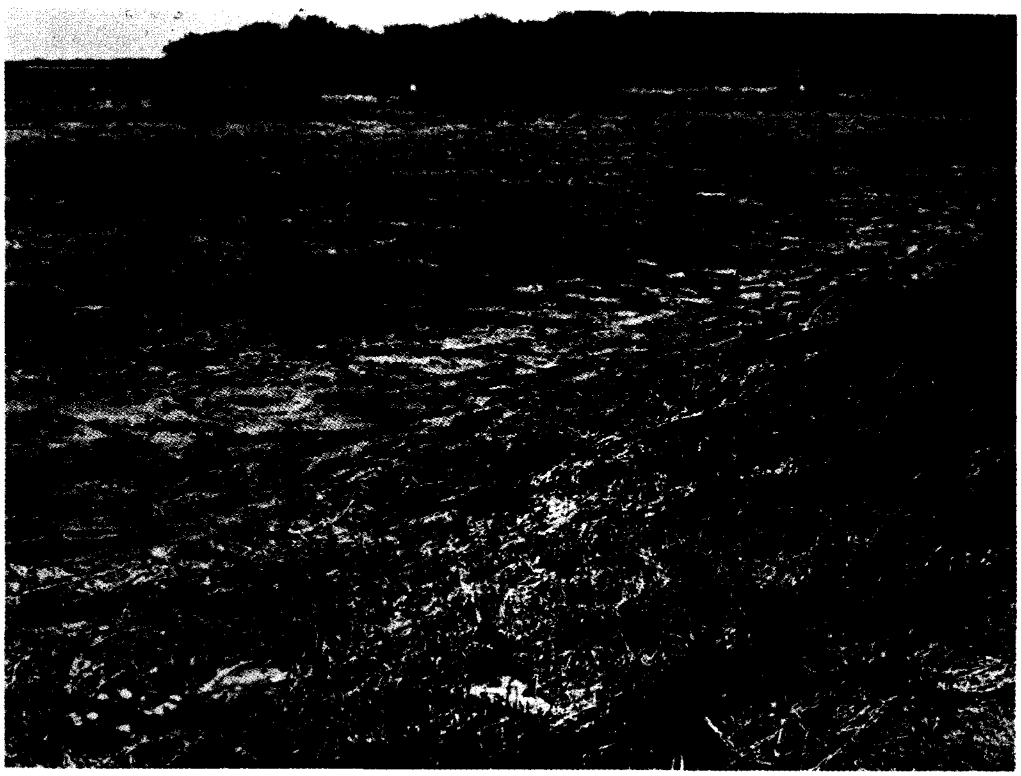

Figure IV-3. Anaerobic lagoon, Iowa Beef Processors, Inc., Dakota City.

Anaerobic Contact Process

The anaerobic contact process consists basically of an anaerobic digester with mixing equipment, a degasification system, and a clarifier. Solids from the digester are sent to a degasifier in order to minimize floating material, and are then settled, with sludge from the clarifier being returned to the raw waste line. The separation and recirculation of seed sludge permits short retention periods, ranging from 6 to 12 hours. Solids retention time for a high degree of treatment is approximately 10 days at 90° F. As the operating temperature drops, the solids retention time must be increased.

Control of pH is essential to insure proper operation, and lime or sodium bicarbonate is commonly used to raise the pH of the raw wastes. Inorganic salts in high concentrations may be toxic to the anaerobic organisms.

Anaerobic contact digester units are loaded in the range of 0.10 to 0.20 pound BOD per cubic foot per day at approximately 90°-95° F. Flow equalization is employed in order to maintain a uniform feed rate to the digester. This practice is necessary because of the short contact time involved in the process. Either draft tube or turbine-type mixers are used to provide complete mixing. Digester gas may be used to heat the digester.

The degasification step may be accomplished by vacuum degasification or air stripping. In vacuum degasification, a vacuum of 20 inches of mercury is maintained in a vessel that has a diameter equal to its length. The influent is elevated to the top of the vessel and cascaded down over slotted trays with removed gases sent to a waste gas burner. The air-stripping process involves passing diffused air through the waste to scrub off the gas. This method is less expensive, but it has more operational problems than the vacuum process.

The clarifier receiving the sludge should be provided with a well-designed recirculation system to move the light floc and to avoid a temperature loss.

Treatment efficiencies of 85-93 percent removal of BOD can be obtained with the anaerobic contact system, but usually additional aerobic treatment is required. The overall cost of such a system usually lies between that of an anaerobic lagoon system and an activated-sludge plant.

An anaerobic contact system is currently in use at the Wilson Certified Foods, Inc., plant in Albert Lea, Minn. This facility consists of a flow-equalizing basin, two digesters of approximately 12 hours' detention time, loaded at 0.156 pound BOD per cubic foot per day, two vacuum degasifiers, two sludge separation units (clarifiers), and two oxidation ponds receiving the separation effluent. The separators are designed for a detention time of 1 hour, based on total flow including recirculation. The recirculation rate is approximately one-third of the raw waste flow.

Table IV-1 presents actual operating data taken from the Wilson anaerobic contact system. BOD removal is approximately 91 percent through the anaerobic contact process and 98 percent in the stabilization ponds. Good removals (80 percent) are also obtained for suspended solids. Lagoon treatment provided after the contact process is lowering the effluent concentrations to acceptable levels and is an essential segment of the total treatment system.

AEROBIC LAGOON SYSTEMS

Treatment of domestic and industrial wastes, including those from meat packing plants, frequently is accomplished in aerobic lagoons. Two types of lagoons generally are classified as being

Table IV-1.—*Anaerobic contact system, Wilson Certified Foods, Inc., Albert Lea, Minn.. average operating data for all killing days in 1960*

Component	Raw waste[1]		Anaerobic process effluent[1]		Plant effluent corrected for seepage[2]	
	mg/l	Pounds	mg/l	Pounds	mg/l	Pounds
BOD	1,381	16,220	129	1,517	26	304
Suspended solids	998	11,610	198	2,325	23	268
Suspended volatile solids	822	10,370	153	1,800	20	232
Total solids	2,100	36,500	2,080	24,450	1,076	12,500
Total solids, water supply	560	6,500	560	6,500	560	6,500
Total solids after deducting TS in water supply	2,540	30,000	1,520	17,950	516	6,000
Total volatile solids	1,700	19,980	800	9,400	367	4,310
Total volatile solids in water supply	300	3,520	300	3,520	300	3,520
Total volatile solids after deducting TVS in water supply	1,400	16,460	500	5,880	67	790

[1] Flow, 1,410,000 gallons.
[2] Pond effluent, 772,000 gallons; loss in pond, 638,000 gallons.

SOURCE: "An Industrial Waste Guide to the Meat Packing Industry," U.S. Department of Health, Education, and Welfare, Washington, D.C., 1965.

aerobic: aerated lagoons, which mechanically introduce oxygen by aeration; and oxidation ponds, which are lightly loaded and rely on sunlight and wave action to accomplish bio-oxidation and photosynthesis. Aerobic lagoons are used frequently to provide additional treatment to the effluent from an anaerobic lagoon system. An example of an aerobic lagoon appears in figure IV-4.

Aerated Lagoons

Aerated lagoons usually are designed with detention times of 2-10 days, have liquid depths of 8-15 feet, and use some type of aeration equipment—either fixed mechanical turbine-type aerators, floating propeller-type aerators, or a diffused-air system.

In most cases, not enough turbulence is maintained in the basin to maintain the solids in suspension, and those solids that settle may be degraded anaerobically on the bottom. In those instances where sufficient turbulence does exist, the system approaches the conditions of an extended aeration system without sludge return.

BOD removal in aerated lagoons depends on temperature, detention time, and influent waste characteristics. Treatment efficiency decreases as temperature decreases. In northern climates, lower BOD reduction is experienced during the winter months. Aerated lagoons treating meat packing wastes generally are designed to achieve an average BOD reduction of 50-60 percent.

Power requirements are a major consideration. Treatment facilities handling a high industrial flow may use several hundred horsepower. Facilities for small meat-processing plants may use no more than 20 hp.

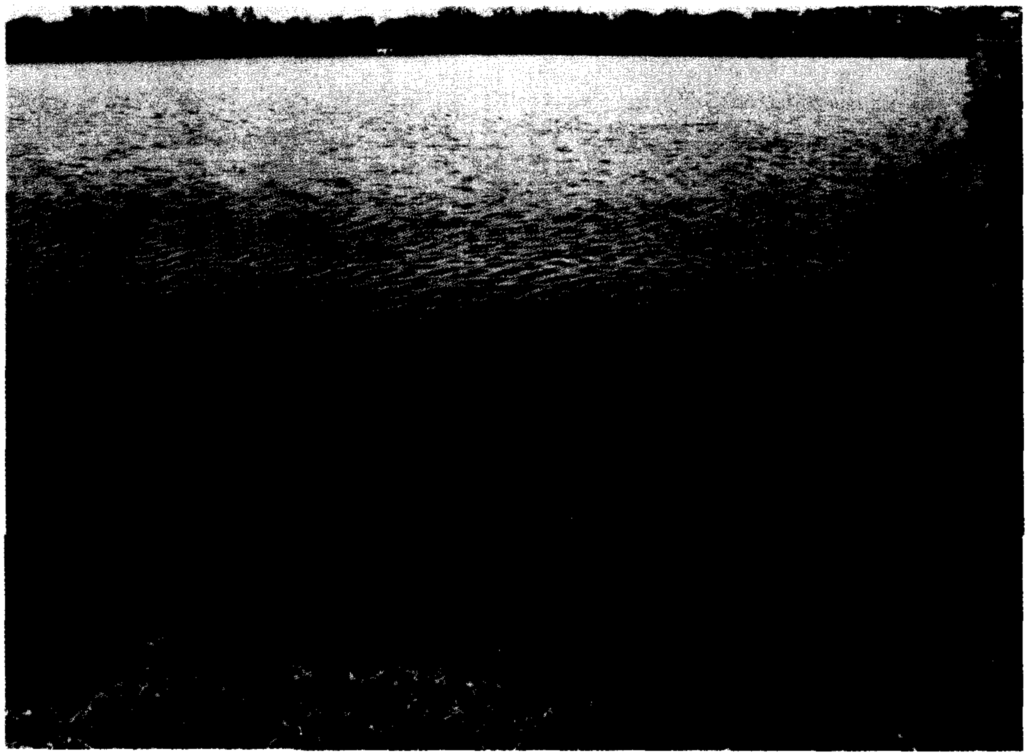

Figure IV-4. Aerobic lagoon, Iowa Beef Processors, Inc., Denison.

When aerated lagoons are used in series with anaerobic lagoons, sufficient oxygen is added to restore the waste to an aerobic state, including oxidation of sulfides, and to provide for the additional biological treatment.

The most significant advantage of an aerated lagoon system is its relatively small land requirement. The high cost or unavailability of land can easily offset the higher operational cost of the aerated lagoon system. There is, however, only a minimum reduction of ammonia nitrogen in an aerated lagoon. Furthermore, aerated lagoons must always be followed by an oxidation lagoon to capture the suspended solids and to provide additional treatment.

Oxidation Ponds

Oxidation ponds consist of relatively shallow, lightly loaded lagoons (20-40 pounds of BOD per acre) with detention times often as long as several months. They will provide a high degree of BOD reduction and have been used widely in the past for both domestic and industrial wastes. As effluent quality requirements become more stringent, however, the treatment efficiency achievable in oxidation ponds may be inadequate for discharge into a particular receiving stream. In areas where the effluent would flow into a recreational body of water, the BOD and suspended solids must be reduced in some States to 5 mg/l or less, and ammonia reduced to less than 3 mg/l.

Even when effluent requirements are less stringent, problems may develop due to the development of algae growth on the lagoon surface. The algae escape with the pond effluent and create an undesirable appearance, odor, and taste in the receiving stream.

Oxidation ponds that treat wastes from the meat-processing industry frequently are preceded by anaerobic lagoons or anaerobic lagoons in conjunction with aerated lagoons. Even with this prior treatment, the BOD remaining in the flow entering the oxidation pond may still be substantial. Since the loading rate to oxidation ponds generally is kept quite low to minimize odor problems and to provide for a high degree of treatment, large areas of land are necessary to provide adequate surface area for the wastewater.

The water depth in oxidation ponds varies usually from 4 to 8 feet. Frequently a level-control system is provided to permit rapid discharge of the effluent during periods of higher flow in the receiving stream, dropping the water level to a minimum of 2 feet before cutoff of discharge and temporary storage.

Loadings for oxidation ponds are expressed in pounds of BOD per acre of water surface. Generally accepted values for industrial ponds range from 20 to 40 pounds per acre, with 25 to 30 pounds per acre being a commonly used design loading. Loadings as high as 100 and 150 pounds of BOD per acre have been used for meat-processing wastes with reasonably high initial treatment efficiencies; however, odor problems usually have occurred and the quality and efficiency of the lagoons frequently have deteriorated after a period of several years. For this reason, State and Federal health officials are increasingly reluctant to approve these high loading rates, and engineers no longer recommend them.

Suitable soil conditions are of basic importance to stabilization pond design, as it is essential that the compacted earth below the maximum water surface be essentially impermeable. Sandy or other granular soils are unsuitable for lagoon construction and require some type of liner. Owing to the extensive surface area involved, lining of large stabilization ponds with any material other than clay soils found in upper soil layers or nearby excavation is usually prohibitive in cost. Smaller ponds may be sealed or lined with bentonite or some type of vinyl or asphalt liner.

It is usually unnecessary to chlorinate the effluent from a stabilization pond, although such chlorination may be required whenever effluent standards for pathogenic bacteria are not met.

The large surface area required for adequate treatment of meat-processing wastes often results in ponds sufficiently large to have significant wave action and accompanying erosion of dikes. Riprap is often placed on those dikes subject to the wave action caused by high winds. Continuous maintenance of the dikes is essential for good operation, as excessive weed growth will lead to septic areas and mosquito breeding, and weakening of dikes caused by erosion or burrowing by rodents can result in potential flooding of surrounding land.

The configuration of stabilization ponds is generally rectangular, with acute angles avoided to prevent dead areas. Inlet and outlet structures are placed to prevent short circuiting of the flow through the lagoon. Two or more ponds may be used in parallel to avoid the excessive unbroken surface area of one large pond. Oxidation ponds are often constructed in series to provide succeeding degrees of treatment. Stabilization ponds that follow anaerobic or aerated lagoons generally will have an average efficiency of approximately 80 percent (in the first stage), and as high as 90 percent in the summer and 70 percent or less in the winter months. Efficiency tends to drop off somewhat in successive stages, reaching as low as 50 percent in a third-stage aerobic pond.

Stabilization ponds provide an excellent means of treating meat-processing wastes before use of the wastewater for irrigation purposes. Owing to increasingly stringent effluent quality standards, however, the discharge from a stabilization pond frequently may not be satisfactory for discharge into a receiving body of water.

Probably one of the most efficient and widely used systems of biological treatment of wastewater is the activated-sludge process. Aeration of wastewater containing biologically degradable material in the presence of micro-organisms produces a mass of settleable solids known as activated sludge. Stabilization occurs as organic matter in the wastewater is used as food by the micro-organisms. There are several variations of the activated-sludge process, four of which are shown in figure IV-5 and all of which are described in the sections that follow.

Conventional Activated Sludge

The conventional activated-sludge process is composed of four functional steps.

- Primary sedimentation to remove settleable solids
- Aeration of a mixture of waste and biologically active sludge
- Separation of the biologically active sludge from the treated waste by sedimentation
- Recycle of this settled biological sludge

Following sedimentation in a primary clarifier, the wastewater is mixed with recycled sludge in an aeration basin (see figs. IV-6 and IV-7). This procedure insures that adequate numbers of

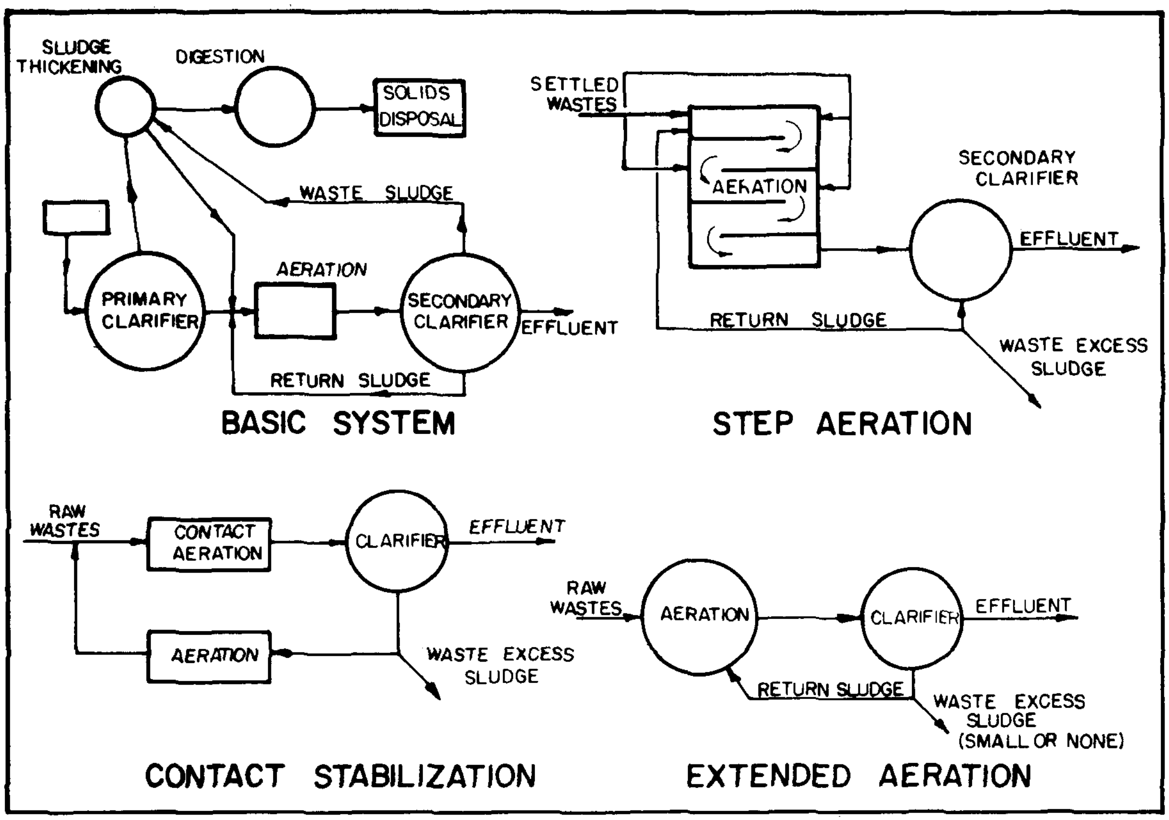

Figure IV-5. Variations of the activated-sludge process.

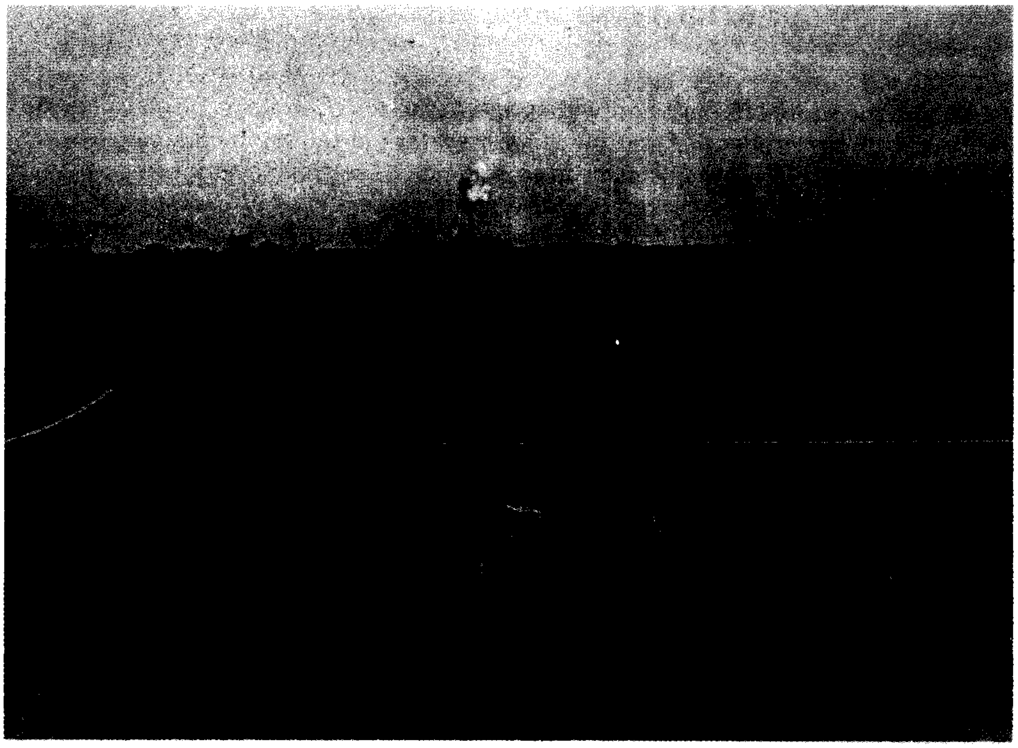

Figure IV-6. Aeration basin, American Beef Packers, Inc.

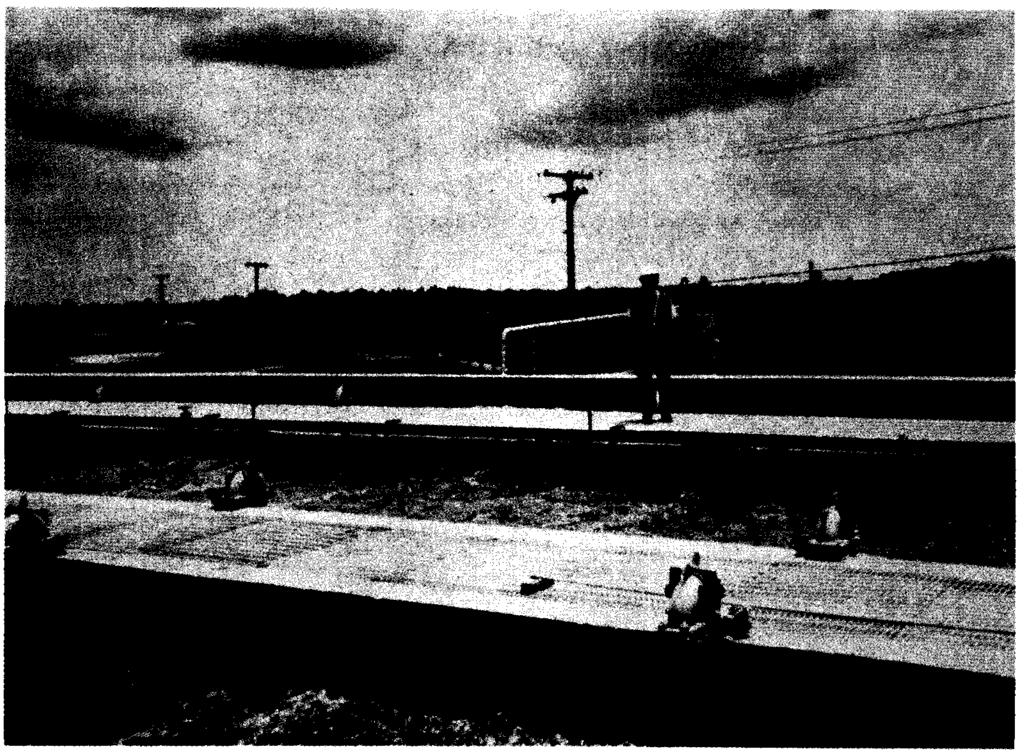

Figure IV-7. Aeration basin, Lykes Brothers Packing Plant.

micro-organisms are present to carry out the degree of waste stabilization desired. In the aeration basin the mixture of wastewater and recycled sludge is aerated for a specified length of time to provide an aerobic environment for the biological oxidation of the organic matter present. Final sedimentation following this aeration allows the activated sludge to settle, producing both a clear effluent, low in organic content, and a biologically active sludge for recycle.

The conventional process is capable of achieving BOD reductions of 90-95 percent and can produce a stable effluent with little nitrification.

The conventional activated sludge is affected adversely by the occasional spills or dumps of high organic wastes, such as blood. Also, the widely varying flows can be troublesome.

Owing to problems encountered in the basic activated-sludge system when dealing with a particular waste or when a higher degree of treatment is desired, a number of modifications have been devised.

Tapered Aeration and Step Aeration

In the basic activated-sludge system, air requirements decrease as flow proceeds through the aerated basin. Two systems, the tapered-aeration system and the step-aeration system, have been devised to match the oxygen supply with the oxygen demand.

The tapered-aeration system provides for the introduction of air to the aerated basin in decreasing amounts in an attempt to match the air applied with the air requirements of the system. Reducing the air applied in no way affects the biological process in the basin so long as sufficient amounts of air are present. The procedure does, however, increase the air application efficiency, as only that air actually required is supplied to the basin.

The step-aeration system splits the wastewater flow to the aerated basin and feeds it separately at different points along the aeration basin. The return activated sludge is introduced with the first portion of the raw waste at the head of the basin. Step aeration evens out the air requirements over the length of the tank, allowing higher BOD loadings, shorter detention times, and more efficient use of applied air.

Contact Stabilization

The BOD in sewage is rapidly adsorbed by micro-organisms after initial contact between waste and organisms. In the conventional activated-sludge system, the time and air necessary to stabilize this adsorbed material is provided in the same tank where original contact between waste and organisms was made.

The contact-stabilization process provides separate tanks for initial micro-organism waste contact and stabilization. The micro-organism-waste-contact part of the process generally requires 15-30 minutes. Following the tank in which initial contact takes place, a clarifier is used to settle out the micro-organisms and the organic material entrapped with them. The settled sludge is then pumped to a second aerated basin where the time and air required to stabilize the entrapped organic material is furnished. The overflow from the clarifier is then chlorinated and discharged directly to a receiving stream.

The contact-stabilization process allows a substantial savings in basin size over the conventional system. The short detention time in the first basin and the smaller volumes of sludge recycled to the second basin make this savings possible. There are not many designed true contact-stabilization systems, and none for meat packing wastes.

Completely Mixed Activated Sludge

By providing enough mixing in the aeration tank to mix completely the incoming wastewater with the contents of the tank, it is theoretically possible to obtain any degree of treatment desired. The rapid mixing produces a homogeneous mixture of wastewater and activated sludge within the aeration basin. Any slugs of incoming waste are mixed quickly and distributed evenly throughout the basin, reducing the chance of system upset commonly associated with conventional systems.

Extended Aeration

A completely mixed, activated-sludge system designed for long detention time (24 hours or more) is known as an extended-aeration system. Extended-aeration systems operate at the lowest BOD loadings of any activated-sludge system. Due to the smaller amounts of food available to the organisms, nearly complete oxidation occurs for micro-organisms and BOD removals are high. Removals in excess of 95 percent are not uncommon.

Provision must still be made, however, for wasting sludge, as solids tend to accumulate within the system. Generally, provision is also made for 50-100 percent sludge recycle to the aeration basin from the final clarifier.

Advantages of the extended-aeration system include ability to handle shock loads, low capital investment due to elimination of primary clarifiers and sludge digestion equipment, as well as the capability to produce a nitrified effluent.

Nitrification in Extended Aeration

Long detention times and aerobic conditions found in extended-aeration systems provide an ideal atmosphere for the process of nitrification. Under aerobic conditions, ammonia is converted to nitrites and nitrates by specific groups of nitrifying bacteria. A sludge detention time of 8-10 days is required for the nitrifying organisms to establish themselves in sufficient numbers to accomplish any significant degree of nitrification. Usually, extended-aeration systems designed to accomplish nitrification are designed for sludge detention times in excess of 10 days. Although liquid detention times in the system are generally approximately 24 hours, the sludge age may be controlled by regulating the amounts of sludge recycled and wasted each day.

Oxygen (for the oxidation of ammonia) must be supplied in excess of that required for BOD reduction. About 4.33 pounds of oxygen are required to convert 1 pound of ammonia nitrogen to nitrates. This need results in a substantial increase in air requirements over those required for BOD reduction alone, necessitating the installation of larger, more expensive aeration equipment.

Extended-aeration systems that follow anaerobic lagoons are capable of producing an effluent low in BOD and ammonia nitrogen. Anaerobic lagoons are capable of BOD reductions in excess of 80 percent; however, under anaerobic conditions the protein in the packing-plant wastes are decomposed, resulting in the conversion of most nitrogen forms present to ammonia nitrogen and some nitrogen gas. The nitrogen gas escapes to the surrounding atmosphere, but the ammonia nitrogen remains in the anaerobic pond effluent, creating an additional oxygen demand if discharged to a receiving stream. Further, ammonia nitrogen is toxic to fish at low concentration. The use of an extended-aeration system following anaerobic lagoons provides the time and air required to reduce the remaining BOD and convert the ammonia nitrogen to nitrates. Following final sedimentation and chlorination, the effluent may be discharged to a receiving stream with a minimum of impact.

It should be noted that although the nitrogen in the plant effluent does not create a significant oxygen demand upon the receiving stream, it does remain a nutrient source, enhancing the possibility of undesirable aquatic plant growth and algae blooms.

Activated-Sludge Treatment for Meat-Processing Wastes

All of the previously mentioned activated-sludge systems may be used to treat wastes characteristic of the meat packing industry. The particular system chosen will depend on the degree of treatment desired and the existing facilities available for use.

The conventional, tapered-air, step-aeration, contact-stabilization, completely mixed, and extended-aeration systems will all produce an effluent capable of meeting effluent standards for BOD reduction. In many cases the particular system chosen will depend to a large extent upon the characteristics of the effluent from existing treatment facilities.

For example, many meat processors use anaerobic lagoons for reduction of BOD. The effluent from these lagoons is usually still quite high in BOD and contains large amounts of ammonia nitrogen. Extended aeration following anaerobic lagoons, as mentioned earlier, performs quite well in reduction of the remaining BOD and nitrification of ammonia nitrogen. This treatment system functions well, meeting both BOD and ammonia nitrogen effluent standards.

Some of the loading and operational parameters for the activated-sludge processes described earlier are presented in table IV-2. BOD loadings to aeration tanks are calculated using the influent wastewater BOD only. Loadings are expressed as pounds applied per day per 1,000 ft^3 of aeration tank volume and pounds of BOD per day per pound mixed-liquor suspended solids (MLSS) in the aeration basin. Aeration periods, expressed in hours, are calculated using the daily average flow without regard to return sludge flow. The return sludge flow usually is expressed as a percentage of the daily average flow.

TRICKLING FILTERS

Trickling filters commonly are used for biological wastewater treatment. With this system, wastewater that has undergone primary settling is sprayed over beds of rock or other media to achieve contact between micro-organisms present on the surface of the media and organic material in the wastewater.

A trickling filter is composed of three main components.

- The rotary distribution arms (fig. IV-8)
- The media (fig. IV-8)
- An underdrain system

Where ample head is available, rotary distribution arms are turned by the reaction of water leaving nozzles in the arm. Distribution arms are used to distribute uniformly the wastewater flow over the filter media. Where sufficient head is not available, water must be pumped to the distributor.

Table IV-2.—*General loading and operational parameters for activated-sludge processes*

Process	BOD loading		Aeration period, hours	Average return sludge rates, percent	BOD efficiency, percent
	Pounds BOD per 1,000 ft^3	Pounds BOD per pound MLSS			
High rate (complete mixing)	100 up	0.5-1.0	2.5-3.5	100	85-90
Step aeration	30-50	0.2-0.5	5.0-7.0	50	90-95
Conventional (tapered aeration)	30-40	0.2-0.5	6.0-7.5	30	95
Contact stabilization	30-50	0.2-0.5	6.0-9.0	100	85-90
Extended aeration	10-30	0.05-0.2	20-30	100	85-90

SOURCE: *Water Supply and Pollution Control,* p. 507, Clark, Viessman, and Hammer, International Textbook Co., 1971.

Figure IV-8. Trickling-filter arms and media, Farmland Foods.

The filter media provides both a surface for the biological growth as well as voids for movement of air and water through the filter bed.

Because of its low cost, durability, and availability, stone or crushed rock has been the most popular filter media in the past. New materials have been developed recently and are on the market. They include various plastic media and redwood slats. Advantages of the newer media include lower weight, chemical resistance, and a high specific surface area with a large volume of void spaces. Thus the synthetic media will require significantly less space to accomplish the same degree of treatment.

The underdrain system provides the means to carry away the filter effluent, allows circulation of air through the filter bed, and provides structural support for the filter media.

Filters using lightweight plastic media are able to make use of much deeper beds (up to 21.5 feet) than those using crushed rock.

The high-rate filter and the roughing filter are the most common trickling-filter systems presently used. Flow diagrams for the high-rate- and roughing-filter systems are shown in figure IV-9.

BOD loadings to trickling-filter systems generally are expressed either as pounds of BOD per 1,000 ft^3 of filter media, or as pounds per acre-foot of media. Hydraulic loadings are expressed as million gallons per acre per day of filter area, or as gallons per minute per square foot of filter area. The hydraulic loading is computed using both the raw wastewater flow plus the recirculated flow.

The high-rate trickling filter is capable of achieving BOD reductions as high as 90 percent with proper recycle and loading rates. Removals in the roughing filter are considerably less than those in the high-rate system.

The major use of trickling filters in the meat-processing industry involves their use as roughing filters. Roughing-filter systems operate at hydraulic and BOD loadings much higher than those of conventional trickling-filter systems. Their major function is to smooth out influent shock loads and provide some initial reduction of BOD. In most cases roughing filters are used prior to some type of the activated-sludge system.

ROTATING BIOLOGICAL DISKS

The use of rotating biological disks (see fig. IV-10) is a new approach to the treatment of meat-processing wastes. The disks were first developed in Europe in 1955 for the treatment of domestic wastes. Today there are approximately 1,000 domestic installations located primarily in West Germany, France, and Switzerland. Development work on the rotating biological disks in the United

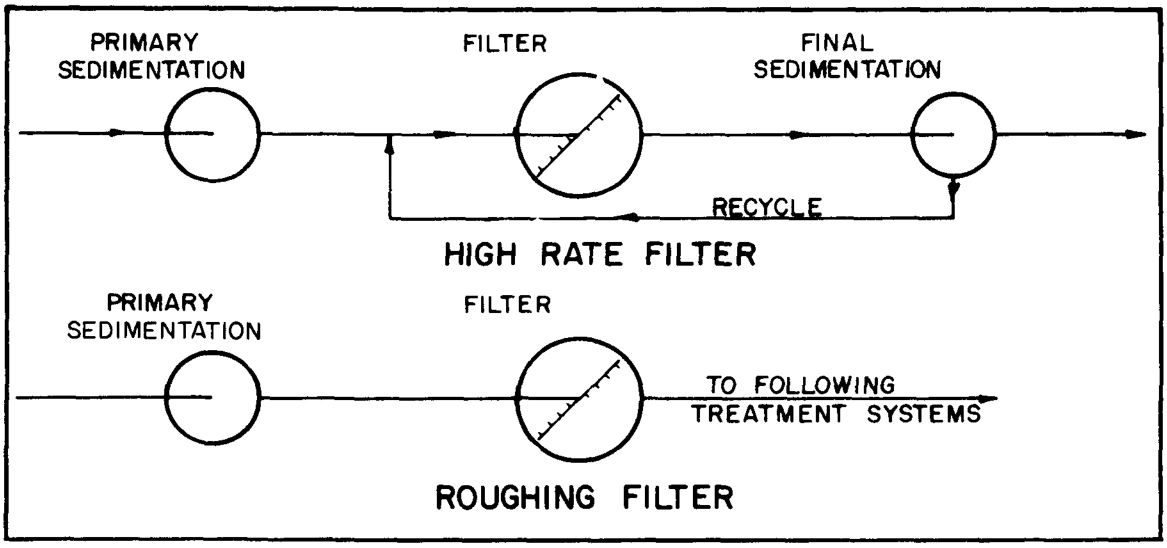

Figure IV-9. Flow diagram, high-rate and roughing trickling filters.

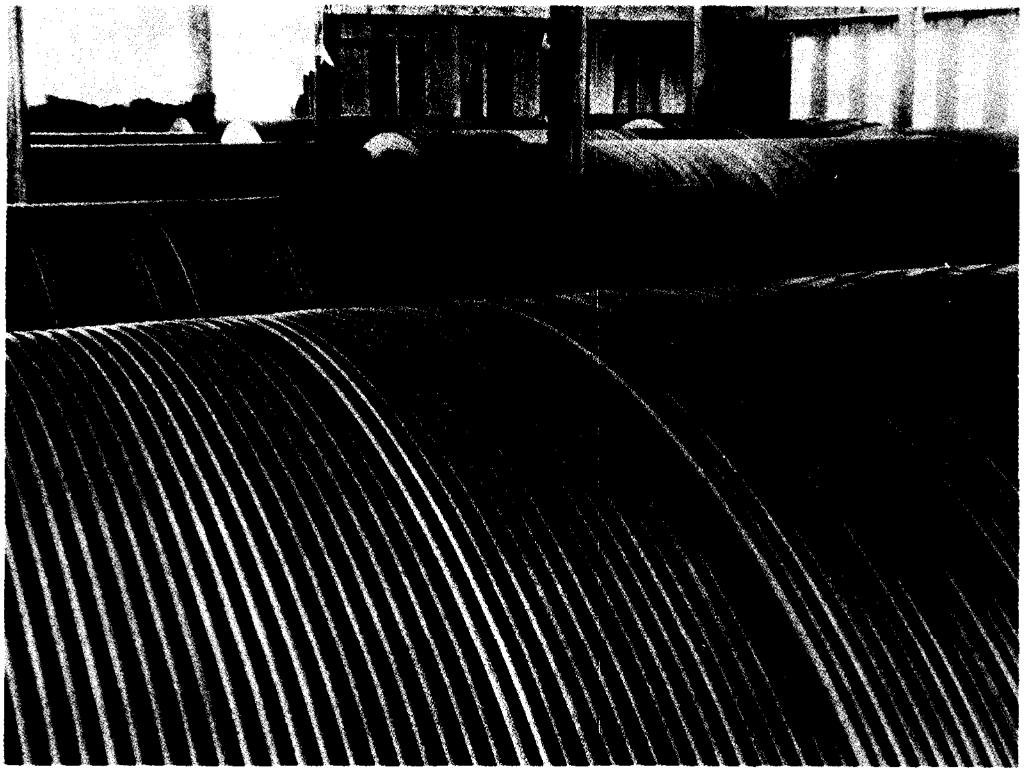

Figure IV-10. Rotating biological disks, Iowa Beef Processors, Inc., Dakota City.

States began in 1965. Use of the disks in the treatment of meat-processing wastes is recent, and, to date, no operational data are available except on a pilot-plant scale. A large treatment facility for the Iowa Beef Processors plant at Dakota City, Nebr., is currently under construction and should be in operation later this year.

The rotating-biological-disks system consists of large-diameter, lightweight plastic or high-density Styrofoam disks, mounted on a horizontal shaft and placed in a semicircular tank containing wastewater. Organisms present naturally in the wastewater adhere to the rotating surfaces and begin to multiply. The disks rotate through the wastewater, which adheres to them. The wastewater then trickles down the disks, absorbing oxygen. The aerobic organisms present in the wastewater then use the oxygen to reduce the organic matter in the wastewater. As the disks continue to rotate through the wastewater, the organic material is reduced further. The disks support a growth of organisms, provide aeration of wastewater, and also provide contact of organisms with the wastewater. Excess growths of organisms slough off the disks. This activity minimizes clogging problems and maintains a nearly constant growth of organisms on the disks. The mixing action of the disks in the wastewater prevents the solids that have sloughed off from settling in the tank. These solids are removed in a final clarifier following the disks.

BOD removal and oxidation of ammonia nitrogen have been found to be directly proportional to the hydraulic loading on the disk units. At a specific hydraulic loading, a given percentage of BOD generally is removed even with fluctuation of the influent BOD. As a result, the principal design criterion is hydraulic loading.

Wastewater temperature will affect rotating-biological-disk efficiency, but this effect is negligible for normally encountered ranges of temperature. Wastewater temperatures in the range of 60° to 80° F have little effect on disk-treatment efficiencies. Waste temperatures from packing plants will average generally from 80° to 95° F; thus, the treatment efficiency will be higher than normally experienced.

The arrangement of biological media (organisms) in a series of stages has been shown to enhance the overall treatment of a wastewater, because the organisms that develop on each successive stage (disk) are adapted to treat the characteristics of the wastewater in each stage. Generally, the organisms present in the first stages remove the organic (carbonaceous) material present in the wastewater, while the last-stage organisms are adapted to converting ammonia nitrogen to nitrate nitrogen (nitrification). Nitrogen in the ammonia form is toxic to aquatic life.

The rotating biological disks should be enclosed to protect the organisms from cold temperatures and to help control odor emissions. As discussed earlier, waste-treatment efficiencies are reduced considerably when temperatures fall below 55°-60° F. The enclosure helps to prevent winter weather from adversely affecting the treatment system. The enclosure will help also to control odor problems that may occur, by confining the odors in the building. Adequate ventilation is imperative, however, particularly if the waste flow is anaerobic when it enters the system. An odor control system may be required.

The type of enclosure generally used for a rotating-biological-disk system is a timber or concrete building with a poured-concrete floor. Steel construction is not generally suitable since the air within the rotating-biological-disk building has a high degree of humidity.

A simplified, typical flow schematic illustrating the treatment of a meat packing waste using rotating biological disks is shown in figure IV-11. The raw wastewater flows into anaerobic lagoons or into a pretreatment facility, where suspended solids and BOD are removed and where flows are equalized. The partially treated flow then goes to the rotating biological disks, where the organic material is converted to a biological floc that can be settled in the final clarifiers. The wastewater is then disinfected by chlorination before discharge to the receiving stream.

Rotating biological disks also can be used in completely aerobic systems. The disks must be preceded by adequate grease removal. The number of stages of disks required will depend upon the desired degree of treatment. The system will also include a final clarifier and chlorination. A system of this type currently is treating wastes at Kralis Poultry in Olney, Ill. The effluent is discharged to the municipal sewer system. With four stages, BOD and suspended solids less than 200 mg/l have been achieved.

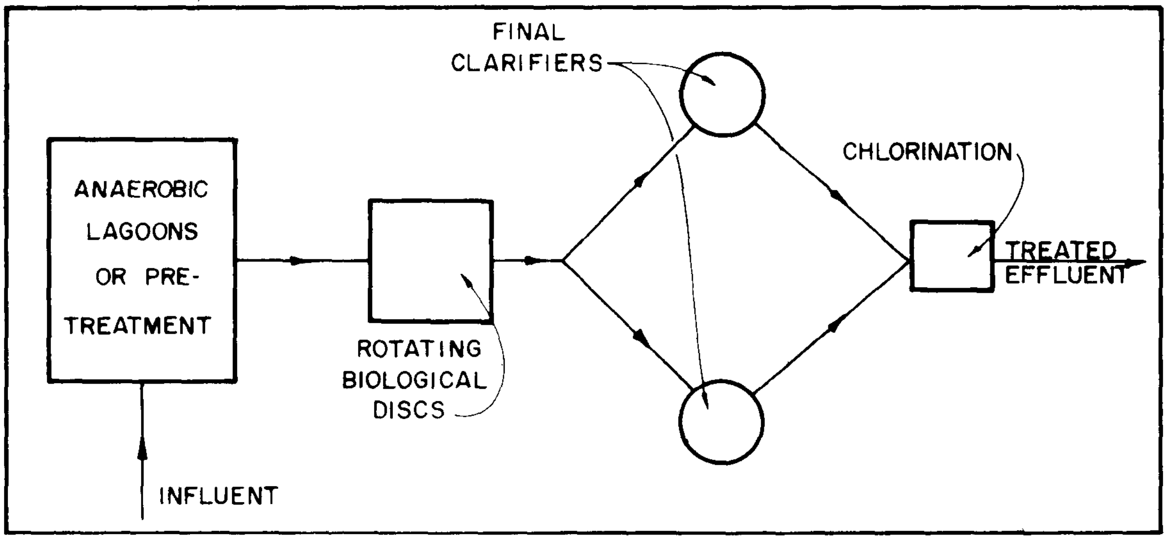

Figure IV-11. Typical flow schematic, rotating biological disks.

As water quality standards become more stringent, increasingly elaborate and complex treatment systems become necessary. These tertiary treatment systems will have a high first cost as well as high annual operation and maintenance costs, all of which must be borne by the meat packer. One possible alternative is the disposal of treated wastewater by application to the soil. Where sufficient land area is available, this method may be less expensive in first cost, as well as in operation and maintenance costs, when compared to a highly sophisticated tertiary treatment facility.

Application of wastewater on the soil can be a natural and efficient method of waste disposal. During movement into and through the soil, contaminants are removed by chemical, biological, and physical action. Generally, soil disposal systems are classified according to the mode of application of wastewater. In the physical sense, they differ with respect to the volume of water applied and the pathway taken by the liquid through the soil. There are three basic methods of irrigation that can be used for ultimate disposal of wastewater: spray irrigation, overland runoff, and rapid infiltration.

Spray Irrigation

Spray irrigation is defined as the controlled spraying of wastewater onto the land, at a rate measured in inches of wastewater per week, with the flow path being infiltration and percolation within the boundaries of the disposal site with no surface runoff. Natural precipitation is a factor, because wastewater applications must be suspended or greatly reduced when the ground is very wet from heavy or prolonged rain or snow. Because spray irrigation is limited generally to the plant-growing months, adequate storage ponds must be constructed as part of the system.

The major limiting factor in spray irrigation is the maintenance of infiltration capacity, which is reduced due to clogging of the soil by solids present in the wastewater. The most common method of restoring the infiltration capacity of a soil involves the intermittent application of wastewater with intervening rest periods. If wastewater were to be applied continuously to the soil, an equilibrium infiltration rate eventually would be established—a rate generally too small to be acceptable.

Another important factor in spray irrigation is the necessity of maintaining aerobic conditions in the soil to insure proper treatment of the wastewater. Consequently, application rates should be significantly less than infiltration capacities if unsaturated soil conditions (i.e., aerobic conditions) are to exist in the infiltration surface.

Ground water characteristics must be studied thoroughly before spray irrigation is commenced in order to preclude the possibility of ground water contamination. The soil mantle between the ground surface and the water table must be of sufficient depth to insure treatment of the wastewater before it reaches the ground water. Caution must be exercised where geologic conditions include fracture zones (e.g., limestone formations) for rapid water movement with little filtration may result in contamination. Minimum depths from the ground surface to the ground water table may vary from 10 feet to 15 feet depending on the infiltration rate of the particular soil.

Spray application rates usually are expressed in terms of inches of liquid depth per unit of time. Net weekly applications may range from 0.2 inch to 6 inches, but the most common application rate is 2 inches. Application rates and weekly application amounts generally are selected in terms of the capacity of the vegetation to take up nutrients. Usually this method results in application rates being less than infiltration rates.

Many different crops have been used successfully in land disposal operations, including wheat, corn, alfalfa, clover, and Sudan grasses. Corn and some of the grasses grown as hay crops have significant nutrient uptake capabilities.

Spray irrigation can be practiced on land that is either flat or gently rolling. Land areas characterized by steep slopes will become eroded before infiltration can take place.

Spray equipment will vary, depending on the site topography and crop. (Conventional aluminum irrigation pipe commonly is used.) For large, permanent facilities, the pipe network can be buried, with only risers and spray nozzles appearing above the ground surface. At sites with flat or rolling terrain, center-pivot irrigation systems can be used successfully. Self-propelled traveling sprinkler systems (figs. IV-12 and IV-13) are another common type of equipment.

Overland Runoff

Overland runoff is defined as the controlled discharge (of wastewater onto the land) by spraying or other means, at a rate measured in inches per week, with the flow path being downslope sheet flow. This method of wastewater application relies on the treatment of the wastewater during its passage over the ground as a thin liquid layer, due to contact with the soil and plant roots. Overland runoff is best suited to sloping sites with impermeable subsoils.

Natural precipitation is a factor in overland runoff, requiring either the suspension of wastewater applications or substantial reduction in rates during periods of sustained rain or snowfall.

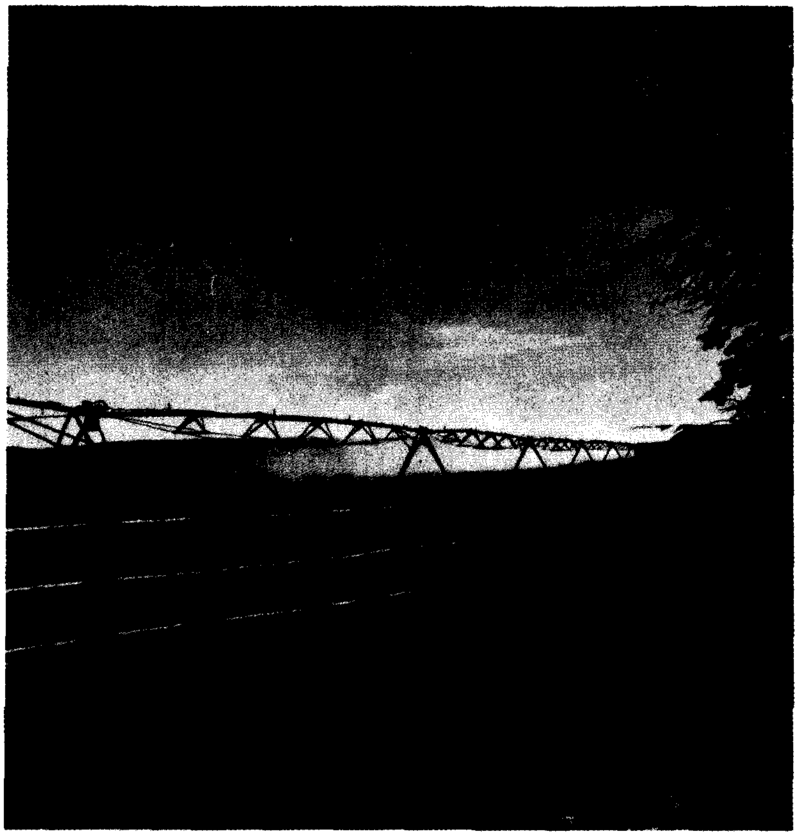

Figure IV-12. Traveling sprinkler system.

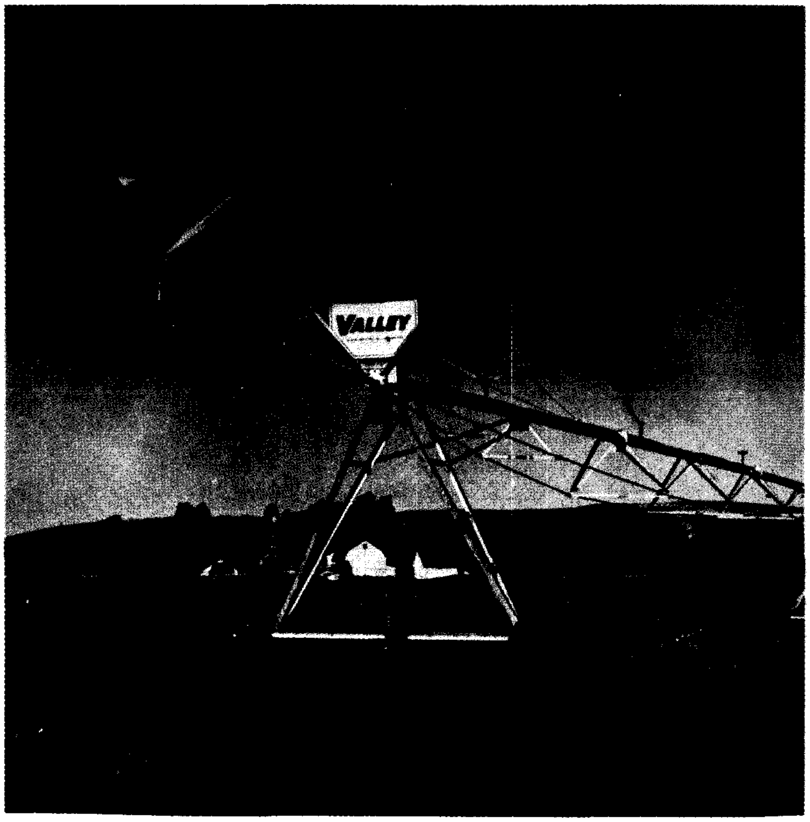

Figure IV-13. Detail, traveling sprinkler system.

One of the major design considerations in designing an overland runoff system is achieving and maintaining proper overland flow. Flow that is too slow can result in ponding and anaerobic conditions; too rapid flow will result in inadequate contact time between the wastewater and the soil and vegetation. The site must be steep enough to maintain desired flow without causing erosion. Slopes for overland flow may vary between 2 percent and 6 percent. Unbroken slope lengths should not exceed 300 feet, while application rates average 2 inches per week.

The treated wastewater is intercepted in collection ditches at the toe of the slope, and then discharged directly to a receiving stream. If the wastewater is not yet adequately treated, it may be discharged across a second slope before ultimate discharge to the stream or ditch.

Fixed spray nozzles are usually used in applying wastewater to the land for overland runoff. The pipe network may be buried with only risers and spray nozzles appearing above the ground surface.

Plant species currently used in overland runoff installations consist of grasses grown for hay cropping, such as Kentucky blue, Bermuda, red top, and fescue.

Rapid Infiltration

Rapid infiltration is similar to spray irrigation in that the wastewater is intended to infiltrate the soil and become treated during percolation. With a rapid-infiltration system, however, the application rates are substantially higher and the wastewater is applied by spreading or flooding rather than by spraying. Precipitation is not a significant factor, because the liquid volume of the spreading basins will be relatively unaffected by rainfall.

The limiting factor in rapid infiltration is the maintenance of infiltration capacity. Surface clogging can be controlled by the intermittent application of wastewater, with intervening rest periods.

The depth of the ground water table is of major concern in rapid infiltration, just as it is in spray irrigation, owing to the possibility of ground water contamination. Minimum distances between the ground surface and water table may range between 10 and 15 feet, depending on the type of soil.

Application rates will vary considerably, ranging from 6 inches to 2 feet per day.

Irrigation Design Report

Before the time an irrigation system is placed in operation, most State regulatory agencies will require an irrigation design report. This report usually must include maps and diagrams of the area affected by the irrigation system, as well as any additional pertinent material about the location, geology, topography, hydrology, soils, areas for future expansion, and adjacent land use. The system must be designed to prevent surface runoff from leaving and entering the site, and must be adequately fenced.

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Chapter V

OPERATION AND MAINTENANCE OF WASTE-TREATMENT PLANTS

The construction of a wastewater-treatment facility is only the first step in the process of achieving successful waste treatment. The second, equally important step is the proper operation and maintenance of the physical plant to insure the treatment that the system was designed to achieve. Responsibility for this program should be in the hands of well-trained and conscientious personnel.

Industries using complicated treatment facilities and plants using relatively simple treatment systems both require someone in charge who has a thorough knowledge of his job. The plant operator is often called upon to make adjustments or modifications in the treatment units to obtain maximum treatment efficiency. The equipment must receive proper care if the treatment system is to provide the degree of treatment designed into the system.

A good program of waste flow sampling can help substantially in obtaining the optimum degree of treatment. In addition to providing the required data for regulatory agencies, a complete record of treatment factors may help the operator cope with present inconsistencies and future expansion in the waste treatment system. Familiarity with the physical appearance of the raw influent and of the well-treated or undertreated effluent flow will provide an indication to the operator of an upset or change that will require more detailed and careful sampling. A reliable and workable arrangement must be made for the analytical work that is required, whether this work is performed by company personnel or by an outside agency.

The operational problems to be encountered will depend on the waste characteristics, type of treatment, climate, and design. All manufacturers' data should be read, understood, and kept as a permanent record, along with all shop drawings. A detailed manual relating to proper operation of treatment plants, such as one published by the Water Pollution Control Federation, should be readily available as a reference for all employees associated with the waste-treatment facilities. Such manuals contain information on the causes and cures of many operational difficulties encountered in usual types of treatment. Operational practices for anaerobic and aerobic lagoons may be found in numerous textbooks or published articles in wastewater journals. Further, an operation and maintenance manual dealing with the specific waste-treatment system should be provided to the industry by the engineer who designs the facility.

In addition to proper operation, the importance of maintaining the physical structures cannot be underestimated. A system of routine inspection and maintenance should be established, based on the nature and needs of the equipment. All literature from the manufacturer relating to equipment upkeep should be filed for future reference after being studied by the operations staff. A supply of spare parts, as recommended by the manufacturer, should be kept on hand at all times.

If possible, daily attention should be given to the operation and maintenance of the system. Simple systems may require little day-to-day care, but they should be checked regularly. Care of the treatment site is also important. Mowing should not be neglected, fences and gates should be kept in good repair, and utilities should be maintained.

There follows a schedule listing some of the many types of maintenance required on various segments of the complete system. This schedule should serve only to provide a base upon which each individual plant operator may build his own waste-treatment operation and maintenance program.

Pumping Stations

1. Hose down wet well to control grease accumulations.

2. Check packing glands for correct tightness (centrifugal pumps).

3. Adjust V-belt drive as necessary.

4. Lubricate pumps according to manufacturers' recommendations, using high-grade lubricants.

5. Check bearings for overheating after starting pump.

6. Inspect pump and bearings on shutdown so that necessary maintenance can be performed during shutdown period.

7. Inspect water-level controls in wet well to insure proper operation.

8. Check electric motor pump drives periodically.

9. Alternate pumps weekly if automatic alternation is not provided.

Screening Facilities

1. Check daily to determine if screens require cleaning.

2. Rake screens and dispose of material by burying or other suitable means.

Sedimentation Tanks (Clarifiers)

1. Check tanks and equipment several times daily for proper operation.

2. On a regular schedule, clean inlet baffles, effluent weirs, and scum removal mechanisms.

3. Hose down all spills.

4. Keep lubrication records for all equipment, and use high-grade lubricants.

5. Drain tanks annually and inspect all systems for wear and corrosion. Replace badly worn equipment and adjust all chains.

Trickling Filters

1. Inspect rotating-arm nozzles daily for clogging. Clean as required.

2. Check bearings and lubricate in accordance with manufacturers' recommendations.

3. Adjust guy lines to account for seasonal temperature variations, thus allowing arms to remain horizontal.

4. Check filter surface daily for contaminants, such as leaves or debris.

5. Periodically inspect underdrain system for clogging.

6. Follow recommended courses of action if trouble develops, such as ponding, filter flies, odor, and icing.

Chlorination Facilities

1. Check daily for proper functioning of all systems.

2. Check for leaks every 8 hours.

3. Check safety equipment monthly.

4. Check feed rates every 8 hours.

Activated-Sludge Systems

1. Check air compressors for lubrication and overheating.

2. Check air filters daily for cleanliness. Clean monthly.

3. Use rotation schedule for compressors to insure even wear.

4. Check compressor for satisfactory performance.

5. Check air flow in tanks every 8 hours.

6. Check all aeration tanks annually and repair or replace worn equipment.

Sampling

1. Check raw flow rate weekly, preferably daily.

2. Perform periodic settleable solids tests on influent and effluent flow.

3. Perform daily DO, BOD, suspended solids, and settleable solids tests on activated-sludge systems to insure proper operation.

4. Run BOD, suspended solids, and DO tests daily or biweekly at trickling-filter plants, but not less than two times a week.

5. Run tests for nitrates, ammonia nitrogen, and organic nitrogen, and possibly for phosphates on samples collected preceding and following treatment at regular intervals.

6. Perform daily tests for settleable solids, suspended solids, and total and volatile solids on samples from sedimentation units. Check sludge for total and volatile solids to provide information required for proper operation of sludge recirculation and drawoff systems.

7. Perform, at regular intervals (for both influent and effluent), grease determination on all grease removal systems.

8. Perform all tests on plant effluents required by regulatory agencies.

General

1. Mow grass on ground dikes.

2. Keep in good repair all external construction, such as buildings and sheds.

3. Check for leaks in valves and other appurtenances.

4. Check operability of all valves and gates.

Chapter VI

CASE HISTORIES

AMERICAN BEEF PACKERS, INC.

The American Beef Packers, Inc., plant at Council Bluffs, Iowa, was constructed in 1969. The plant consists of beef-slaughtering and -processing facilities in a main plant, with hide-processing facilities located in an adjacent building. Waste-treatment facilities included with the plant construction consisted of an air flotation tank to remove grease from the slaughtering-processing waste stream, followed by an aerated lagoon. Effluents from the flotation tank and the hide-processing building were discharged separately to the aerated lagoon before disposal in the city sewer system. Four 50-hp, slow-speed, pedestal-supported mechanical aerators, located at the south end of the aerated basin, were used to supply oxygen for BOD reduction.

Anaerobic odors emanating from the aerated basin owing to an insufficient amount of aeration, coupled with recently increased sewer surcharge fees established by the city of Council Bluffs for discharge of the plant effluent into the municipal sewer system, made upgrading of the existing treatment facilities necessary and economically advantageous. Modifications to the existing facilities were investigated that would stop the odor nuisance caused by anaerobic conditions in the aerated basin and increase overall BOD removals to comply with standards required for discharge to the city sewer without surcharge.

The system designed to upgrade the existing facilities was an extended-aeration system based on the following design data:

- BOD loading = 18,000 lb/day
- Design flow = 1.5 mgd

At a design flow of 1.5 mgd, the existing basin provides a detention time of 3.5 days, which is more than adequate for the extended-aeration system. The air supplied to the basin was considered insufficient both for the necessary mixing and for BOD reductions, as evidenced by the anaerobic conditions existing at the northern end of the basin. Consequently, eight 40-hp, high-speed floating aerators were added to the existing aeration basin to provide the additional air required. As an integral part of the extended-aeration system, a 55-foot-diameter, concrete clarifier (fig. VI-1) was constructed, with provisions for sludge return in an amount equal to 100 percent of the design flow. Effluent from the clarifier is discharged to the existing city sewer system. The schematic flow diagram for the plant is shown in figure VI-2.

Grease skimming and solids screening are provided for the hide-processing effluent (brine curing) before discharge to the aeration basin. (See figs. VI-3 to VI-5.)

The eight 40-hp aerators were installed in the aerated basin before completion of the clarifier in order to correct the prevailing anaerobic conditions. The aeration equipment was furnished at a cost of $35,000, and was installed by American Beef Packers. The new 55-foot-diameter clarifier,

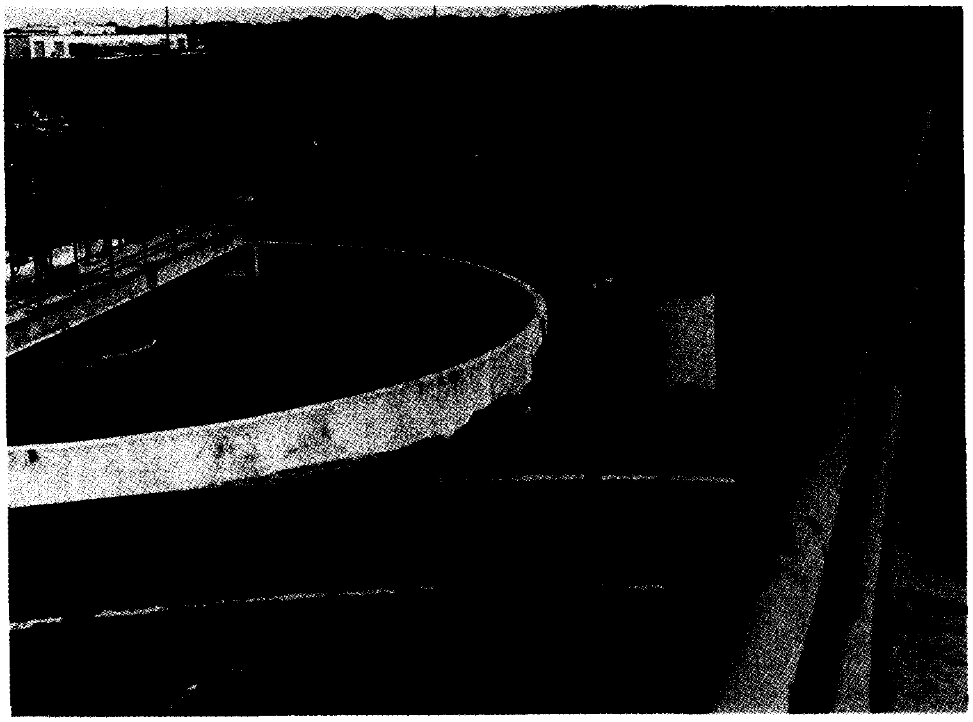

Figure VI-1. Final clarifier, American Beef Packers, Inc.

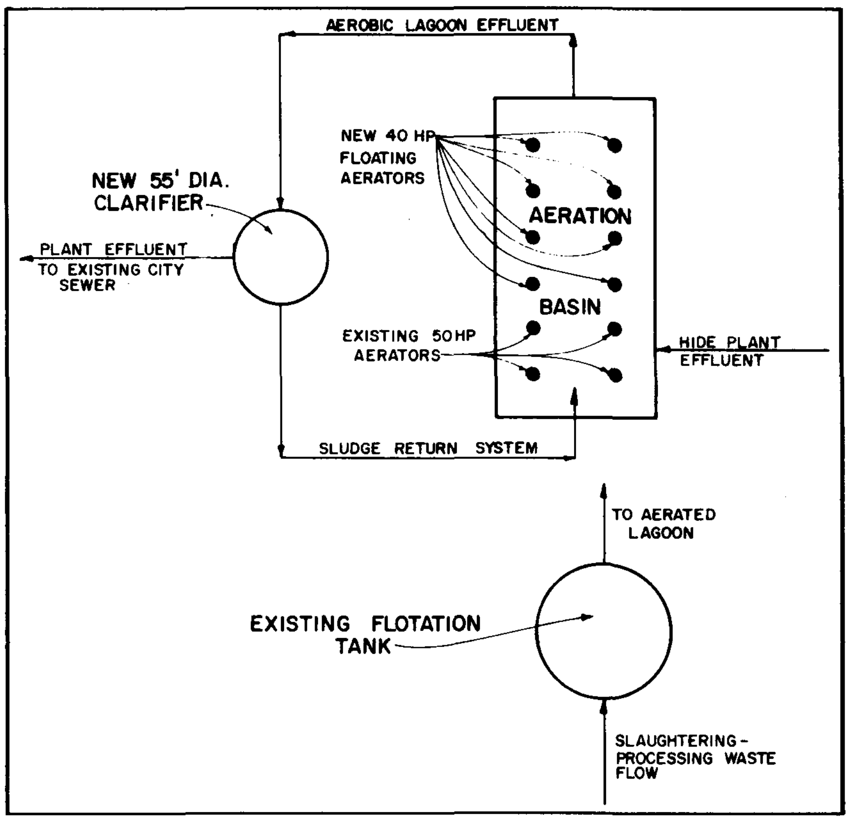

Figure VI-2. Flow schematic, American Beef Packers, Inc.

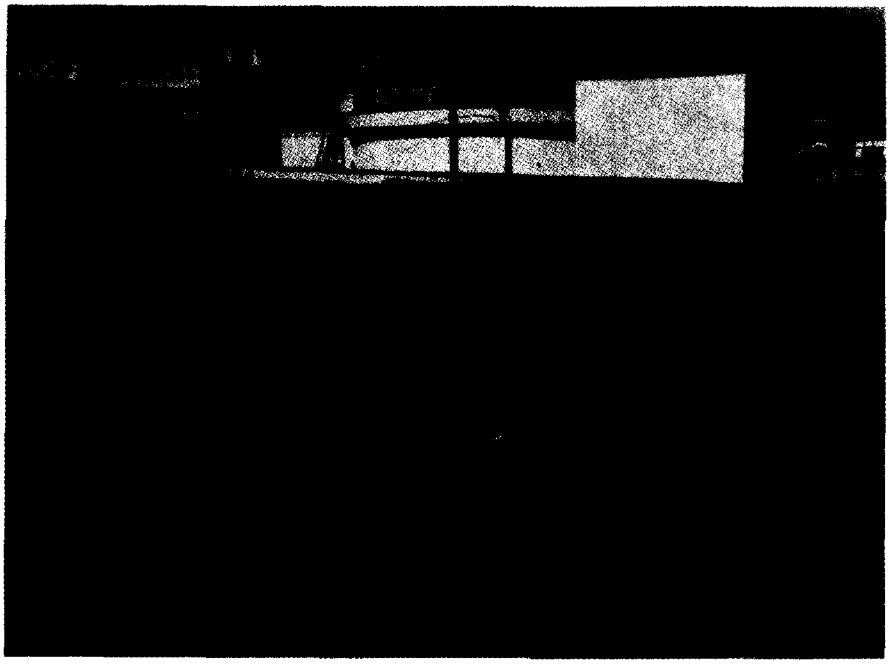

Figure VI-3. Grease flotation tank, American Beef Packers, Inc.

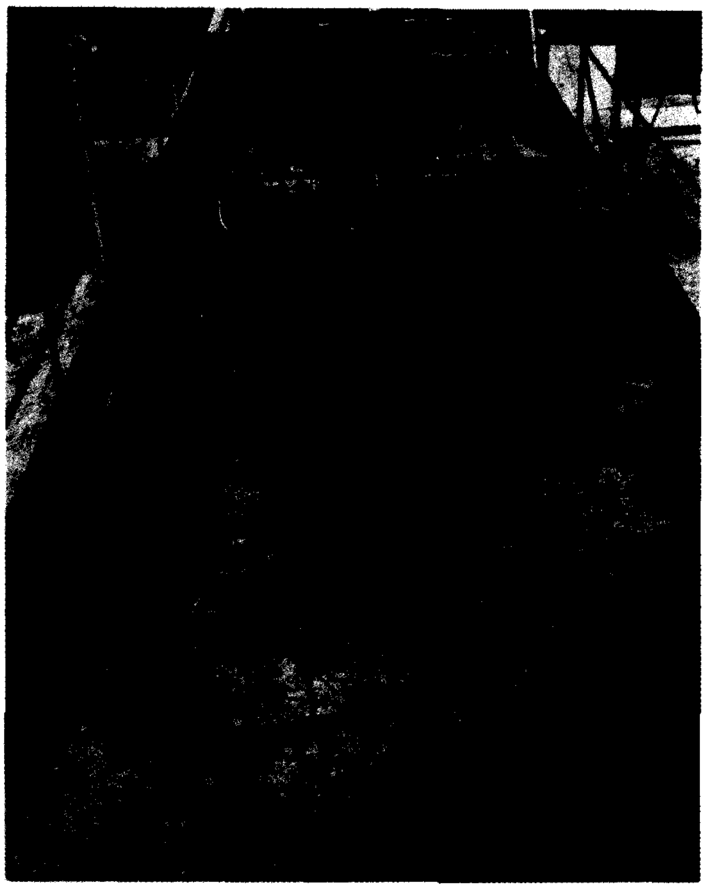

Figure VI-4. Hide-settling tank, American Beef Packers, Inc.

Figure VI-5. Solids-screening facility and hide-processing settling tank,
American Beef Packers, Inc.

including the recirculation system and all piping, cost $70,000 to construct, with an additional $20,000 for equipment. The system is operating as an extended-aeration system, providing a high degree of secondary treatment. Recent sampling data from the effluent of the final clarifier resulted in a BOD of 100 mg/l, suspended solids concentration of 100 mg/l, and a grease concentration of 90 mg/l. The site plan for the facility is shown in figure VI-6.

IOWA BEEF PROCESSORS, INC., DENISON

Iowa Beef Processors, Inc., recognized in 1966 the need for secondary waste treatment for their beef slaughtering plant at Denison, Iowa. An anaerobic-aerobic lagoon system was determined to be the best type of treatment facility, and was designed using the following factors:

- BOD loading = 9,600 lb/day
- Design flow = 720,000 gal/day
- Anaerobic lagoon loading = 15 lb BOD per 1,000 ft^3
- Depth of anaerobic lagoon = 15 feet
- Assumed efficiency = 65 percent
- First-stage aerobic lagoon loading = 150 pounds BOD per acre
- Second-stage aerobic lagoon loading = 50 pounds BOD per acre

Figure VI-7 shows the schematic layout and flow diagram for the system. Figure VI-8 presents the layout photographically. Plant waste undergoes pretreatment in an air flotation unit, while pen wastes flow through a settling basin before discharge to the lift station. The combined pen and plant wastes flow through a mechanically cleaned bar screen and measuring flume, and are then pumped to the anaerobic lagoons. These two lagoons are operated in parallel with the effluent discharged to two first-stage aerobic ponds, also in parallel. The effluent from the two cells receives further treatment in a second-stage aerobic pond before discharge into the Boyer River.

Sampling data obtained by the State of Iowa Hygienic Laboratory indicate that the lagoon system has performed well since its completion in November 1968. BOD removal efficiencies of over 80 percent have been achieved consistently in the anaerobic lagoons, and the overall efficiency of the system is approximately 98 percent.

The approximate 1967 cost of construction for the facility was $110,000, with much of the labor performed by Iowa Beef Processors construction personnel.

With an operating anaerobic lagoon treatment efficiency of 80 percent rather than the assumed design value of 65 percent, the actual loading to the first-stage aerobic pond is approximately 85 pounds of BOD per acre, and the final stage is approximately 30 pounds of BOD per acre. The site plan for the facility is shown in figure VI-9.

FARMLAND FOODS

The wastewater-treatment system serving the hog-processing plant owned by Farmland Foods, Denison, Iowa, was designed to treat the varied waste flows from the killing floor, holding pens, blood recovery system, and rendering and processing operations, as well as domestic sewers.

The plant kills 5,000 hogs per day, of which 40 percent usually are kept for further processing operations and the rest are shipped. The processing operations include cutting and processing into hams, bacon, and picnics. Rendering operations are performed on fat and bones, and there is a blood recovery system for the kill floor. The major consideration in designing the waste-treatment facility was the small amount of available land.

Construction on the project was initiated in April 1969. The facility now has been in operation for approximately 2½ years.

The raw waste criteria employed in the design of this treatment system are as follows:[a]

- BOD loading = 21,500 lb/day
- Average flow = 850,000 gal/day
- Maximum daily flow = 1,000,000 gal/day
- Maximum hourly flow = 1,500,000 gal/day

The flow diagram for the treatment facilities is shown in figure VI-10. The wastes from the kill floor are pumped to an air flotation unit for separation of grease, which is then returned for

[a]D. Baker and T. White, "Treatment of Meat Packing Waste Using PVC Trickling Filters," paper presented at National Symposium on Food Processing, Denver, Colo., Mar. 23-26, 1971.

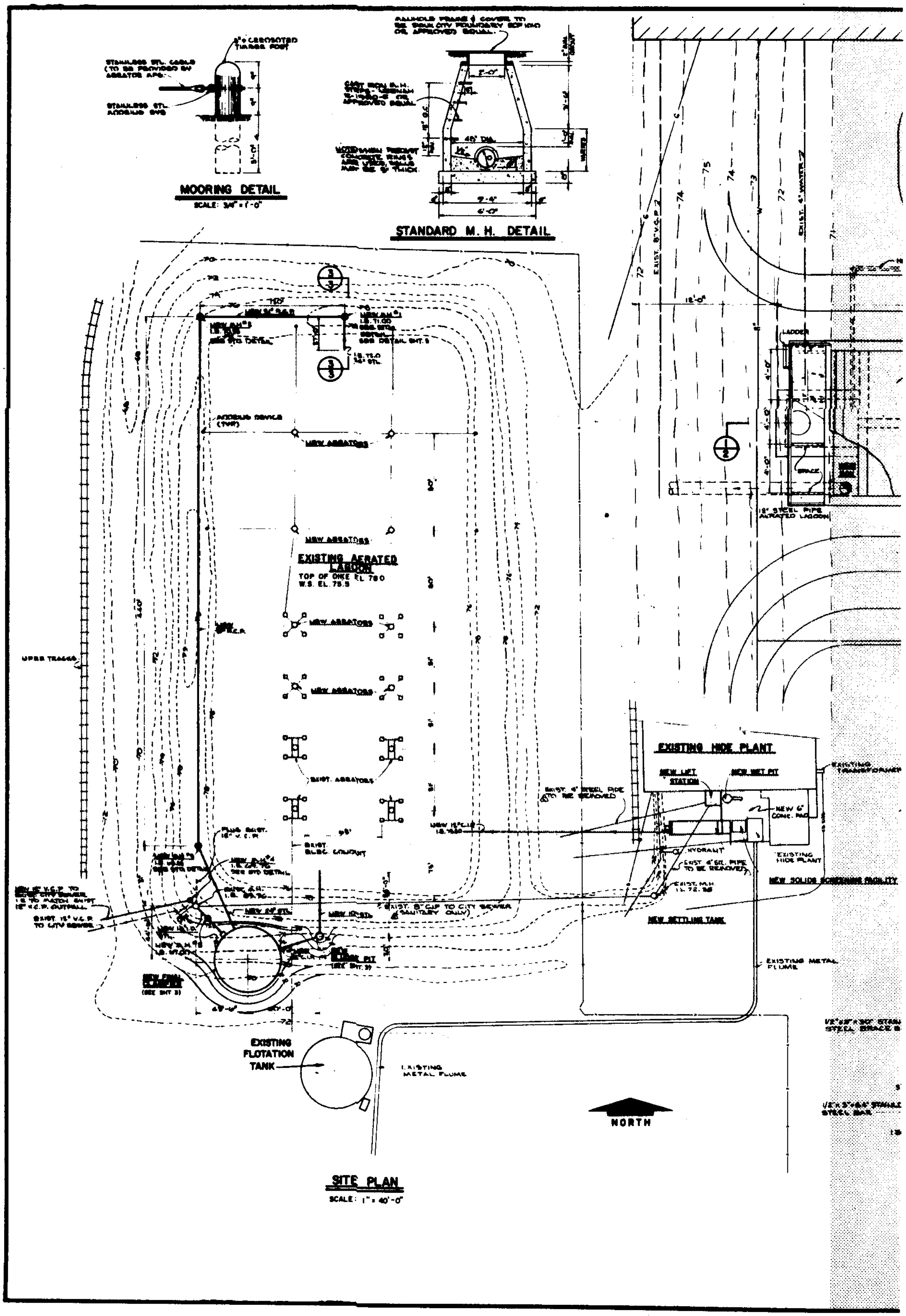

Figure VI-6. Waste-pretreatment facilities site plan, American Beef Packers, Inc. (Shaded areas indicate overlap.)

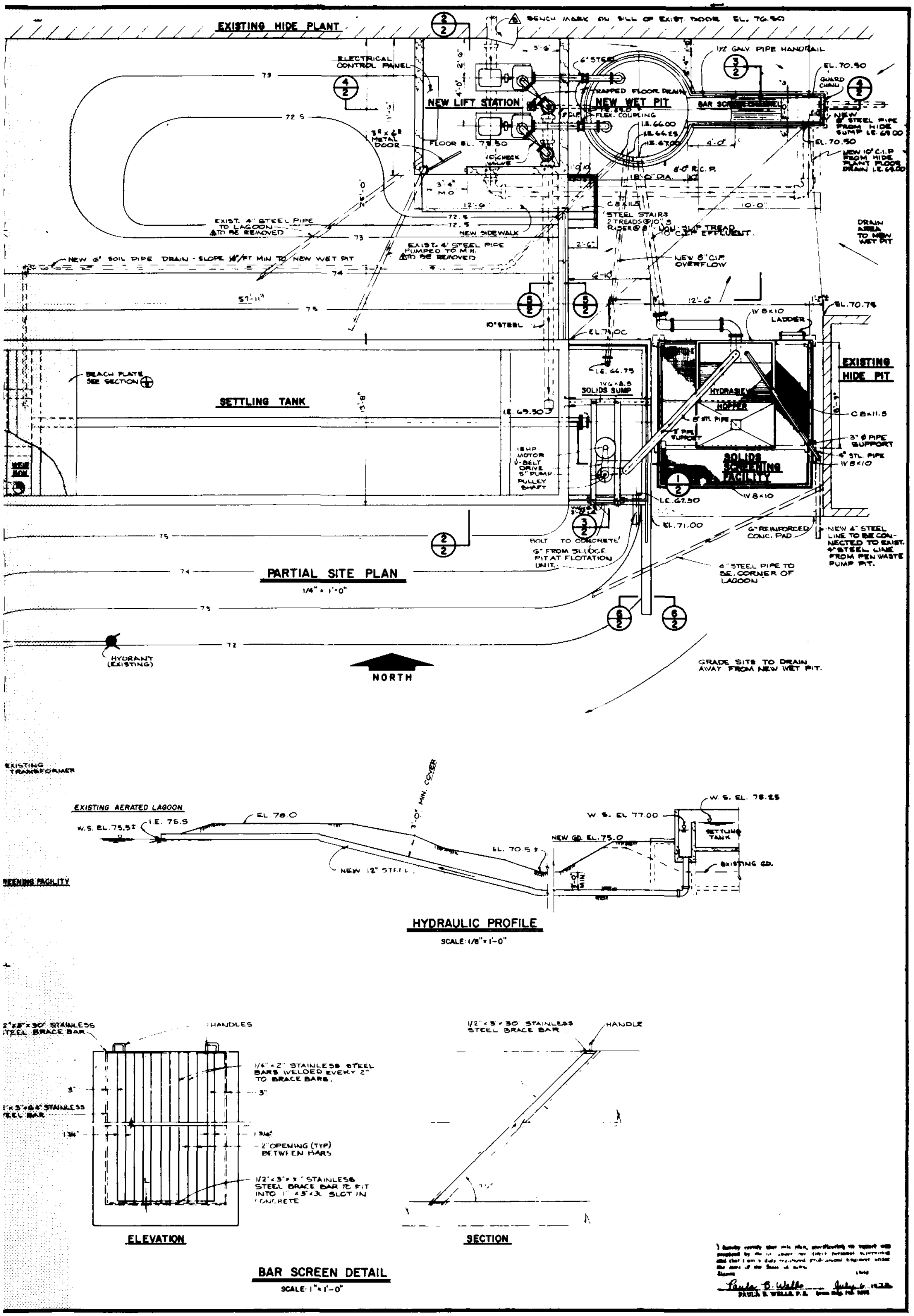

Figure VI-6. Waste-pretreatment facilities site plan, American Beef Packers, Inc.—*Concluded*

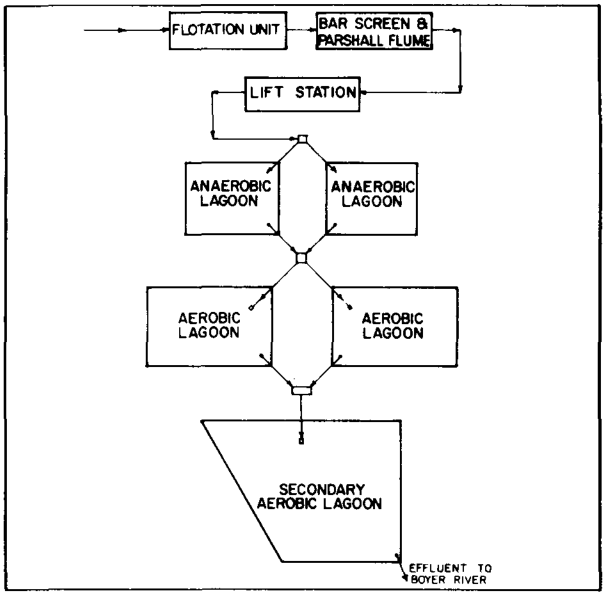

Figure VI-7. Flow schematic, Iowa Beef Processors, Inc., Denison.

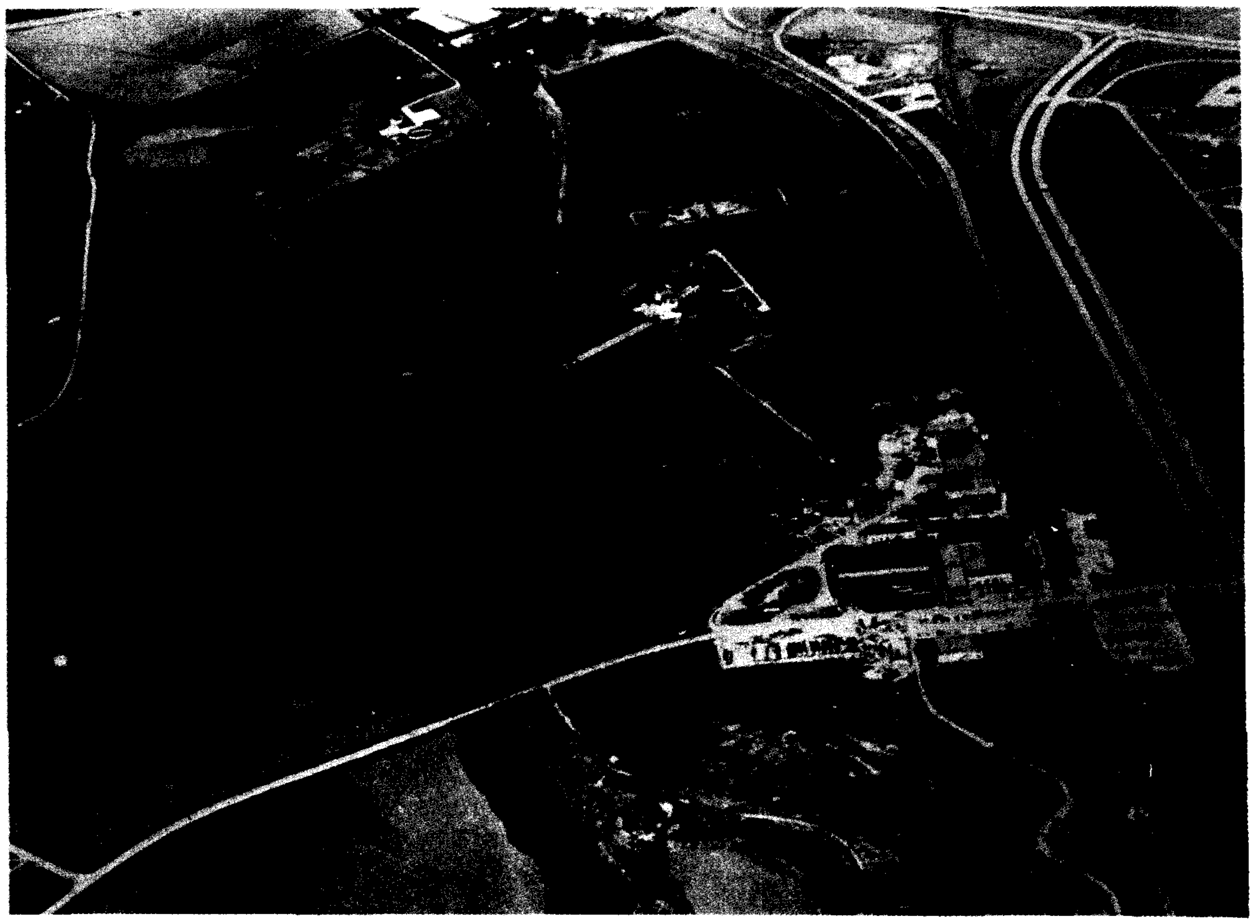

Figure VI-8. Meat-processing plant and lagoon layout, Iowa Beef Processors, Inc., Denison.

rendering. The effluent from the flotation unit is combined with the raw waste from the pens, scald tank, and domestic lines, and is sent to two parallel anaerobic lagoons. The lagoons provide biological treatment and also serve as flow-equalizing basins.

After anaerobic treatment, the waste flow is preaerated to satisfy immediate oxygen demand in preparation for discharge to the plastic media trickling filters. These filters normally are used in series, with provisions for parallel operation. The filter effluent is then clarified and disinfected in a chlorine contact basin before discharge to the Boyer River. Sludge is wasted back to the anaerobic lagoons.

The air flotation unit functions primarily to remove grease, and was designed with the following dimensions and performance criteria:

- Hydraulic loading = 1,500 gal/min
- BOD removal = 40 percent
- Grease removal = 85 percent
- Diameter = 22.5 feet
- Depth = 12 feet

The anaerobic lagoons were designed to achieve a significant reduction in BOD and to prevent shock loads from upsetting the filters. The basis of their design is as follows:

- BOD loading = 12,900 lb/day
- Design loading ≐ 15 pounds BOD per 1,000 ft^3
- Depth = 14 feet
- Surface area = 1.97 acres
- BOD removal = 80 percent

The preaeration basin (fig. VI-11) serves to help reduce odors that may emanate from the anaerobic effluent. Such odors would create serious problems owing to the close proximity of a residential area. The design engineers also hoped to begin converting the effluent from the anaerobic lagoons to an aerobic state before sending it to the filters. With these factors in mind, the unit was designed with 30-minute detention time and an applied air flow of 100 ft^3/min.

The trickling filters have shown the best results when they have been operated in series. The synthetic filter media is polyvinyl chloride (PVC) manufactured by B. F. Goodrich Co. This type of media may be loaded at higher rates, is lighter in weight, and is more uniform than standard rock media. The media is formed in 2-foot by 4-foot by 2-foot sections that are stacked in layers of 11 cells, resulting in a total depth of 22 feet. Design data for the filters are as follows:

- BOD loading, first stage = 101 pounds per 1,000 ft^3
- BOD loading, second stage = 31 pounds per 1,000 ft^3
- Hydraulic loading = 0.5 gal/min/ft^2

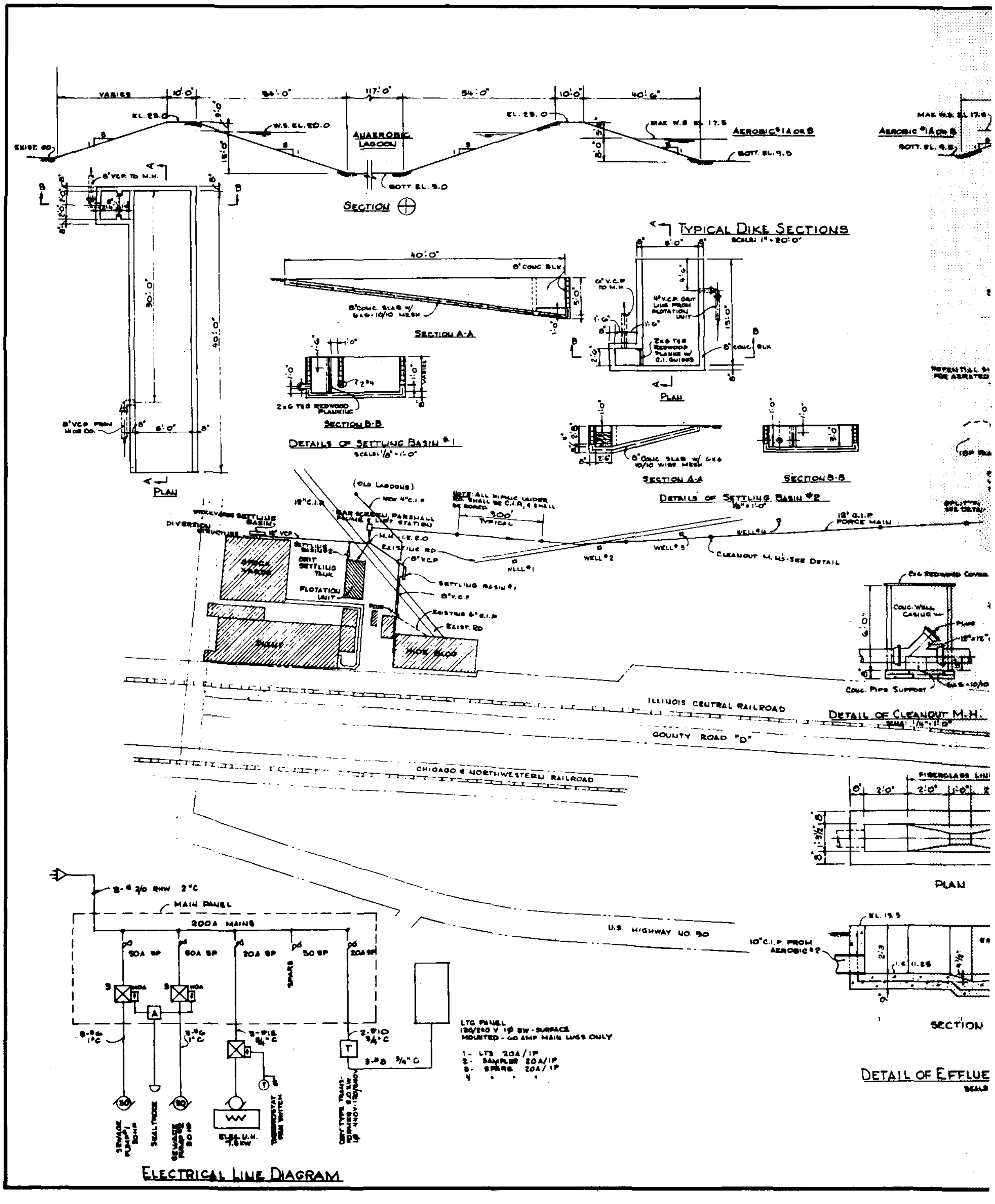

Figure VI-9. Waste-treatment facilities site plan, Iowa Beef Processors, Inc., Denison. (Shaded areas indicate overlap.)

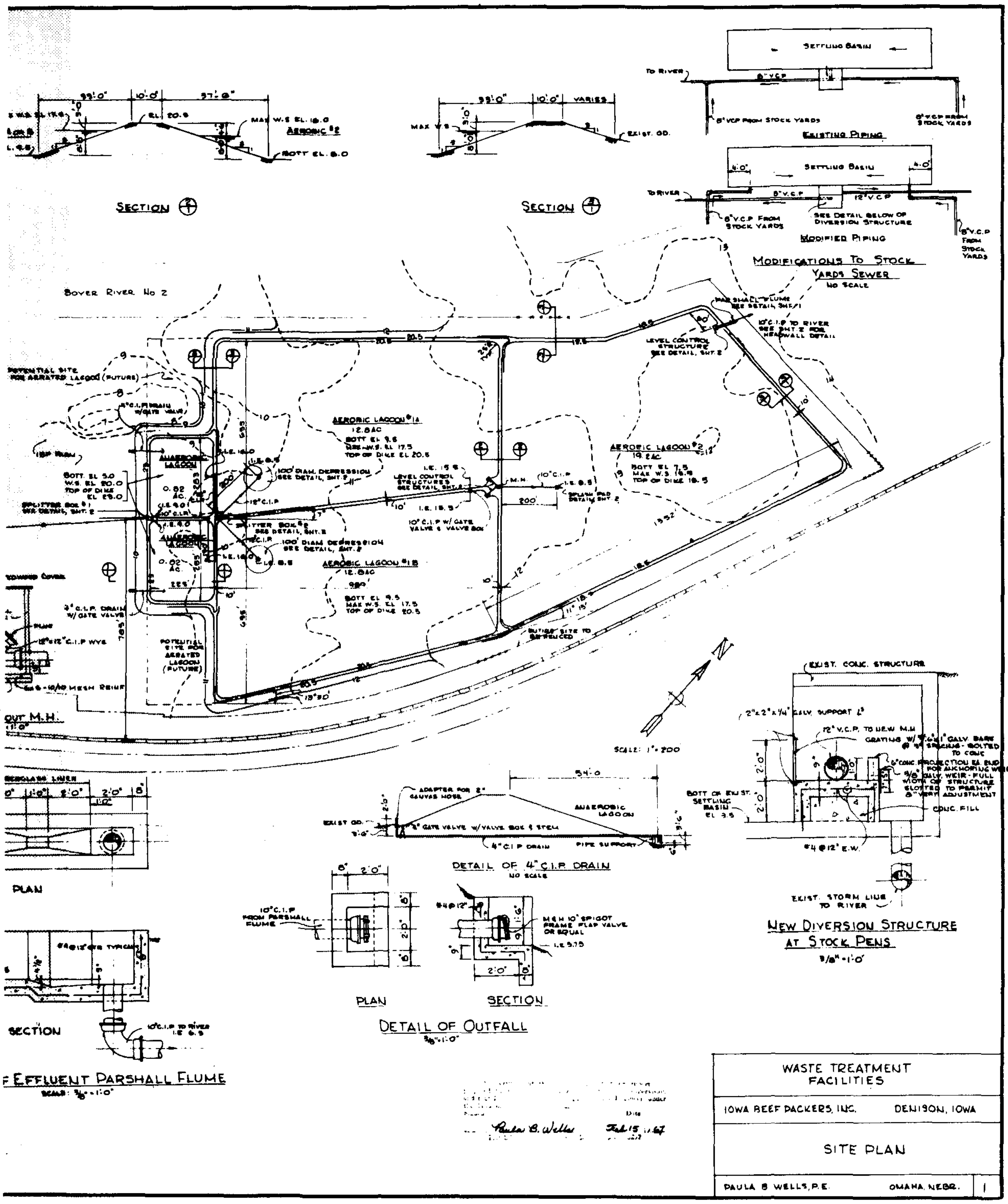

Figure VI-9. Waste-treatment facilities site plan, Iowa Beef Processors, Inc., Denison.—*Concluded*

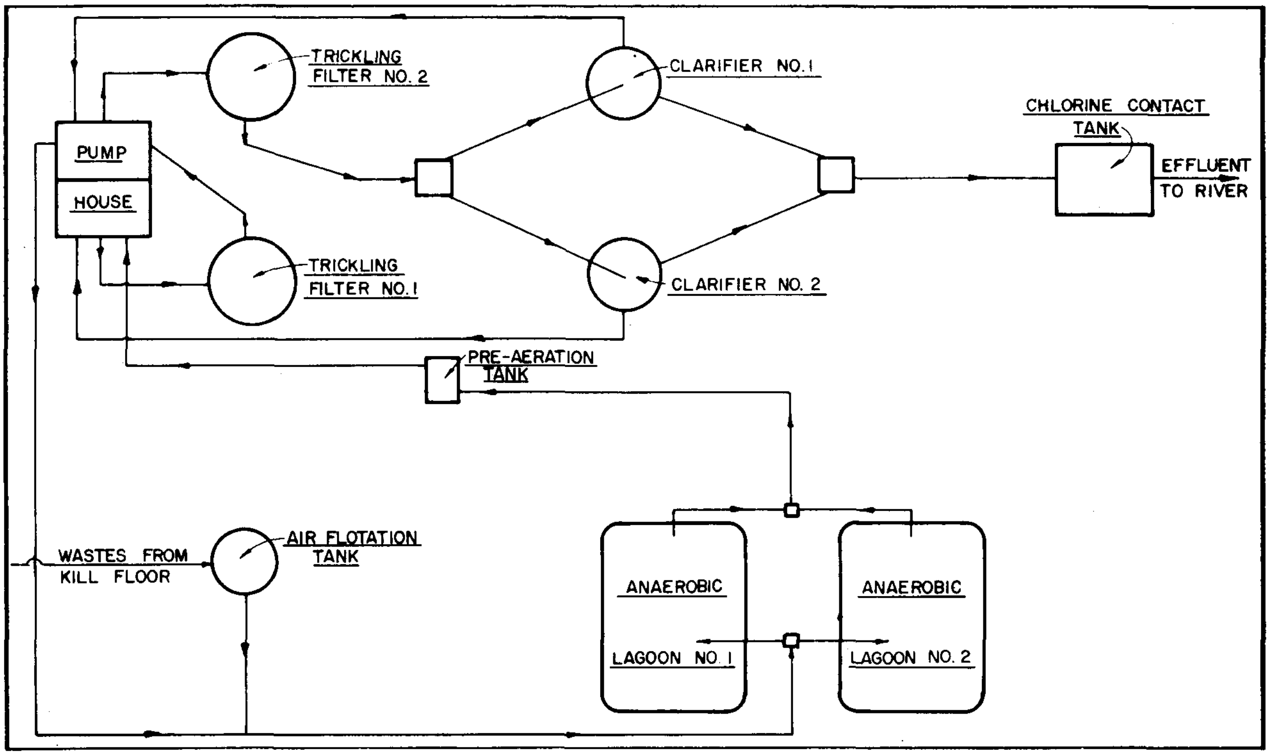

Figure VI-10. Flow schematic, Farmland Foods.

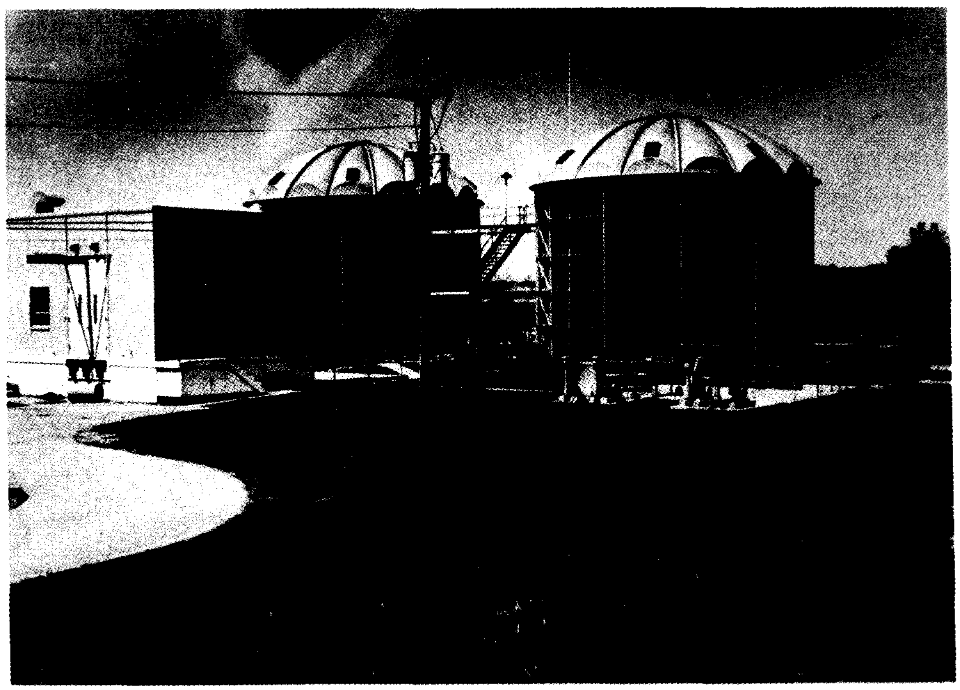

Figure VI-11. Preaeration basin, trickling filters, and control building, Farmland Foods.

- BOD removal = 91 percent
- Diameter = 39 feet
- Medium depth = 22 feet

The final clarifiers (fig. VI-12) are considered part of the trickling-filter system, and are designed to provide adequate settling times for the filter effluent. Two 26-foot-diameter clarifiers are used at Farmland Foods, each with a surface overflow rate of 800 gal/day/ft^2.

The chlorine contact chamber (fig. VI-13) was designed for a contact time of 49 minutes and a chlorine dosage rate of 10 mg/l.

Figure VI-14 shows the treated effluent from Farmland Foods.

Table VI-1 shows the plant efficiencies, both for the total plant and unit by unit.

The operating expenses for the year 1970 are given below in table VI-2. The daily cost of operation was approximately $304.

IOWA BEEF PROCESSORS, INC., DAKOTA CITY

The Dakota City, Nebr., plant of Iowa Beef Processors, Inc., lies just outside the Metropolitan Sioux City, Iowa, area. The plant is bounded by Dakota City on the south, South Sioux City on the north, the Missouri River on the east, and a populous suburban area on the west.

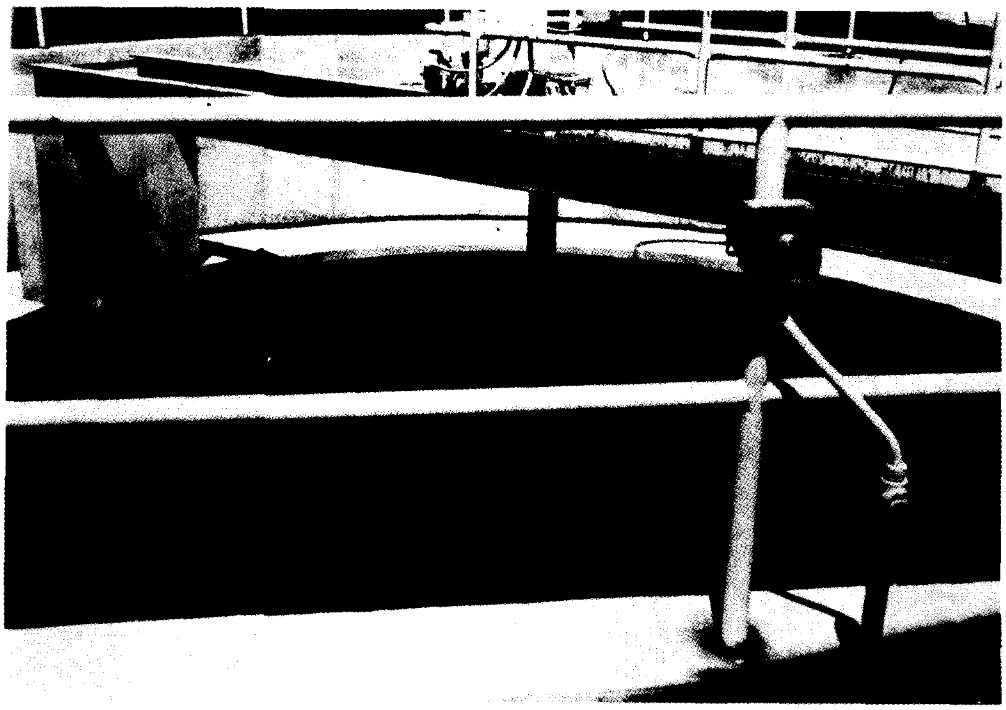

Figure VI-12. Final clarifier, Farmland Foods.

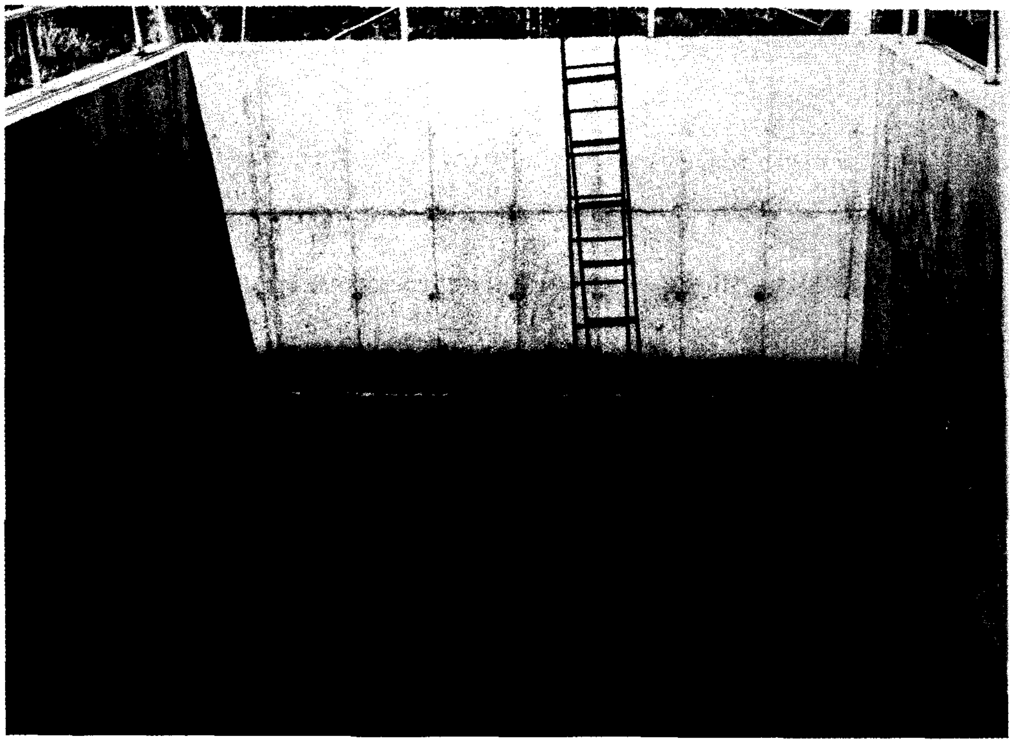

Figure VI-13. Chlorine contact tank, Farmland Foods.

Figure VI-14. Treated effluent, Farmland Foods.

Table VI-1.—*Plant efficiencies, percent removal, Farmland Foods*

Unit	BOD	COD	Grease	Suspended solids	Coliform
Flotation	33	11	62	32	NA
Anaerobic lagoons	82	68	78	59	NA
Trickling filters	74	73	69	80	NA
Chlorine	NA	NA	NA	NA	99+
Total plant removal, excluding flotation	97.4	91.5	96.5	93.5	99+

SOURCE: D. Baker and T. White, "Treatment of Meat Packing Waste Using PVC Trickling Filters," paper presented at National Symposium on Food Processing, Denver, Colo., Mar. 23-26, 1971.

Table VI-2.—*Operating expenses, 1970*

Item	Dollar cost
Salaries	47,893
Utilities	1,443
Maintenance	10,413
Capital cost debt retirement	50,900
Total	110,648

The plant has the capacity to slaughter 2,400 head of cattle per day, to process 3,000 head per day into institutional cuts, and to bone completely 900 animals per day. The average wastewater flow rate is 3 mgd, and the raw waste load to the treatment facility is 33,600 pounds BOD per day and 28,000 pounds suspended solids per day. The average temperature of the waste coming from the combined slaughtering and processing operations ranges between 90° and 105° F. The high strength of the wastes, combined with the high temperature, provided ideal design conditions for anaerobic lagoons, which were chosen for the first stage of the new waste-treatment facility.

The concept of using rotating biological disks following anaerobic treatment had not been tried before development of the Iowa Beef Dakota City project. All previous research and operational data had been in the area of domestic wastewater, and it was necessary to establish independent data for the design. As a result, a pilot test program, using the anaerobic effluent from one of the company's existing waste-treatment facilities, was initiated to evaluate the rotating biological disks. The pilot plant consisted of three stages of 4-foot rotating disks, each capable of delivering 1,750 gal/min, with 50 disks in each stage, followed by a small steel circular clarifier. Composite samples were taken of the influent and effluent from each stage and of the effluent from the final clarifier. Variations were made in speed of rotation of the disks as well as in rate of flow to the units. As a result of the pilot study, design parameters were established for application in the full-scale design.

The total waste-treatment facility, now nearing completion, consists of a lift station and force main, anaerobic lagoons, rotating biological disks, final clarifiers, and chlorination facilities, as shown in figure VI-15. Iowa Beef Processors, Inc., Dakota City, applied for and received a Federal demonstration grant to assist in the construction of the project.

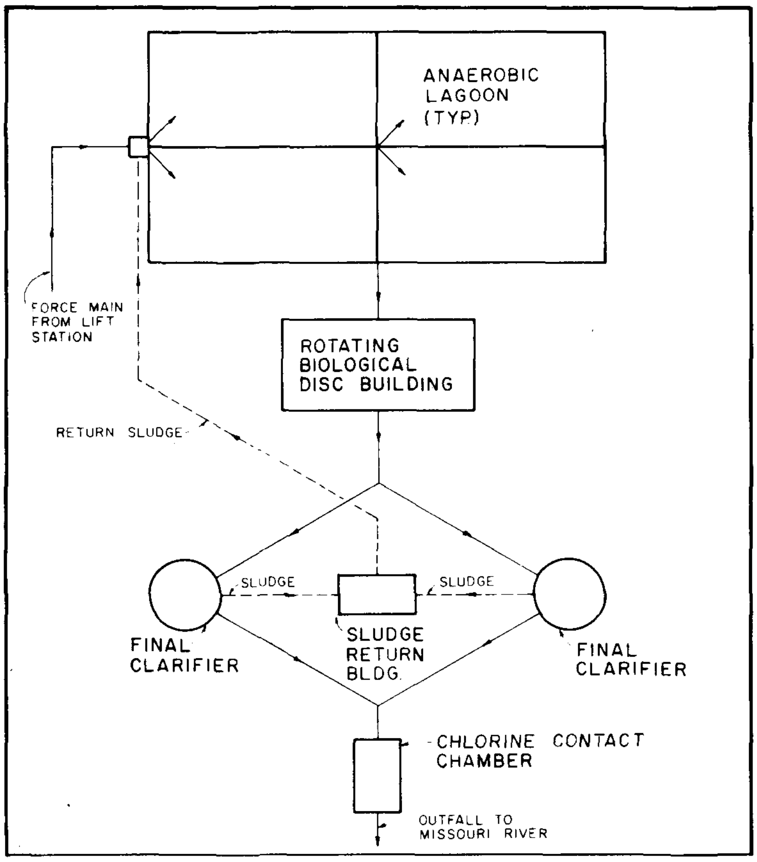

Figure VI-15. Waste-treatment facilities flow diagram,
Iowa Beef Processors, Inc., Dakota City.

The following design criteria were used in the design of the waste-treatment facilities:

- Design BOD = 33,600 lb/day
- Design average flow = 3,000,000 gal/day

The lift station consists of three self-priming centrifugal pumps, each capable of delivering 1,750 gal/min. The pumps are driven by 40-hp motors, and deliver the wastewater to the anaerobic lagoons through 6,200 feet of 18-inch force main.

The wastewater is discharged into four anaerobic lagoons operating in parallel. Each lagoon is 15 feet deep with a water surface area of 1.5 acres. The design BOD loading for these lagoons is 12 pounds per 1,000 ft^3, and BOD removal averages approximately 85 percent.

The wastewater then flows to the rotating biological disks, which are housed in a timber pole building (fig. VI-16). The design hydraulic loading on the disks is 4.8 gal/day/ft^2, resulting in a total required disk area of 625,000 ft^2. This area is supplied by 24 shafts of 139 disks each. The disks are 11 feet in diameter and have a surface area of 190 ft^2 each. The anticipated BOD reduction through the disk system is approximately 70 percent.

Following treatment in the RBS units, the wastewater is discharged to 55-foot-diameter clarifiers (fig. VI-17), each designed for a design average flow of 1.5 mgd. Sludge from the clarifiers is returned to the anaerobic lagoon.

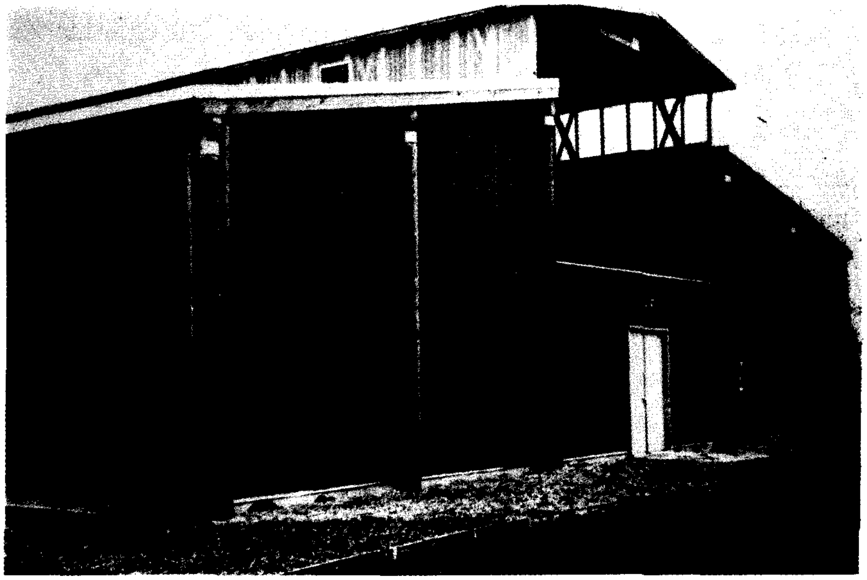

Figure VI-16. Rotating-biological-disk building, Iowa Beef Processors, Inc., Dakota City.

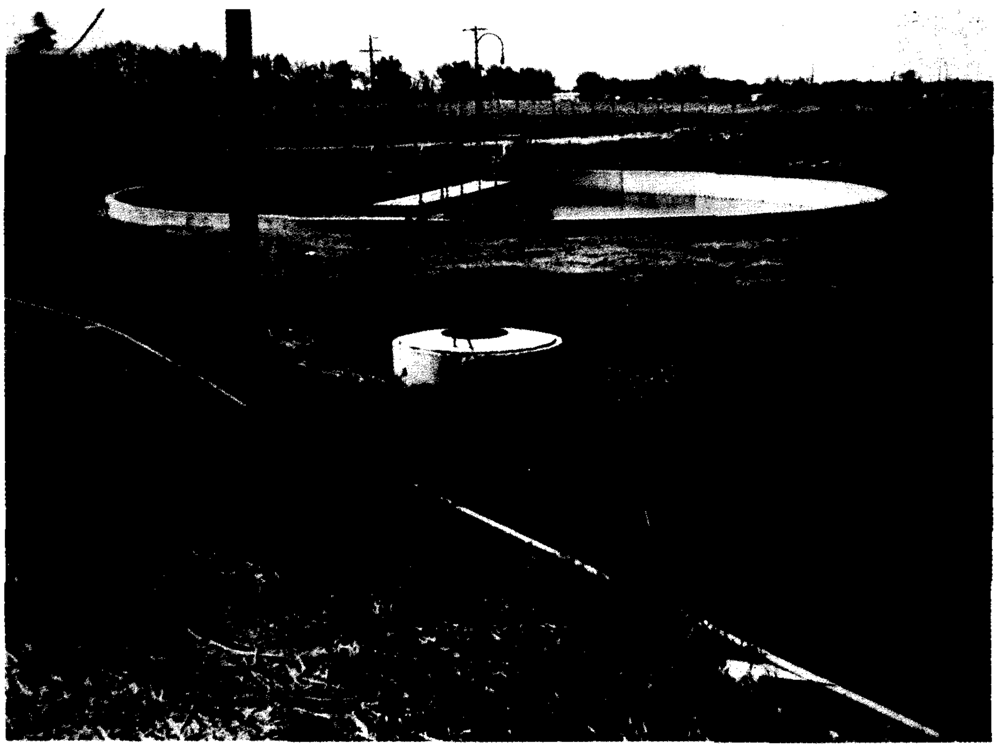

Figure VI-17. Final clarifier, Iowa Beef Processors, Inc., Dakota City.

The wastewater then flows to the chlorine contact basin (fig. VI-18), which provides a chlorine contact period of approximately 20 minutes at design average flow. The chlorine facilities include a building and overhead crane for handling containers.

The effluent from the chlorine contact basin flows 800 feet to the Missouri River through an 18-inch outfall line.

The lift station, force main, and anaerobic lagoons have been in operation for approximately 1½ years. Operation of the entire facility, including the rotating biological disks, final clarifiers, and chlorination system, in combination with the anaerobic lagoons, is expected within the next several months. Since the total plant is not yet on line, operational data are not available regarding treatment efficiencies. The anticipated overall BOD removal through the facility is approximately 90-95 percent. The site plan for the Dakota City plant appears in figure VI-19.

Total construction cost of the project including the lift station and force main is approximately $814,000.

LYKES BROTHERS PACKING PLANT

The Lykes Brothers Packing Plant is located at Plant City Industrial Park in Florida, a State that does not permit construction of anaerobic lagoons. Moreover, the site available for construction of waste-treatment facilities was characterized by high ground water and sandy soil, features that weigh heavily against any type of large lagoon. The treatment-system effluent was to be discharged into a dry ditch, so a high degree of secondary treatment was required. After consideration of several

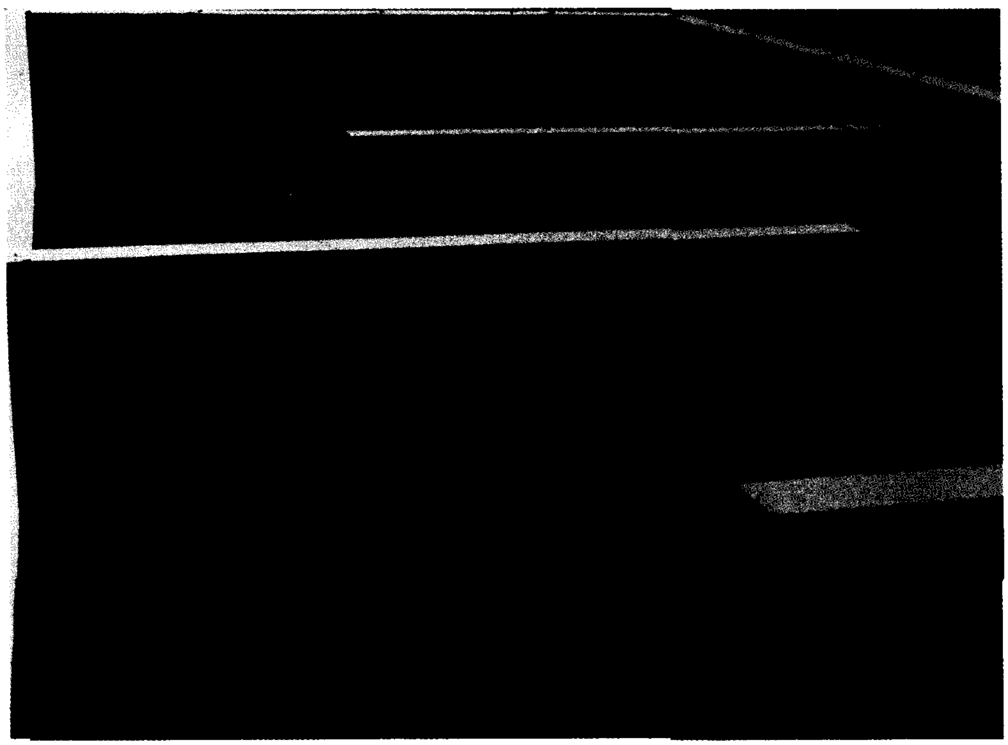

Figure VI-18. Chlorine contact tank, Iowa Beef Processors, Inc., Dakota City.

different treatment schemes, the design engineers concluded that the extended-aeration modification of the activated-sludge process would meet best the treatment needs of this typically high-strength waste.

The packing plant slaughters up to 350 head of cattle per day, and includes beef dressing, smoking, and sausage processing in its operation. An extensive program of water conservation and waste flow pretreatment was undertaken before commencement of design to minimize the hydraulic and organic loading on the treatment system. The final design criteria, based on 6 pounds of BOD_5 and 900 gallons per head, was as follows:

- Total daily flow = 315,000 gal/day
- Total BOD_5 = 2,100 lb/day

The treatment system consists of a grease-skimming and sedimentation tank, two extended-aeration tanks, final clarifier (fig. VI-20), polishing lagoon (fig. VI-21), aerobic digester, and sludge-drying beds. The flow diagram is shown in figure VI-22.

The settling-grease-skimming basin is sized for 30 minutes' detention, with a small amount of air added to aid in water and grease separation.

The extended-aeration tanks are operated in parallel and are sized on the basis of 20 pounds per day of BOD removed per 1,000 ft^3 of tank volume. The two tanks have a total volume of 105,000 ft^3 and, based on the design flow, provide a retention period of 30 hours. Air is supplied to the aeration tanks at the rate of 1,500 ft^3/day/lb of applied BOD. Sludge is wasted periodically to the aerobic digester.

The final settling tank is designed for a surface overflow rate of 800 gal/day/ft^2. Settled sludge is returned at a rate of 540 gal/min by an air lift pump to the head of the aeration tank or to the aerobic digester.

Effluent from the settling tank flows into a 5-acre stabilization pond, which serves to provide tertiary treatment before chlorination. A 30-minute detention period is provided by a small final pond where chlorine is added at a fixed rate to produce an effluent having a 2-mg/l minimum chlorine residual.

The aerobic digester has a volume of 37,200 ft^3. Air is introduced into the digester at the rate of 350 ft^3/min to reduce further the well-oxidized solids developed in the extended-aeration process. Periodically, a portion of the digested sludge is wasted to sludge-drying beds.

Recent sampling data obtained from personnel at Lykes Brothers Packing Plant are given in table VI-3.

Total construction cost of the project in 1966 was approximately $250,000. Operational and maintenance costs, as reported by plant personnel, are approximately $20,000 per year. This figure includes labor, power, chemicals, lubrication, and miscellaneous items.

Information concerning the design of this facility was obtained from a paper published in *Journal of the Water Pollution Control Federation.*[b]

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[b]E. Willoughby and V. D. Patton, "Design of a Modern Meat Packing Waste Treatment Plant," *J. Water Pollut. Cont. Fed.*, Jan. 1968.

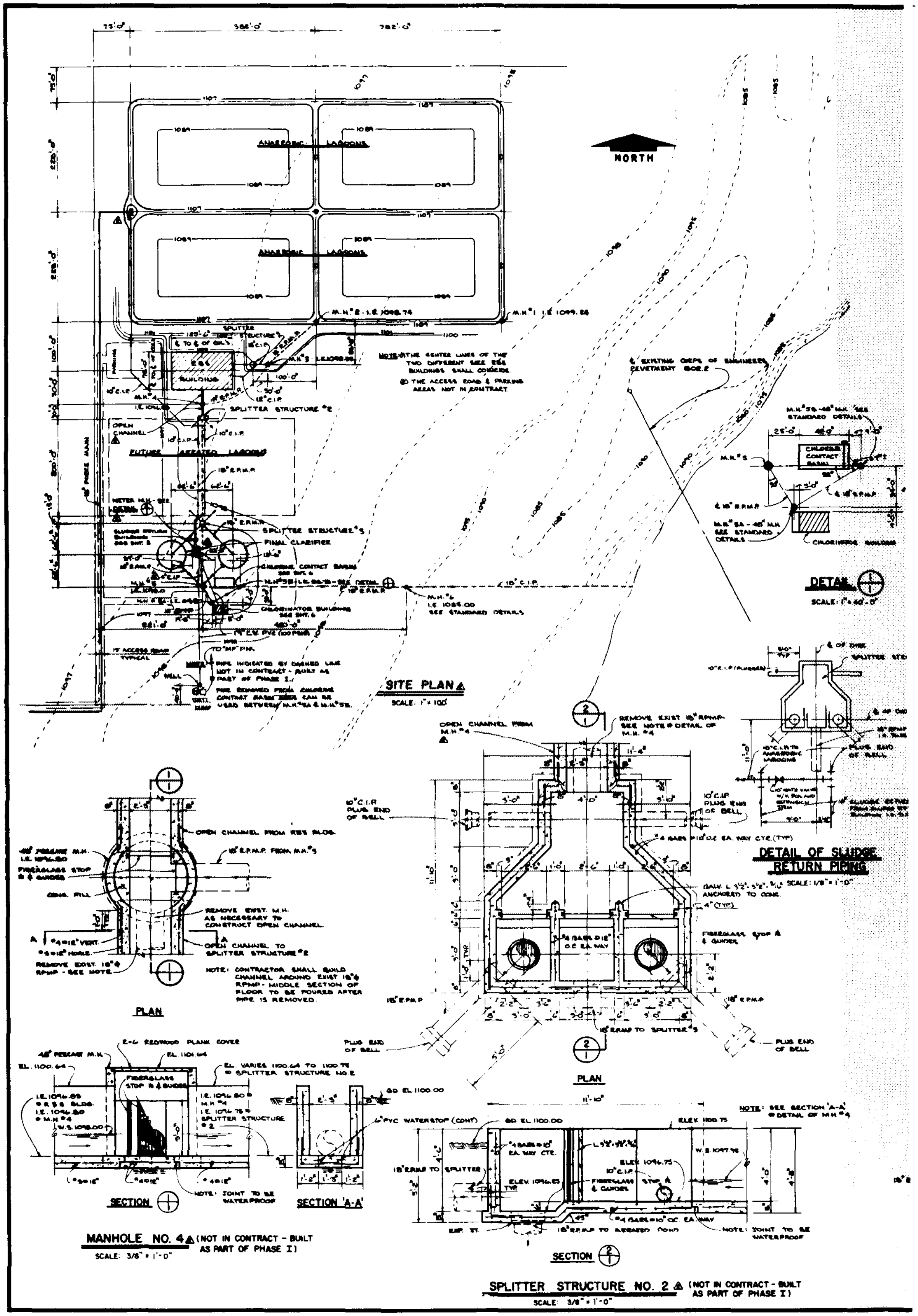

Figure VI-19. Waste-treatment facilities site plan, Iowa Beef Processors, Inc., Dakota City. (Shaded areas indicate overlap.)

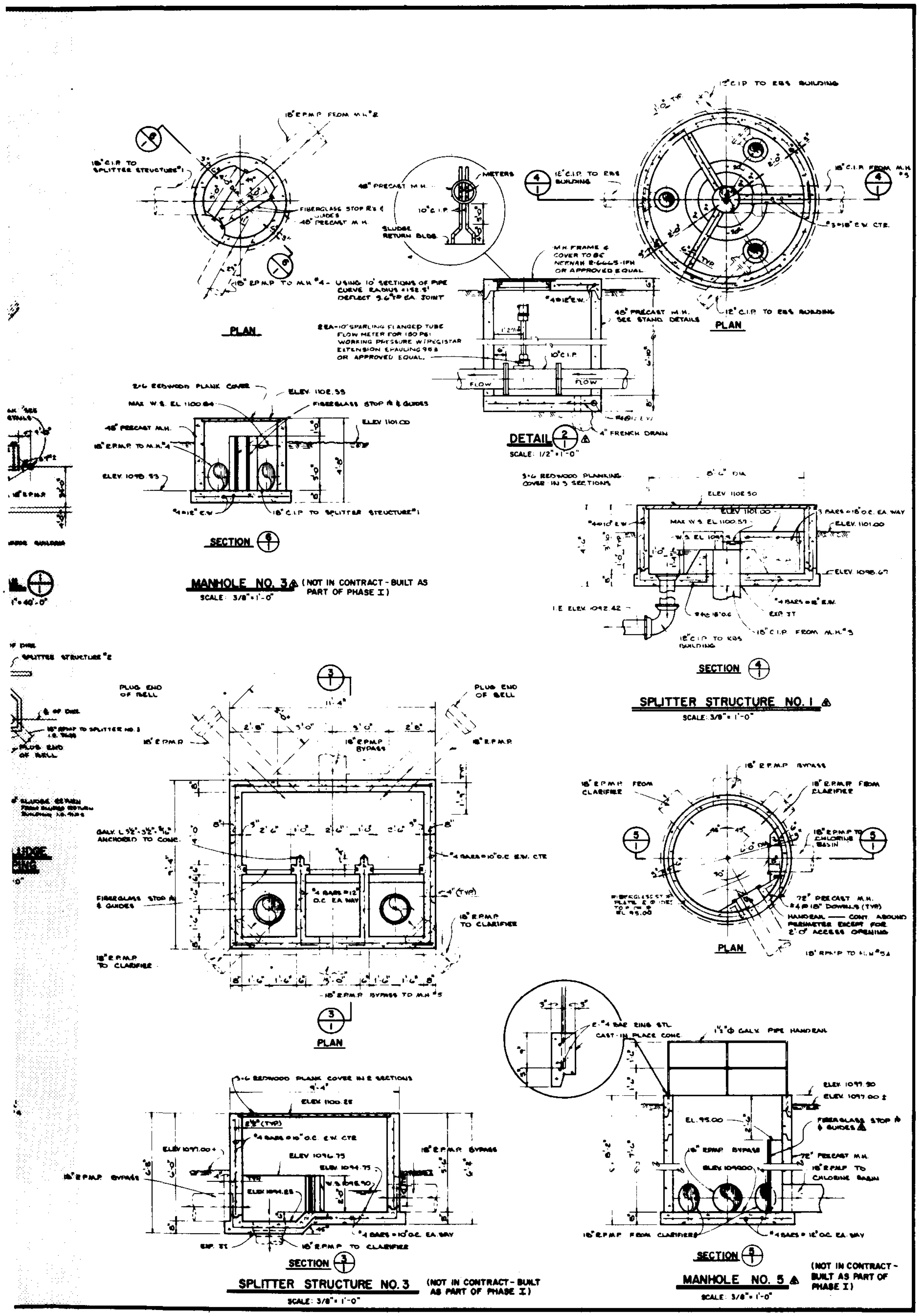

Figure VI-19. Waste-treatment facilities site plan, Iowa Beef Processors, Inc., Dakota City.—*Concluded*

Figure VI-20. Final clarifier, Lykes Brothers Packing Plant.

Figure VI-21. Polishing lagoon, Lykes Brothers Packing Plant.

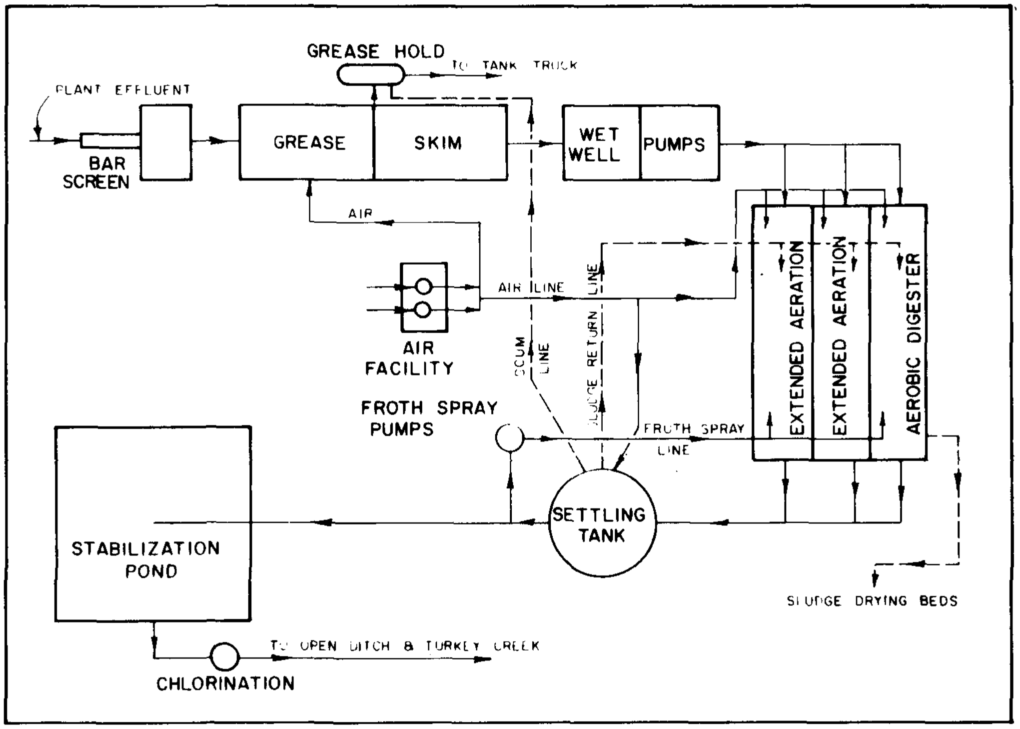

Figure VI-22. Flow diagram, Lykes Brothers Packing Plant.

Table VI-3.—*Wastewater analysis, Lykes Brothers Packing Plant, 6-month average values*

Item	Raw	Effluent from final settling tank	Effluent from pond
	milligrams per liter		
pH	6.9	7.4	7.4
BOD	1,574	89	15.7
Total solids	5,507	3,621	2,884
Suspended solids	396	180	56
Dissolved oxygen	0	.80	4.40
Chlorides[1]	1,787	1,700	1,425

[1] Approximately 1 ton of salt is used every 2 weeks for plant process.

Note.—Sampling data are based on an average water use of 240,000 gal/day.

Chapter VII

SURVEY OF EXISTING WASTE-TREATMENT FACILITIES FOR THE MEAT-PROCESSING INDUSTRY

Questionnaires were sent to all 50 States in order to obtain data on the status of meat-processing waste treatments in the United States. Many States did not have data available, and to date 25 States have responded to the questionnaire. Several of the States indicated the existence of few meat-processing facilities and, in these locations, existing plants were usually very small, often not discharging a waste stream into a surface body of water. In such cases, septic tanks were employed or other underground waste disposal schemes were practiced. Ponds that had only seepage as effluent were also noted in some localities, notably in the Western United States where the weather is arid.

Questionnaires returned from States where more and larger meat-processing operations were located showed that more complex methods of treatment were employed. It is interesting to note, however, that the regulatory agencies from these States felt that only half the treatment facilities under their jurisdiction were effective. Many plants were operating well, but it was indicated that upgrading was needed, and in some cases work was already in progress.

The types of treatment indicated as generally in use are anaerobic lagoons, anaerobic-aerobic lagoons, anaerobic-aerated lagoons, various types of activated-sludge systems (mostly extended aeration), aerobic lagoons or oxidation ponds, aerated lagoons, and trickling filters. An anaerobic lagoon system followed by aerobic treatment was the most frequently listed type of treatment and was reported as working well in achieving good BOD reduction. Values reported were in excess of 90 percent BOD removal, generally over 95 percent. Extended-aeration systems also showed high BOD removals, in the range of 90 percent. There seemed to be a tendency to use extended aeration in smaller plants with the lagoons being employed on large installations (i.e., those having greater than 500,000 gal/day). Less frequently used systems were aerated lagoons or oxidation ponds. Spray irrigation was used as a means of disposal, particularly in arid climates. Use of trickling filters, based on the limited data, was not widespread. Such installations are in existence, of course, and are capable of providing good treatment if properly loaded and operated.

Table VII-1 lists the types and number of waste-treatment facilities reported by the 26 States responding to the questionnaire.

Table VII-1 is general in nature; in many cases the treatment scheme has been simplified for this use. For example, if a system consisted of grease removal, primary screening, flow equalization, extended aeration and chlorination, the overall system was classified as extended aeration. Flow and performance data were taken from systems on which the information was provided, some units being reported without data. It is interesting to note that one of the plants with no treatment slaughtered 1,000 head per day and had a BOD of 2,250 mg/l. The report went on to state, however, that a program is underway to provide treatment.

Table VII-1.—*Existing waste-treatment facilities for the meat-processing industry*

Treatment	Number of installations	Size range, mgd	BOD reductions, percent
Anaerobic-aerobic lagoons	26	0.40-2.50	90-99
Anaerobic-aerated lagoons	6	0.66-1.97	98-99
Aerated lagoons-aerobic lagoons	11	0.005-0.75	91-98
Lagoons	30	0.005-1.20	87-99
Extended aeration	21	0.001-0.10	85-99
Activated sludge	3	0.060	99
Trickling filters	7	1.0-1.85	92-99
Spray irrigation	2	-	-
Septic tanks	33	0.01-1.15	-
Other	14	-	-
None	2	-	-

SOURCE: Results of a questionnaire distributed to State water pollution control agencies. Data received from the States of Alaska, Arizona, Delaware, Florida, Hawaii, Illinois, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Michigan, Missouri, Nebraska, New York, Nevada, North Carolina, Ohio, Pennsylvania, Tennessee, Texas, Utah, Virginia, Wisconsin, and Wyoming.

METRIC CONVERSION TABLES

Recommended Units

Description	Unit	Symbol	Comments	Customary Equivalents
Length	metre	m	*Basic SI unit*	39.37 in.=3.28 ft= 1.09 yd
	kilometre	km		0.62 mi
	millimetre	mm		0.03937 in.
	micrometre	μm.		3.937 X 10^{-3}=10^3A
Area	square metre	m^2		10.764 sq ft = 1.196 sq yd
	square kilometre	km^2		6.384 sq mi = 247 acres
	square millimetre	mm^2		0.00155 sq in.
	hectare	ha	The hectare (10 000 m^2) is a recognized multiple unit and will remain in international use.	2.471 acres
Volume	cubic metre	m^3		35.314 cu ft = 1.3079 cu yd
	litre	l	The litre is now recognized as the special name for the cubic decimetre.	1.057 qt = 0.264 gal = 0.81 X 10^{-4} acre-ft
Mass	kilogram	kg	*Basic SI unit*	2.205 lb
	gram	g		0.035 oz = 15.43 gr
	milligram	mg		0.01543 gr
	tonne or megagram	t Mg	1 tonne = 1 000 kg 1 Mg = 1 000 kg	0.984 ton (long) = 1.1023 ton (short)
Time	second	s	*Basic SI unit*	
	day	d	Neither the day nor the year is an SI unit but both are important.	
	year	year		
Force	newton	N	The newton is that force that produces an acceleration of 1 m/s^2 in a mass of 1 kg.	0.22481 lb (weight) = 7.233 poundals
Moment or torque	newton metre	N-m	The metre is measured perpendicular to the line of action of the force N. Not a joule.	0.7375 ft-lbf
Stress	pascal	Pa		0.02089 lbf/sq ft
	kilopascal	kPa		0.14465 lbf/sq in

Recommended Units

Description	Unit	Symbol	Comments	Customary Equivalents
Velocity linear	metre per second	m/s		3.28 fps
	millimetre per second	mm/s		0.00328 fps
	kilometres per second	km/s		2.230 mph
angular	radians per second	rad/s		
Flow (volumetric)	cubic metre per second	m^3/s	Commonly called the cumec	15,850 gpm = 2.120 cfm
	litre per second	l/s		15.85 gpm
Viscosity	pascal second	Pa-s		0.00672 poundals/sq ft
Pressure	newton per square metre or pascal	N/m^2 Pa		0.000145 lb/sq in
	kilometre per square metre or kilopascal	kN/m^2 kPa		0.145 lb/sq in.
	bar	bar		14.5 b/sq in.
Temperature	Kelvin	K	*Basic SI unit*	$\frac{5F}{9} - 17.77$
	deqree Celsius	C	The Kelvin and Celsius degrees are identical. The use of the Celsius scale is recommended as it is the former centigrade scale.	
Work, energy, quantity of heat	joule	J	1 joule = 1 N-m where metres are measured along the line of action of force N.	2.778 X 10^{-7} kw hr = 3.725 X 10^{-7} hp-hr = 0.73756 ft-lb = 9.48 X 10^{-4} Btu
	kilojoule	kJ		2.778 kw-hr
Power	watt	W	1 watt = 1 J/s	
	kilowatt	kW		
	joule per second	J/s		

Application of Units

Description	Unit	Symbol	Comments	Customary Equivalents
Precipitation, run-off, evaporation	millimetre	mm	For meteorological purposes it may be convenient to measure precipitation in terms of mass/unit area (kg/m^3). 1 mm of rain = 1 kg/m^2	
River flow	cubic metre per second	m^3/s	Commonly called the cumec	35.314 cfs
Flow in pipes, conduits, channels, over weirs, pumping	cubic metre per second	m^3/s		
	litre per second	l/s		15.85 gpm
Discharges or abstractions, yields	cubic metre per day	m^3/d	1 l/s = 86.4 m^3/d	1.83 X 10^{-3} gpm
	cubic metre per year	m^3/year		
Usage of water	litre per person per day	l/person day		0.264 gcpd
Density	kilogram per cubic metre	kg/m^3	The density of water under standard conditions is 1 000 kg/m^3 or 1 000 g/l or 1 g/ml.	0.0624 lb/cu ft

Application of Units

Description	Unit	Symbol	Comments	Customary Equivalents
Concentration	milligram per litre	mg/t		1 ppm
BOD loading	kilogram per cubic metre per day	kg/m^3d		0.0624 lb/cu-ft day
Hydraulic load per unit area; e.g. filtration rates	cubic metre per square metre per day	m^3/m^2d	If this is converted to a velocity, it should be expressed in mm/s (1 mm/s = 86.4 m^3/m^2 day).	3.28 cu ft/sq ft
Hydraulic load per unit volume; e.g., biological filters, lagoons	cubic metre per cubic metre per day	m^3/m^3d		
Air supply	cubic metre or litre of free air per second	m^3/s l/s		
Pipes diameter	millimetre	mm		0.03937 in.
length	metre	m		39.37 in. = 3.28 ft
Optical units	lumen per square metre	$lumen/m^2$		0.092 ft candle/sq ft

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