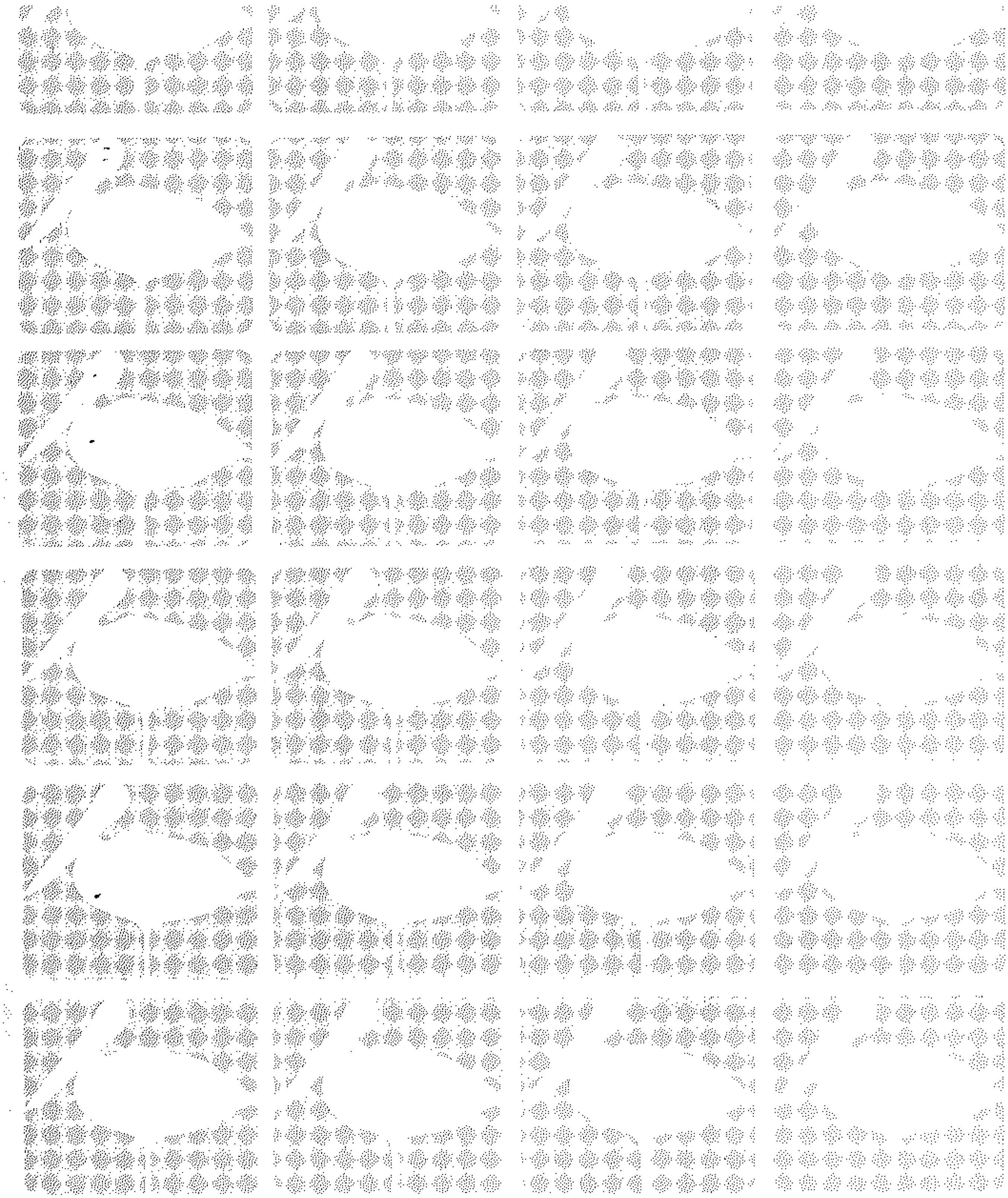

OVERLAND FLOW IN THE LOUISIANA COASTAL ZONE

Mark Meo · John W. Day Jr. · Theodore B. Ford

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OVERLAND FLOW IN THE LOUISIANA COASTAL ZONE

The Potential for Land Treatment of Waste Water on Diked Dredge Spoil Disposal Sites in South Louisiana

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Publication No. LSUSG-T-75-04
November, 1975

ACKNOWLEDGMENTS

The authors would like to thank the following individuals who contributed to the development and application of the concept of land treatment by overland flow in Louisiana's coastal zone: Rodney Adams, Edwin Bishop, Robert Brupbacher, Patrick Doody, Elvin Dantin, Joanne Hardy, Mary Hood, Raphael Kazmann, Samuel Meyers, William Patrick, William Pendleton, and William Gill Smith.

Photomosaics and dredging charts were generously supplied by Ross Jarrell of the U.S. Army Corps of Engineers, New Orleans District.

Financial support for this project was provided by the LSU Sea Grant Program, which is part of the National Sea Grant Program maintained by the National Oceanic and Atmospheric Administration of the U.S. Department of Commerce. Support was also provided by the Louisiana Water Resources Research Institute, under contract A-033-LA from the U.S. Department of the Interior.

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ABSTRACT

This report discusses the attractiveness of land treatment of organic waste water through overland flow as an effective and economical means of dealing with increased waste loads and achieving federally mandated water quality criteria. A pilot project carried out in an enclosed marsh area in Dulac, Louisiana, and using effluent from a menhaden processing plant indicated that overland flow is a valuable means for providing secondary and, in some cases, tertiary treatment of high-load organic waste water. In the experimental design primary-treated organic waste was sprayed at low rate on a naturally vegetated slope. The soil-plant system removed 58 percent of the total organic carbon, 51 percent of the total nitrogen, and 53 percent of the total phosphate phosphorus as the effluent flowed over the 6 percent, 30 m (100 ft) slope.

Overland flow seems well suited to the organic waste water problems of the Louisiana coastal zone because of:

1) silty clay and clayey soils which are widely distributed throughout the active and abandoned delta zones,
2) high water table,
3) long vegetative growing season, and
4) the nature of many discharged wastes such as fish processing and canning wastes, sugarcane processing wastes, and municipal sewage wastes.

As a result of the extensive dredging activities carried out in coastal Louisiana, new elevated land areas are being created by disposal of dredge spoil in confined sites. Many such areas are located near sources of organic waste water and could provide effective sites for overland flow treatment facilities.

There are numerous possible beneficial applications of overland flow systems in south Louisiana. Aquacultural systems could utilize the nutrients in organic wastes to raise commercial finfish, shellfish, or crustaceans or to grow aquatic vegetation which could be used as feedstock for animal production or for methane generation via anaerobic fermentation. Overland flow designs could be coupled with agricultural systems to provide increased nutrients for efficient production of rice, sugarcane, or roseau cane.

While there exists no specific legislated policy for land treatment in Louisiana, the existing laws in no way prohibit the implementation of land treatment, provided adequate health precations are taken. The overland flow process is not only ecologically sound but is within the best interests of the biology, sociology, hydrology, and economy of the Louisiana coastal zone.

INTRODUCTION

Coastal water pollution is a problem that has many sources and one for which effective solutions must be found. In response to a growing population and increasing coastal development, activities such as haphazard disposal of sewage effluents from coastal cities and poorly managed dredging of harbors, canals, and river estuaries have jeopardized environmental quality. Fish kills, closed beaches, abandoned pipeline canals, and marsh deterioration reflect the final result of hastily conceived environmental planning. In the near future the growing demands on the densely populated coastal zone for food production, adequate waste disposal, and navigable waterways will only be met by complementary and well managed programs.

Recycling sewage wastes allows carbon, nitrogen, and phosphorus to be extracted in a beneficial and usually productive manner while producing clean water. Aquaculture is an example of an activity which can be productively linked with waste water treatment efforts. Through recycling, the nutrients in sewage effluent can help produce commercially important finfish and shellfish while providing a treated water resource (Kildow and Huguenin, 1974). Similarly, areas containing confined dredge spoil can be used for land treatment of waste waters, creating land suitable for wildlife habitat or agronomic crop production.

We recognize the need for sufficient coastal resource planning in south Louisiana to meet present and future management requirements. Therefore, our purpose in this report is to consider the feasibility of using diked dredge spoil disposal sites for sewage and organic waste recycling, a technique that can make effective, efficient, and economical use of water and land resources.

The Water Pollution Problem

The Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) are one source of increasing interest in using terrestrial ecosystems to achieve legislated water quality standards in the imminent future. "Best practicable control technology" required by July 1, 1977 precedes "the national goal that the discharge of pollutants into the navigable waters be eliminated by 1985." Section 201(b) requires that waste treatment technology "*include reclaiming and recycling of water and confined disposal of pollutants so they will not migrate or cause water or other environmental pollution*." Technology development must also "*provide for consideration of advanced waste treatment techniques*." Land treatment of industrial and municipal waste water fulfills the above requirements by producing clean water and keeping wastes out of streams and lakes. In addition, it reclaims "pollutants" such as nitrogen, phosphorus, and carbon for use in fertilization of agronomic crops or natural vegetation.

Methods of applying sewage wastes onto the land are not new; sewage farming has been practiced worldwide for years. In the latter half of the nineteenth century extensive sewage farms disposed of municipal waste waters outside Berlin and Paris, but poor management coupled with ignorance of proper public health practices caused the demise of open land disposal as a solution to waste treatment. Growth of urban population and industrial centers fostered technological waste treatment practices that provided improved quality control and better public health safety for a greater volume of raw waste waters. Due to increased understanding of water treatment principles, and because of space limitations and the need to control water-borne diseases, many states maintain legal restrictions against open land disposal of untreated sewage.

Present day sanitation engineering practices for waste water treatment commonly include primary and secondary treatment to achieve a reduction of the organic load or biochemical oxygen demand (BOD) of the waste. In most situations, however, no attempt is made to utilize the resource potential of the waste water. Primary treatment is a physical process in which solids are allowed to settle and are removed from the water. Secondary treatment uses biological processes and is quite efficient in reducing the organic load; up to 90 percent can be removed by microbial action resulting in a treated effluent with a BOD varying from 10 to 50 parts per million. The two principal types of secondary treatment are the trickling filter and the activated sludge process. A trickling filter is simply a broad bed of stones from 1 to 3 m (3 to 10 ft) deep through which the sewage passes. Bacteria and zoogleal slime which grow on these stones consume most of the organic matter in the sewage. The activated sludge process speeds up the work of the microbiota by bringing air and sludge heavily laden with microorganisms into close contact with the sewage. In areas where water treatment plants are not present, lagoons or oxidation ponds are used to purify water by using sunlight, algae, and microbial action in the presence of oxygen. The final step in secondary treatment is chlorination to kill as much as 99 percent of the pathogenic bacteria in the waste effluent. Tertiary or advanced treatment entails the removal of nutrients such as nitrogen and phosphorus as well as the remaining oxygen demanding compounds and the purification of the water to achieve drinking water quality. This may be accomplished by further biological treatment or by physical-chemical separation techniques such as adsorption, distillation, and reverse osmosis.

Where advanced treatment is not available or is impractical to use, secondary effluent is discharged into receiving waters such as lakes and streams where the aquatic ecosystem is used to achieve water purification. Too often, however, discharge of wastes has caused eutrophication and degradation of the receiving water. The Federal Water Quality Administration (FWQA) reported in 1970 that of 233 sub-basins in the U.S., 214 had 95 percent or more of their stream miles "continuously or recurrently in violation of established physical, chemical, or biological criteria." The costs resulting from water pollution have been estimated to be $12.8 billion annually (Stevens, 1972). This total includes costs due to losses of productive commercial fisheries and their nursery areas, degradation of recreationally and aesthetically valuable areas, befouling of public and industrial water supplies, and the increase in medical care to treat water-borne diseases.

Using the Land to Clean Water

Land treatment of waste water and sewage is a natural recycling process that combines the soil and plant ecosystem with the applied effluent. It can provide secondary as well as advanced treatment to a variety of waste waters. Purification of the waste water is accomplished by the microbiota, the plant communities, and the chemical and mechanical action of the soil. Land treatment processes, as opposed to land disposal techniques, are designed to produce a renovated water resource while producing the best possible benefits to the environment. The waste load is adjusted to the long-term treatment capacity of a particular soil system. Such a practice utilizes the resource potential of valuable nutrients normally considered to be pollutants.

There are other advantages to land treatment besides recycling biostimulants through the vegetative growth cycle. Increasing groundwater use in the coastal zone has in numerous cases lowered the water table, allowing salt water intrusion to degrade water supplies. This is presently happening in the metropolitan areas of Baton Rouge and New Orleans. Groundwater recharge with waste water can help to overcome this problem by raising the water table and replenishing potable groundwater reserves. In other areas land degraded by improper farming techniques and surface strip mining activities has been restored to fertile and agriculturally productive use by proper management and application of treated waste waters. In addition, land treatment techniques are often more economical than conventional methods for the maintenance and improvement of our water resources. The National Water Commission has estimated that meeting the 1972 Federal Water Pollution Control Act's requirement of "best available technology" by 1983 will cost $467 billion (about $200 billion more than the entire Federal budget proposed for Fiscal Year 1974). This would amount to more than $2,200 for every person in the United States today. The cost of eliminating the first 99 percent of pollution is half the cost of cleaning the final

1 percent. Land treatment not only achieves the legislated water quality goal but is also considerably less expensive than other types of advanced treatment, especially for eliminating the "final 1 percent." Although land treatment is not a panacea for all water pollution problems, it is widely adaptable to a variety of environmental situations.

Three types of land treatment are commonly used depending upon soil composition, porosity, and drainage qualities. These are rapid infiltration, spray irrigation, and overland flow. Rapid infiltration is a high-rate system useful in areas of highly permeable soils. Depending on soil permeability, the rate of waste application is sometimes about 60 cm (2 ft) per week. (Application rates given as here in terms of depth denote volume per unit area: 2 ft per week = 2 acre-ft per acre per week.) Soils such as gravel or sandy loams are subjected to alternate periods of flooding and drying, usually in constructed basins. Purification takes place through microbial and chemical action as the effluent percolates through the soil column. High-rate loading systems are advantageous for groundwater recharge and reuse, requiring only a small area to purify a large volume of effluent. This technique is used at the Flushing Meadows reclamation facility in Phoenix, Arizona, and the Whittier Narrows reclamation project in California (Stevens, 1972; Bouwer, 1974). The latter has proven so successful that it is being expanded to accomodate 4.7×10^5 m^3/day (125 million gallons per day [mgd]) from the present level of 5.7×10^4 m^3/day (15 mgd). Two additional plants being built to handle 4.7×10^5 m^3/day (125 mgd) each.

Spray irrigation and overland flow are low-rate systems used in areas with less permeable soils. The treated effluent, usually following the chlorination of secondary treatment, is applied at a rate of from 5 to 10 cm (2-4 inches) per week. Therefore, greater land area is necessary for these systems to perform properly. At an application rate of 5 cm (2 inches) per week, for example, a city of 100,000 people could dispose of its sewage effluent using 600 ha (1500 acres). Low-rate systems purify water through infiltration and percolation as do high-rate systems, but because of their use on less permeable soils a much larger fraction of the applied water is lost through evapotranspiration and runoff.

In spray irrigation, the purification of waste water occurs in the top few feet of the soil as the liquid percolates downward. Organic matter is decomposed by bacteria, nitrogen and phosphorus nutrients are removed by surface plants or soil, and heavy metals are absorbed by organic matter and clay particles. These processes produce tertiary effluent with more than 99 percent of the BOD, 99 percent of suspended solids, and up to 40 percent of nitrogen and phosphorus removed. This method of water purification which takes place in the aerobic zone of the soil has been termed the "living filter" because of the interrelationships of the plant, soil, and microbial systems that purify the water. Spray irrigation has been practiced at Pennsylvania State University since 1963. Application of secondary effluent there has provided a valuable source of fertilizer for increasing agricultural and silvicultural production, a useful technique for replenishing the underground water supply, and a cheap, effective alternative for restoring the recreational and scenic quality of Spring Creek in Nittany Valley.

Muskegon County in Michigan is using spray irrigation to design for the future requirements of its population in 1996 and also to help revitalize a tired local economy. The system will accomodate a projected population of 170,000 persons, generating an average waste water flow of 1.64 x 10^5 m^3/day (43.4 mgd) including an industrial flow of 9.0 x 10^4 m^3/day (24 mgd). Previously Mona, Muskegon, and White Lakes all received polluting levels of sewage effluent. Now effluent receives initial treatment in aerated lagoons and, following chlorination, is spray discharged onto fine textured sandy soils for advanced treatment. The biggest advantage other than a cleaner environment is the low operating cost. Treatment costs for the Muskegon system are $24 per thousand cubic meters ($90 per million gallons), approximately half the operating cost of conventional advanced treatment.

Overland flow is used on soils of low permeability and high water tables. It differs from spray irrigation and rapid infiltration in that waste effluent is purified in the top several inches of the soil surface employing microbial processes to a much larger extent. "Grass filtration" is another name for overland flow because of the large fraction of nutrients removed and the advanced level of treatment achieved by cultivating and periodically harvesting rapidly growing grasses on slightly inclined (2%) slopes. A water tolerant plant such as reed canary grass (Phalaris arundinaceae) must be grown because of periodic but slow flooding of about 5 cm (2 inches) per week. Most of the water applied by overland flow is lost to runoff downslope (60%) with the remainder removed through infiltration (20%) and evapotranspiration (20%). Distinct advantages of this design are that groundwater contamination and soil pore clogging, important constraints in spray irrigation and rapid infiltration, are not detrimental to prolonged use. Because of its surface recycling characteristics, this method is well suited for use on clayey and silty clay soils overlying high water tables, conditions such as those found in coastal Louisiana.

Overland flow has been successfully used since 1964 for reclaiming cannery waste water at a Paris, Texas vegetable processing plant. Prior to initial operation, the heavy clay soil on the 200 ha (500 acre) tract was molded to form 0.8 to 4-ha (2 to 10-acre) watersheds which are 60 to 120 m (200-300 ft) wide. These areas are sloped (1 to 12%) toward a collecting terrace at the foot of each watershed. The grass-covered slopes are sprayed with about 1.5 x 10^4 m^3/day (4 mgd) of cannery waste, which for the area used equals an application rate of about 1.5 cm (0.6 inch) per day. Microbial activity in the plant and soil systems removes over 90 percent of the total nitrogen, phosphorus, and organic carbon from the effluent as it flows slowly over the slopes.

The technological development and proliferation of land treatment operations has been swift. From the pioneering work in 1948 at Seabrook Farms, New Jersey, involving spray irrigation, some 950 municipalities and 1,300 industrial plants including more than 300 canneries were using some form of land treatment by 1973. So effective and efficient are the three methods of land treatment that as of July 1, 1974, the Environmental Protection Agency required any community that applies for a waste treatment construction grant (under PL 92-500) to show that it has considered all alternative methods--including land treatment (Chandler, 1974).

Louisiana's Coastal Zone

Louisiana's 3 million hectares (7.5 million acres) of estuary and marsh support a high production of commercially important finfish and shellfish. In 1970, for example, Louisiana coastal waters yielded 435.4 million kg (959.8 million lbs) of menhaden valued at $18.9 million (dockside), 79 percent of the total Gulf states landings. That same year, 41.2 million kg (90.9 million lbs) of shrimp worth $34.6 million (dockside) were caught in Louisiana, leading the other Gulf states. This combined catch valued at $53.5 million is a major facet of the numerous capacities of Louisiana's estuarine and marsh environments. Nutrients are continuously supplied by the Mississippi River, and vast estuarine areas form nursery refuges where larval and juvenile organisms enjoy ample food and protection. Marsh environments, however, provide other valuable services besides fisheries production; Louisiana's wetlands supply recreational opportunities, buffering for coastal storms and hurricanes, fur bearing animal production, and treatment of municipal and industrial waste effluents. The total cost of all these services has not been thoroughly investigated, but one estimate has valued the services of the marsh at several thousand dollars per acre per year (Gosselink et al., 1974). The coastal marsh performs numerous functions interrelated with man's activities and should be managed wisely in a comprehensive plan to insure the continued resource potential of the ecosystem.

Dredging, canal building, and dredge spoil disposal operations are recurrent in the Louisiana coastal zone. Population growth in coastal cities, increasing boat and barge traffic on the waterways, and the continuing search for fossil fuels have left a maze of canals and cuts in the coastal marsh. Maintenance dredging of these waterways is a formidable task encompassing several kinds of dredging techniques and very specialized equipment. In Louisiana, hopper and pipeline dredges are responsible for removing about 31 and 15 million m^3 (41 and 20 million yd^3) of spoil per year, respectively. Where open ocean disposal is not conducted, spoil is disposed of on land or marsh. Because of the growing awareness of the importance of the marsh, however, land disposal is commonly practiced using retaining dikes that prevent the free flow of spoil.

In recognition of the dredging and disposal problem, the U.S. Army Corps of Engineers Waterways Experiment Station in February 1973 commenced the Dredged Material Research Program to develop technically satisfactory, environmentally compatible, and economically feasible alternatives for dredging and disposal. The program, divided into the four divisions of aquatic disposal, habitat development, disposal operations, and productive uses, has been granted a 5-year, $30 million budget to achieve these ends. The Center for Wetland Resources at Louisiana State University is also interested in finding methods of managing confined dredge spoil disposal areas. Waste disposal from Louisiana's fishery industries and growing population centers has become a significant problem for meeting present and future coastal zone water quality standards. Land treatment on confined disposal sites is a partial potential answer to this problem and could be economically utilized in the Louisiana coastal zone. Of the three methods of land treatment, overland flow is best suited for use on confined dredge spoil disposal sites because of: 1) silty clay and clayey soils which are widely distributed throughout the active and abandoned delta zones, 2) high water table, 3) a long vegetative growing season, and 4) the nature of many discharged wastes such as fish processing and canning wastes, sugarcane processing wastes, and municipal sewage wastes.

DULAC, LOUISIANA - A PILOT PROJECT IN OVERLAND FLOW

A pilot project using overland flow was conducted in cooperation with an industrial fisheries plant at Dulac, Louisiana, from April through August, 1974. This period coincides with the growing season for most plants and also with the open fishing season for menhaden and shrimp in Louisiana. The project was designed to evaluate the suitability of the indigenous spoil bank and marsh systems for waste water treatment. Particular attention was paid to the activity of the soil microbes in the effluent-treated soil and to the depth the effluent percolated into the treated ground. The warm, humid subtropical climate causes rapid plant growth and bacterial decomposition, two integral processes for biological water purification and nutrient recycling. In Louisiana marshes a significant fraction of marsh plant production is exported into surrounding estuaries. Therefore, the overland flow project was designed to assimilate waste nutrients into plant tissue with subsequent bacterial decomposition allowing dispersal through detrital export. In this manner, nutrients are discharged into receiving waters as a suitable food source for higher trophic consumption by fish and shrimp, rather than as biostimulants for irregular algal blooms.

Description of the Area

The Zapata Haynie Corporation owns and operates a fish meal production plant in Dulac, Louisiana, based on a fishery for Gulf menhaden, Brevoortia patronus. The plant is situated along the eastern bank of the Houma Navigation Canal, about 11 km (7 miles) north of Terrebonne Bay (Figure 1). The company operates its own fleet of radio-contact spotter planes which aid a modern fleet of large, refrigerated menhaden boats. The facility is modern and well run and has extensive advanced treatment lagoons that can accomodate organic waste water resulting from the fish meal production process. The plant operates year round but is most active during the legal fishing season, from mid-April to mid-October. The landed menhaden are pumped out of ships with canal (bail) water and into the plant where they are screened, cooked, pressed, and dried into a high protein fish meal (Figure 2). All process streams that may pick up organic material are evaporated for production of solubles, with the evaporator condensate undergoing further treatment prior to discharge. According to previous operating procedures, two organic waste streams (bail water and stickwater; see Figure 2), both proteinaceous in character, were piped into a 4-ha (10-acre) primary treatment settling pond prior to discharge into the navigation canal. After the pond discharge was discontinued, the waste water remaining in storage was allowed by the company to be used in the overland flow project. Because the experimental waste remained in the pond for almost a year, the ammonium nitrogen level increased to about 600 mg/l. This is believed to have resulted

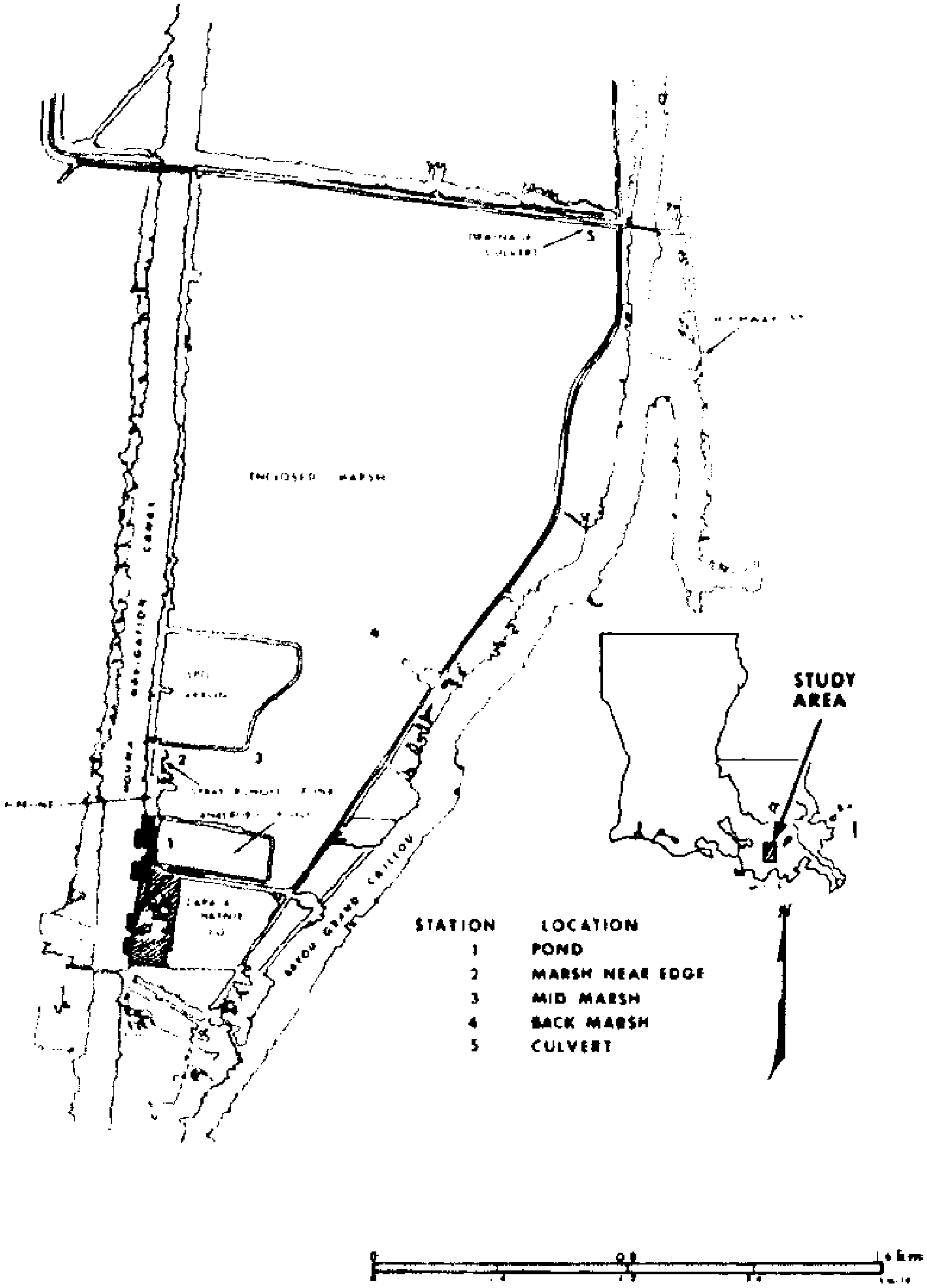


Figure 1. Location of the Zapata Haynie menhaden plant, the experimental area, and the enclosed marsh.

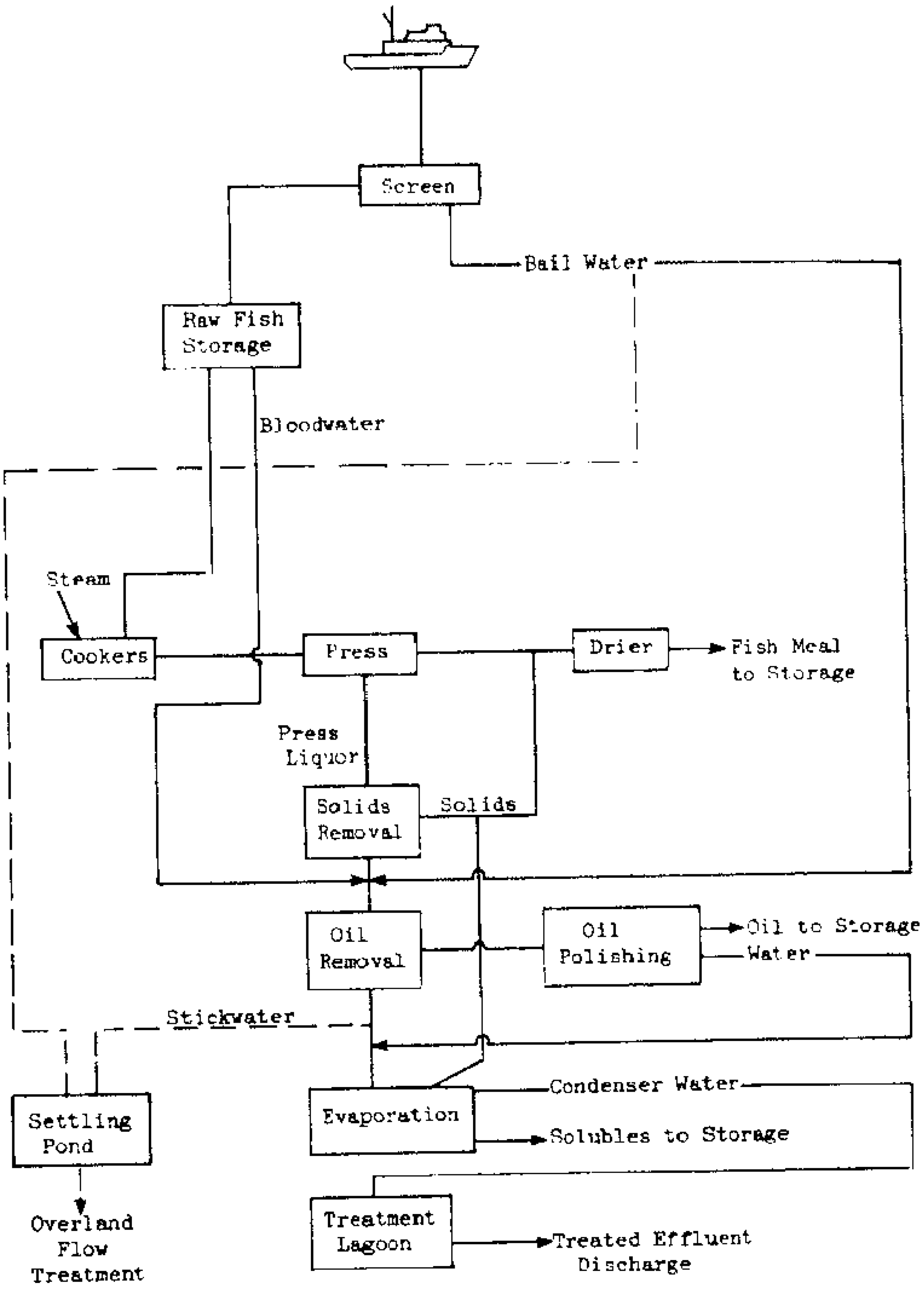


Figure 2. Flow diagram for fish meal production showing waste streams used for overland flow pilot project (dashed lines).

from deaminization of the waste protein.

The menhaden facility borders an enclosed marsh that is connected to the navigation canal by a single culvert (Figure 1). This culvert permits only limited and indirect water exchange between the marsh and canal. Rainfall dominates the water volume entering the marsh. Bayou Grand Caillou, containing fresh water at this point (Gagliano et al., 1970), does not receive water from nor contribute water to the enclosed marsh except during hurricane storm periods when higher tides cause bayou waters to flood their levees. Because of the confined nature of the marsh, it was deemed a suitable area for a controlled waste disposal study.

The most satisfactory land area for the project was located 1,000 m (3,300 ft) north of the plant along the canal bank (Figure 1). Although a large diked spoil disposal area lies just beyond this point, attempts to use this land were thwarted because of maintenance dredging on the navigation canal. No attempt was made to remove or plant vegetation except for a pair of sampling transects from which vegetation was periodically harvested. The canal bank sloped irregularly toward the receiving marsh for about 30 m (100 ft) at a 6 percent incline. Soil composition was predominantly silty clay and clayey silt material. A total land area of 20 x 30 m (65 x 100 ft) was employed for the overland flow project. Routine tests included sampling of effluent runoff downslope, groundwater at several depths below the treated area, soil microbial activity, plant nutrient levels, soil chemistry, and surface waters in the receiving marsh.

The engineering design, environmental constraints, and experimental results have been presented elsewhere in considerable detail (Meo, 1974). The general scheme will be discussed here. The stored menhaden waste was pumped from the pond to the crest of the canal bank where it was spray-discharged at low pressure at a rate of 5.08 cm (2 inches) per week (Figure 3). Waste was sprayed for 3 hours daily, Monday through Thursday each week, for the 6 month period. Mechanical breakdown and maintenance repair decreased the spraying time by about 25 percent of the total period. The long weekend drying period was necessary to allow for dissipation of any ponding or puddles that may have formed.

Treatment Results

Total organic carbon, total nitrogen, and total phosphate phosphorus concentrations in the waste averaged 800, 600, and 50 mg/liter, respectively. These concentrations were reduced by 58, 51, and 53 percent, respectively, by the soil-plant system as the effluent flowed over the 6 percent, 30 m (100 ft) slope. The soil surface remained considerably impermeable to effluent infiltration and percolation. In the saturated soils near the receiving marsh edge, groundwater nitrogen just exceeded 10 mg/liter

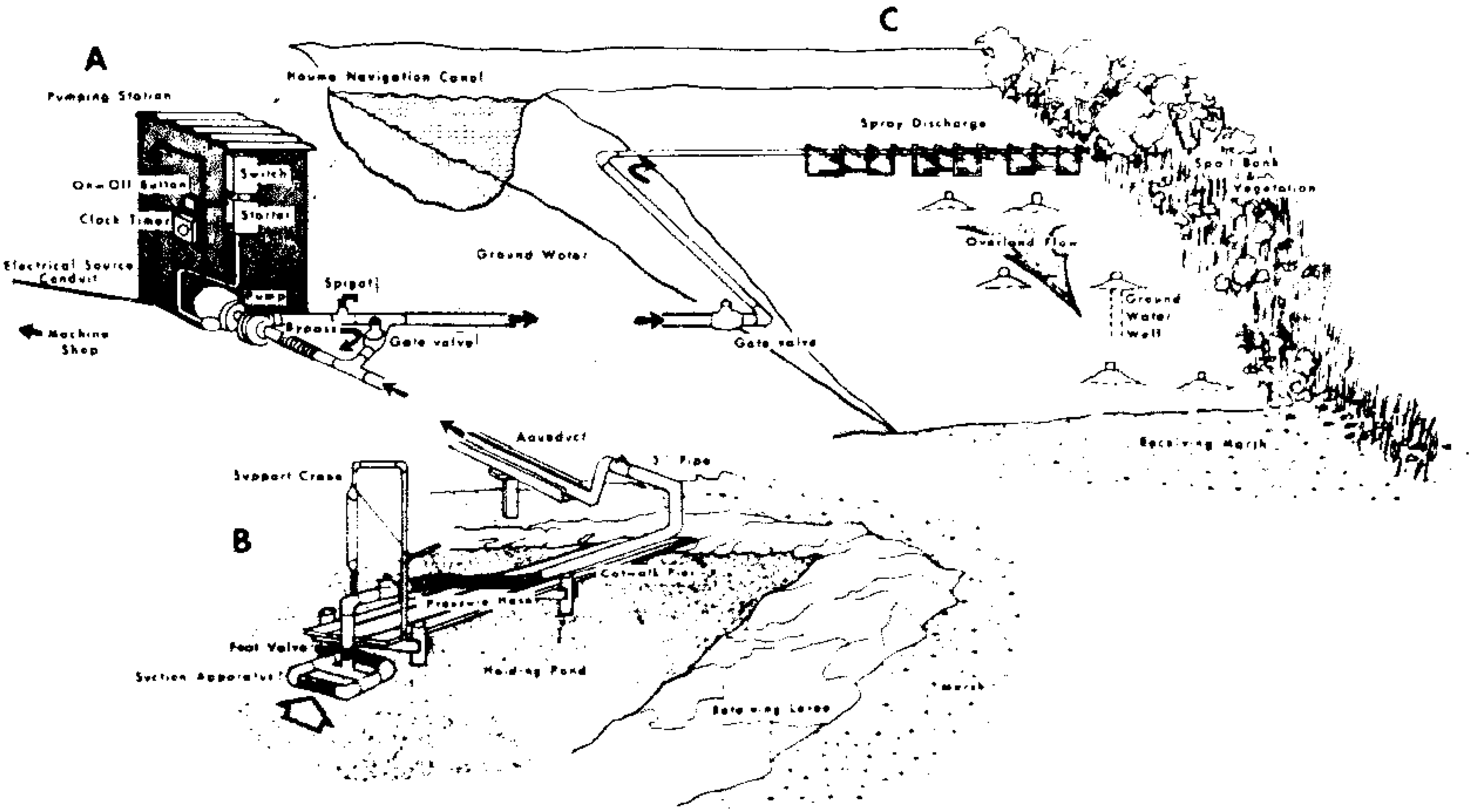


Figure 3. Schematic diagram of the overland flow system showing the (A) pumping station, (B) input apparatus, and (C) discharge apparatus on the canal bank.

Table 1. **Numbers of general heterotrophic and proteolytic soil microorganisms in the treated and control areas (units are x 10^6/g dry weight).**

Distance Down Slope		No. Microbes in Soil Saturated by Overland Flow		No. Microbes in Soil Not Saturated by Overland Flow		No. Microbes in Soil 3 Days After Overland Flow	
		Gen Hetero	Proteo	Gen Hetero	Proteo	Gen Hetero	Proteo
Canal Bank	7.5 m	184.143	11.236	36.870	1.994	7.456	1.058
	22.5 m	216.720	3.899	44.266	2.620	5.060	0.708
	Control	8.270	3.664	8.920	1.809	3.453	0.566
		June		July		August	
		Gen Hetero	Proteo	Gen Hetero	Proteo	Gen Hetero	Proteo
Marsh	10.0 m Beyond Slope Edge	13.600	1.502	27.353	9.589	3.206	1.111

at a depth of 30 cm (1 ft) after 5 months. Runoff from the treated area increased the nutrient load at the receiving marsh edge, but sampling stations further out in the enclosed marsh (Figure 1) revealed no changes. Analyses of water leaving the enclosed marsh through the culvert varied little in nutrient composition during the study period. The application of primary treated effluent onto the spoil bank was followed by secondary treatment of the organic matter by the soil microbiota and tertiary treatment by both the plant cover and the surrounding marsh (which further removed available nitrogen and phosphorus compounds).

The measurement of soil microbial activity included tests for aerobic heterotrophic, proteolytic, and total coliform microorganisms. The general heterotrophs and proteolytics sampled in treated and control plots showed abundant growth on the effluent sprayed sites (Table 1). The water's total coliform most probable number (MPN) was diminished by 66 percent after flowing down the slope (Table 2). Lower MPN's were found at stations further out in the marsh. The total coliform MPN at the drainage culvert was at background level with the navigation canal upstream of the plant. Groundwater MPN's coincided with this level at a soil depth of 30 cm (1 ft). Salmonella sp., found to be present in the waste, were not found in samples taken in the marsh (N. Hopkinson, LSU Dept. of Microbiology, personal communication). Ordinarily, chlorination is recommended as a precautionary safeguard against pathogen survival in the open environment following land treatment, but in this project chlorination was not necessary because of bacteriostatic agents in the receiving marsh.

Table 2. Total coliform MPN's of selected samples taken in the experimental and surrounding area (July only).

Sampling Location	MPN
Settling Pond (Station 1)	1.7×10^6/100 ml
Receiving Marsh Edge	5.8×10^5/100 ml
Ground Water 81.3 cm Below Treated Soil Surface	170/100 ml
Ground Water 30.5 cm Below Treated Soil Surface	1.2×10^4/100 ml
Mid Marsh (Station 4)	2.4×10^3/100 ml
Culvert (Station 5)	170/100 ml
Navigation Canal 3 km Upstream From the Plant	170/100 ml

Roseau cane, Phragmites communis, is a dominant plant that grows almost continuously through the year over the length of the spoil bank. Minor changes in elevation above mean water level are sufficient to alter the composition of the indigenous plant communities, yet Phragmites, a brackish to freshwater plant, grows vigorously on canal banks as well as in marshes. The warm, humid climate enhances the fragmentation and degradation of the dead plant standing stock. As a result of abundant rainfall, warm climate, and microbial processes, organic matter on the soil surface, complemented by the addition of the menhaden waste, did not accumulate beyond 4 percent of the soil volume. Compared to controls, Phragmites receiving waste treatment increased in live standing crop by 55 percent and in nitrogen and phosphorus content by 47 and 13 percent, respectively, proving it to be of considerable value in the land treatment design.

The overland flow site had an area of 0.06 ha (0.15 acre). Nutrient removal on a mass basis per area (Table 3) reveals a substantial volume reclaimed from the waste water, although the percent removed may not compare favorably with other operations. Removal rates can be improved by optimizing contact time, slope, distance, and surface roughness by mechanical methods of slope preparation and application. The volume removed by vegetative uptake, although important in "grass filtration," does not account for the major fraction of nitrogen and phosphorus removal. It is more plausible that microbial controlled nitrification and denitrification play the critical role in nitrogen loss in flooded soils. Phosphorus removal in alternately flooded and dried soils is dependent more on physical-chemical transformations than biological ones. Research on flooded soils and their nutrient transformations support this general theory (Patrick and Mahapatra, 1968; Patrick and Mikkelsen, 1971; Ponnamperuma, 1972).

Complementary Research

Similar pilot projects have been recently conducted to evaluate the promise of using overland flow as an effective form of advanced treatment for raw domestic waste water and runoff from animal feedlots. In one project at Ada, Oklahoma, domestic waste water (chemical composition given in Table 4) was comminuted and spray-discharged at low pressure at rates of 7.4, 8.6, and 9.8 cm (2.9, 3.4, and 3.8 inches) per week on 11 x 36 m (36 x 118 ft) plots with graded slopes between 2 and 4 percent (Thomas et al., 1974). The project ran for 18 months with the first 6 months designated as the shakedown period of operation, the second 6 months covering the winter season, and the last 6 months including the summer operation. The best performance was achieved during the summer period (Table 5). Percentage removal for total suspended solids and biochemical oxygen demand equalled or exceeded 95 percent. The concentration of these constituents

Table 3. Nutrient balance for the overland flow treatment for 5 months at Dulac.

Flow Pathway	Carbon		Nitrogen		Phosporus	
	lbs	kg	lbs	kg	lbs	kg
Inputs (spray discharge)	908.7	412.3	730.4	331.4	58.4	26.5
Outputs (runoff into marsh)	383.3	173.9	355.5	161.3	27.5	12.5
Retained by slope	525.2	238.3	374.9	170.1	30.6	13.9
Vegetative uptake	--	--	9.7	4.4	0.4	0.2
Percolation to groundwater	--	--	7.7	3.5	1.7	0.8

	Carbon		Nitrogen		Phosporus	
	lbs/acre	kg/ha	lbs/acre	kg/ha	lbs/acre	kg/ha
Amount removed by soil-plant system	3,539	3,967	2,529	2,835	207	237

Table 4. Chemical characteristics of raw waste water for 18-month period (from Thomas et al., 1974).

Parameter	Concentration (mg/l)		
	Mean	Maximum	Minimum
Total Solids	1014	1660	650
Total Volatile Solids	300	525	149
Total Suspended Solids	160	420	52
Total Volatile Suspended Solids	123	306	40
Total Dissolved Solids	854	1504	525
Biochemical Oxygen Demand	150	273	84
Chemical Oxygen Demand	314	620	130
Total Organic Carbon	89	198	21
Total Nitrogen	23.6	36.8	10.7
Kjeldahl Nitrogen	22.8	36.8	8.3
Ammonia Nitrogen	17.0	29.0	6.9
Nitrate plus Nitrite Nitrogen	0.8	-	-
Total Phosphorus	10.0	15.0	4.8

Table 5. Chemical quality of plot runoff for summer operation from May through September, 1972 (from Thomas et al., 1974).

Parameter	Mean concentration (mg/l)		
	7.4 cm/wk plot	8.6 cm/wk plot	9.8 cm/wk plot
Total Solids	814	848	817
Total Volatile Solids	142	143	140
Total Suspended Solids	8	6	8
Total Volatile Susp. Solids	5	4	4
Total Dissolved Solids	806	842	809
Biochemical Oxygen Demand	11	7	8
Chemical Oxygen Demand	73	59	58
Total Organic Carbon	23	18	19
Total Nitrogen	2.6	2.2	2.2
Kjeldahl Nitrogen	1.8	1.7	1.7
Ammonia Nitrogen	1.0	0.7	0.6
Nitrate Nitrogen	0.4	0.5	0.4
Total Phosphorus	4.0	4.3	4.3

in the plots was consistently less than 10 mg/liter.

Feedlot runoff, which causes a significant pollution problem in the midwest, was used in field tests using natural slopes of 3 to 5 percent at a commercial feedlot in northeast Texas. The experimental area of 3.2 ha (8 acres) was divided into two areas with terraces at a spacing of about 76 m (250 ft) (Thomas, 1974). The mass removal data presented in Table 6 record combined overland flow and farm pond removals in the 80 to 90 percent range for the 6 month study. Thomas believes that these modest removals reflect the fact that the treatment system was not given an opportunity to "age" properly through prolonged use. Higher reclamation is expected when a warmup period through the winter season is permissible, as in the preceding study.

Table 6. Mass removal percentage for the overland flow and farm pond components of the treatment train (from Thomas, 1974).

Parameter	Overland flow area	Farm Pond	Combined
Total Dissolved Solids	73	9	82
Total Suspended Solids	59	30	89
Chemical Oxygen Demand	71	12	83
Biochemical Oxygen Demand	77	13	90
Total Phosphorus	78	12	90
Total Nitrogen	67	19	86

Laboratory studies were initiated by the U.S. Army Engineer Waterways Experiment Station at Vicksburg, Mississippi, to study in finer detail the actual biological and chemical transformations occurring during overland flow (Carlson et al., 1974; Hoeppel et al., 1974). A greenhouse model was constructed measuring 1.5 m (5 ft) wide and 6.1 m (20 ft) long. A grass-sod mixture of reed canary grass (Phalaris arundinacea) and low permeable Susquehanna clay was laid to a 15 cm (6 inch) depth with a 2 percent slope. Using secondary treatment waste effluent with several commonly occurring heavy metals added to it, the model was run 12 weeks with effluent flooding of 1.3 cm (0.5 inch) per day (6-hr periods) for 4 days per week. Analyses showed that 100, 95, 91, and 75 percent of the ammonium, nitrate, organic nitrogen, and organic phosphorus, respectively, were removed from the waste water. The harvested cover grass removed 31 percent of the nitrogen and 6 percent of the phosphorus. The model removed from the waste water from 98 to 100 percent of the added cadmium, copper, manganese, and nickel; 91 percent of the added lead; and 72 percent of the zinc. Nutrient reclamation was found to correlate closely with flooded soil nutrient transformations as reported in the literature. Phosphorus was noted to be a limiting factor in overland flow designs.

Recommendations

Land treatment by overland flow has shown itself to be of significant value in reclaiming a variety of organic wastes from effluents on impermeable soils. Normally, such wastes are provided with secondary treatment prior to land application, but where environmental systems are suitable, land treatment could provide adequate secondary and advanced treatment to organic wastes. This design could substantially reduce the total cost for cleaning waste water. Most of the work is done by natural systems whose efficiencies can surpass any mechanical recycling system.

Adding waste effluents to wetland areas, including marshes, has been advocated as a cheap method of obtaining advanced treatment for sewage wastes. However, marsh systems, already subjected to the increased level of aquatic eutrophication associated with populated areas, may be altered substantially by routine waste loads, thus impairing their food production capabilities. By employing confined dredge spoil disposal sites, possibly in conjunction with enclosed wetlands, as waste treatment systems, the need of using pristine marsh for advanced waste treatment can be avoided. Wastes from finfish and shellfish processing plants, usually found in wetland areas, can be recycled on these "new" land areas, enhancing the growth of spoil bank plant communities as well as providing an adequate habitat for native wildlife. However, wastes so purified should remain primarily organic. Complex hydrocarbons, heavy metals, and detergent compounds such as alkyl benzene sulfonate (ABS) have been effectively degraded and assimilated by soil systems in laboratory and field tests, but we have no results or threshold levels presently to recommend overland flow for any or all wastes. Further research on the biodegradability of potentially carcinogenic or harmful compounds by the spoil surface must be done before incorporating land treatment as a purification medium of suspect wastes.

Low-rate land treatment systems such as overland flow generally require a greater land area to clean water than do high-rate systems. Although well-drained land above mean Gulf level is not plentiful in the coastal wetlands, there exists an increasing acreage of drained land areas within this environment which is used very little. These are dredge spoil disposal sites, which have a tremendous potential for use as reclamation and nutrient recycling systems. In this chapter we will discuss the proliferation and distribution of confined dredge spoil disposal sites with respect to their proximity to industrial and urban development. The volume and character of municipal and industrial organic waste effluents that could be reclaimed by overland flow on such areas will be evaluated, and recommendations regarding the future management of spoil disposal sites will be made.

The Dredging Process

Dredging and operational maintenance of canals and harbors is the general responsibility of the U.S. Army Corps of Engineers. Each year the three COE district offices in the Gulf states region oversee the maintenance dredging of about 106 million m^3 (139 million yd^3) of soil material of which 46.5 million m^3 (60.8 million yd^3) (43.7%) is dredged within the New Orleans District (Boyd et al., 1972). Furthermore, almost a third of this volume is accounted for by the Gulf Intracoastal Waterway (GIWW) which transverses the New Orleans District. Although substantial, the aforementioned projects do not encompass the total dredging effort. The mineral extraction industry has dredged many canals to gain drilling access and to lay distribution pipelines. The total surface area of dredged canals comprises 490 km^2 (189 square miles) out of 53,043 km^2 (20,480 square miles) of coastal Louisiana (Gagliano, 1973). This area will likely increase as oil and gas fields are further developed and new waterways are excavated.

The presence of these canals and the often unplanned manner in which they are dredged has resulted in numerous negative impacts and environmental problems in the wetland environment. Gagliano (1973) noted 19 negative impacts while only 3 positive impacts could be described (Table 7). Among those that directly affect the productivity of the marsh environment are: direct loss of productive habitat through dredging; direct loss and/or reduction in habitat through spoil disposal; salt water intrusion causing faunal and floral changes; modification of runoff pattern often causing freshwater deficient areas; and the introduction of agricultural, urban, and industrial pollutants.

Table 7. Negative and positive impacts associated with canal dredging in Louisiana's coastal zone (from Gagliano et al., 1973).

Negative Impacts

Direct loss of productive habitat through dredging;

Direct loss and/or reduction in habitat quality through spoil disposal;

Salt water intrusion causing faunal and floral changes;

Increased storm-generated surge;

Accelerated erosion resulting from increased length of land-water interface;

Increase in runoff rate resulting in loss of fresh water storage;

Modification of runoff pattern, often creating fresh water deficient areas;

Accelerated erosion resulting from increase in tidal prism volume;

Changes in circulation patterns in bays and sounds;

Accelerated erosion resulting from boat-generated wash;

Accelerated erosion along unstable canal banks;

Alteration and/or disruption of longshore drift of sand;

Serve as development corridors;

Introduce agricultural, urban, and industrial pollutants;

Canals segment natural areas, often resulting in drainage and development in resulting smaller units;

Destruction of unique natural habitats and environments;

Destruction of historic and archeological sites;

Reduced aesthetic quality: linear artificial elements usually have less aesthetic value than natural elements;

Pre-empts planning process.

Positive Impacts

Increase in land-water interface;

Spoil may create new habitats and increase habitat diversity;

Increase access for sports, recreation, and commercial activities.

Dredge Spoil Disposal

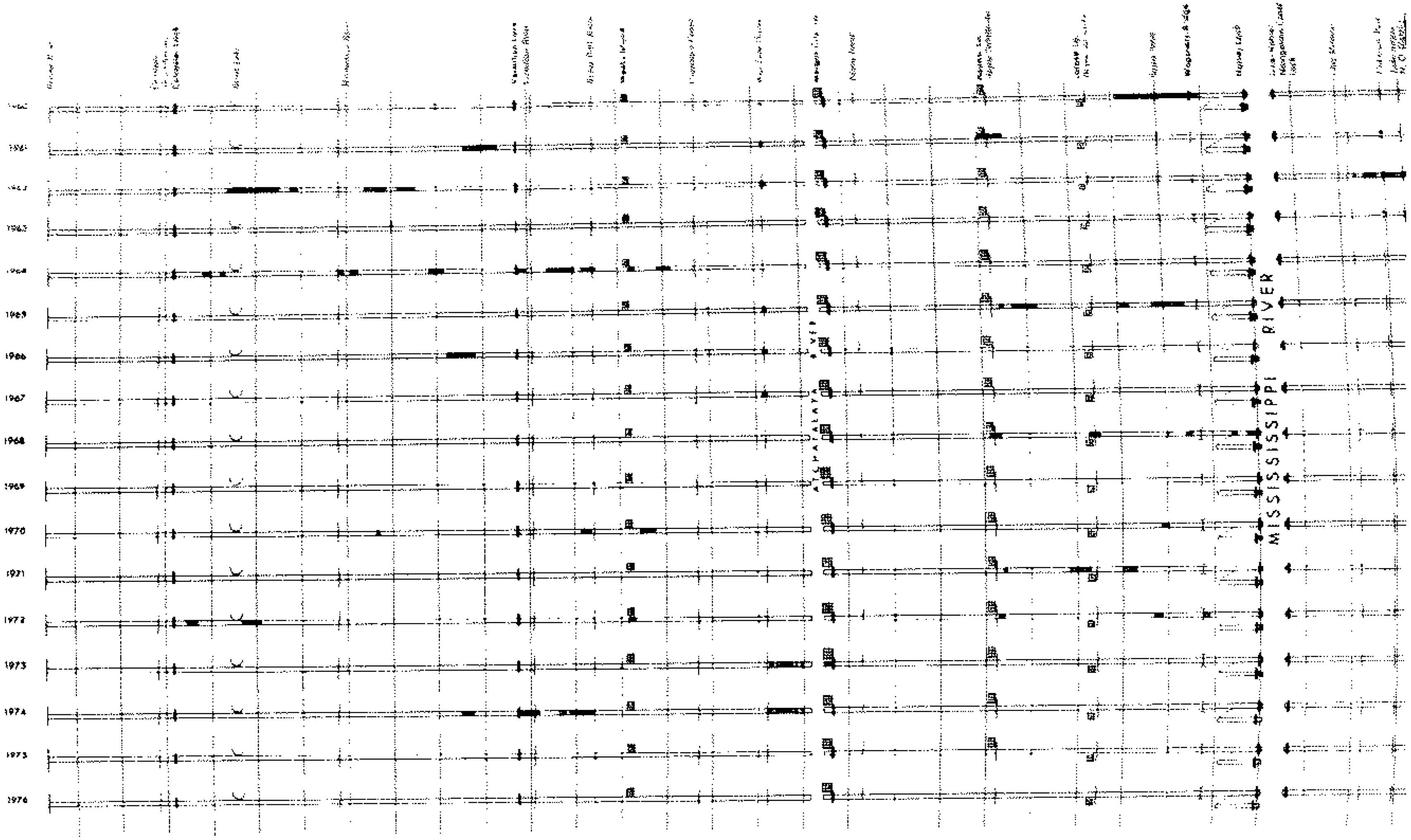
Marsh environments are no longer considered as proper sites for disposal of unconfined or open dredge spoil material. Spurred by an increasing awareness of the highly productive nature of wetland areas, programs have been initiated to consider alternatives to open marsh disposal. These include ocean disposal and confined (diked) land disposal. Ocean disposal is considered practical in areas where spoil generated turbidity and physical loss of benthic flora and fauna habitat are minimal. In 1972, the New Orleans District disposed of 31.0 million m^3 (40.5 million yd^3) of dredge spoil material by this method.

It is generally accepted that the most significant objection to open marsh disposal is the direct loss of physical habitat (Boyd et al., 1972). This loss is accompanied by additional negative impacts such as alteration of water circulation, disruption of material cycling (such as organic detritus and nutrients), and generation of turbidity flows into adjacent water bodies, all of which potentially degrade the area for desirable fauna and flora.

Of the two alternatives to open marsh disposal, confined spoil disposal is more suitable for beneficial multiple use operations. Confined spoil disposal sites vary in size from the 1000-ha (2500-acre) Craney Island disposal area in the Norfolk District to some that are smaller than 4 ha (10 acres). In 1972, 15.5 million m^3 (20.3 million yd^3) of dredge spoil material was deposited in confined sites within the New Orleans District. This volume is expected to increase in future years, but problems involving the procurement of land, usually privately owned, and the construction of suitable dikes are obstacles for protracted use. Because of the recurrent nature of dredging operations and the problems in acquiring new land, permanent disposal areas are favored, and planning for their continued use is practiced. Areas where long-range use has been planned include Mobile Harbor (30 to 40 yr), Norfolk Harbor (45 yr), Delaware River (15 yr), and Coos Bay, Oregon (30 yr) (Murphy and Zeigler, 1974).

The material dredged annually from Louisiana's navigation canals can be considered a "renewable" resource in that it represents "new" land whose abundance and availability should be planned and managed using conventional conservation skills. For example, the Gulf Intracoastal Waterway yields about 15 million m^3 (20 million yd^3) of spoil per year. Since 1945 the COE has kept a record of maintenance dredging activities in the GIWW. A reconstructed segment of that record for the period from 1960 to 1976 is presented in Figure 4. It reveals the sites of dredging activity and the periodic manner in which this activity occurs along the waterway. Although this record is a useful tool for land planning, comprehensive records similar to this one are not routinely prepared by the COE for most of their dredging operatio

Figure 4. Maintenance dredging along the Gulf Intracoastal Waterway.



comprehensive account of the frequency and location of dredging operations throughout the state for optimal use of the dredge spoil resource.

Productive uses of confined spoil disposal areas are presently being investigated by the Corps of Engineers. They include artificial habitat creation, habitat enhancement, land improvement, and products research. However, there is still a minimum of beneficial impacts currently resulting from spoil disposal operations. Consider as an example the proposed dredging operations for the Houma Navigation Canal, where the Dulac overland flow pilot operation was conducted. The Corps of Engineers (COE Draft Environmental Impact Statement, 1975) lists three beneficial impacts: 1) enhanced waterborne transportation and economic benefit (chiefly with the Houma Navigation Canal), 2) mineral resource extraction, and 3) the creation of land suitable for agricultural use or for construction and development. The potential of using the estimated 1,215 ha (3,000 acres) of spoil disposal sites along the Houma Navigation Canal (Figure 5) for waste water treatment and nutrient recycling has not been considered.

Domestic and Industrial Wastes in South Louisiana

Industrial and urbanized areas in south Louisiana are for the most part limited by the distribution and extent of the natural levee ridges of various Mississippi River distributaries. Although the geomorphology of the estuarine environment constitutes a constraint on growth, the population density in this region is expected to increase from 56 people per km^2 (144 per square mile) in 1970 to about 77 per km^2 (200 per square mile) in the year 2000 (National Estuarine Pollution Study, 1970). Adequate land for plants performing conventional waste water treatment, including primary, secondary, and advanced, will become increasingly scarce as the competition for space accelerates. This could severely hamper Louisiana's progress in achieving improved water quality standards relative to her upstream neighbor states.

In the recent past, the discharge of municipal, industrial, and domestic waste effluents has had deleterious effects upon the availability and use of valuable estuarine resources. For example, a commercial fishery involved in interstate shipment of fish from Lake Calcasieu closed when informed by the Food and Drug Administration of mercury contamination of seafoods from these waters (Louisiana Advisory Commission on Coastal and Marine Resources, 1973). Further, sewage pollution from New Orleans has caused the suspension of oyster harvesting in Lake Borgne due to public health precautions. As recreational campsite construction proliferates in the coastal wetlands, sewage treatmen

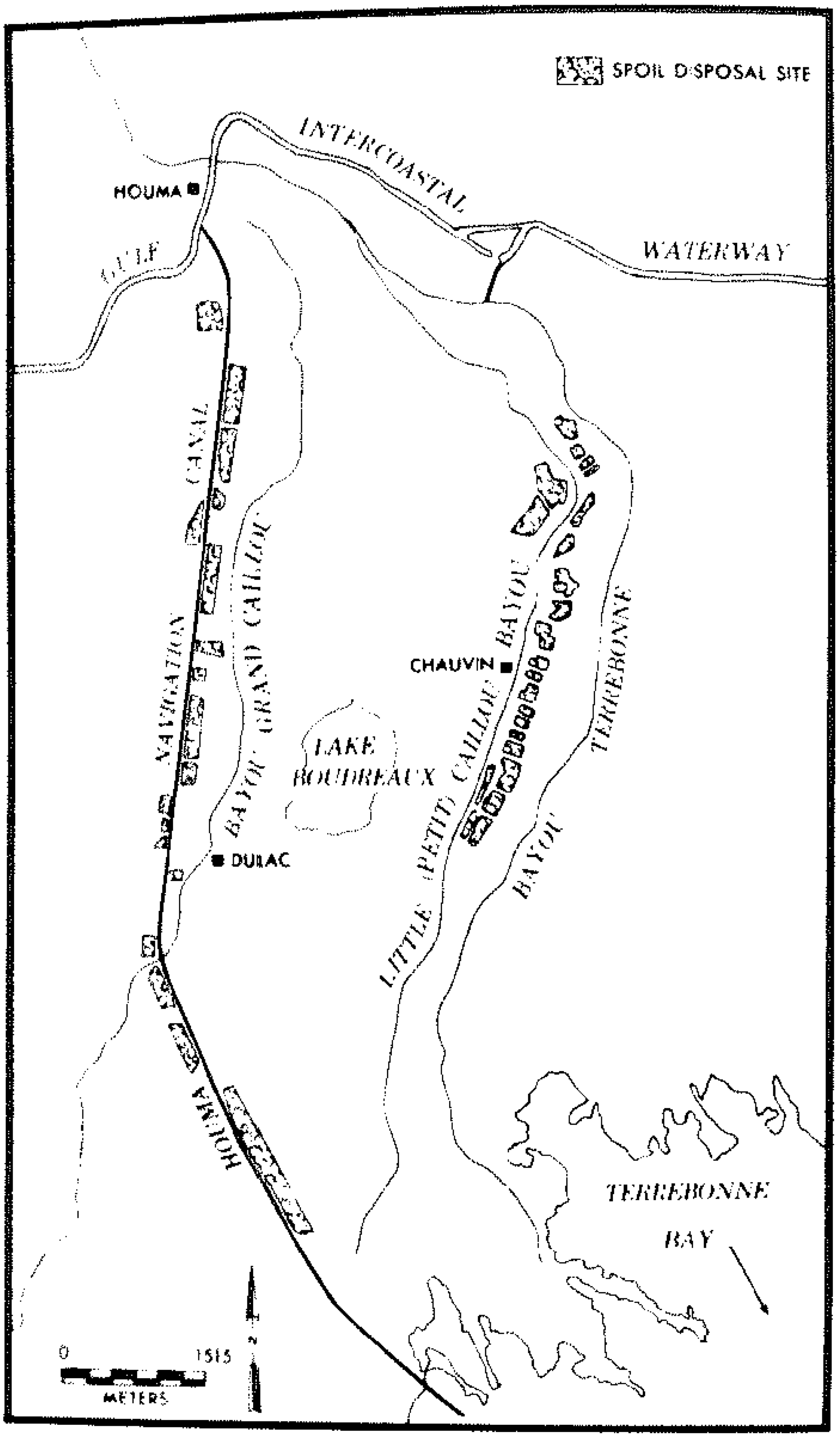


Figure 5. Distribution of confined dredge spoil disopsal sites (1215 ha; 3000 acres) in the vicinity of the Houma Navigation Canal.

in once uninhabited areas will require careful regulation to preserve valuable resource nursery areas.

Domestic Wastes

When considering both domestic and industrial waste effluents suitable for land treatment, the former has received more interest both in historical use and in its potential to jeopardize public health. The major reasons most sewage farms and similar land application systems have failed are inadequate understanding of sewage purification and improper sewage disposal on the land. Coupled with this the scant knowledge of pathogen microbiology and disease control techniques such as chlorination led to a series of misunderstandings as to the proper function terrestrial systems performed in land treatment. Domestic waste should undergo primary and usually secondary treatment with chlorination prior to application on the land. Although the carbon, nitrogen, and phosphorus concentrations may be quite high in organic industrial wastes, the threat of viral and microbial contamination in the open environment is not as acute as with domestic sewage effluent. Furthermore, land systems employing organic industrial wastes are often located in rural areas where odor and wind-borne aerosols are less a problem than in urban areas.

The average daily discharge of domestic waste emptying into estuarine areas and tributaries of the Louisiana coast was about 4.5×10^5 m^3 (120 million gallons) during 1969 (Table 8). All of the reported waste discharged had at least primary treatment while a large percentage received some form of secondary treatment. The major receiving waters were the Mississippi River, Calcasieu River, and Bayou Barataria, which accomodated 56 percent, 9 percent, and 4 percent, respectively, of the effluent discharge, or 69 percent of the total discharge. Since 1969 waste discharges along these waterways have increased, and natural subsidence and deterioration of the coastal wetlands have severely reduced the "buffer" between human activities and vital resource nursery grounds. For example, salt water intrusion from the Gulf and sewage-contaminated water intrusion from developing land corridors have contributed to an increasing acreage subject to permanent closure of oyster harvesting. Navigation canals built to facilitate commerce have upset natural mixing regimes. This has allowed disease microorganisms from domestic discharges to travel further down into the estuaries in circulation patterns that escape sheet flow among the bacteriocidic marsh grasses or avoid an unfavorable salinity concentration. Although increased organic detrital flow into lower Barataria Bay could conceivably enhance secondary production of commercial species, epidemiological problems resulting from domestic discharges could cause greater negative economic impacts than positive.

Table 8. Quantity and quality of domestic waste emptying into estuarine areas and tributaries of the Louisiana coast, 1969[1].

Receiving Waters	Average Daily Discharge (mgd)	Degree of Treatment[2]	Estimated[3] Average ppm BOD Discharge
[illegible]	8.12	B.F. & A.D.	30
[illegible]	0.13	O.P.	25
[illegible]	0.00	A.S.	20
[illegible]	1.00	B.F.	30
[illegible]	3.50	A.S.	30
[illegible]	0.53	E.A.	20
[illegible]	3.47	B.F.	30
[illegible]	0.40	B.F.	30
[illegible]	0.72	B.F.	30
[illegible]	2.10	B.F.	30
[illegible]	0.05	E.A.	20
[illegible]	0.45	S.A.	20
[illegible]	0.08	E.A.	20
[illegible]	0.06	E.A.	20
[illegible]	[illegible]	A.S.	20
[illegible]	1.16	B.F.	30
[illegible]	0.02	E.A.	20
[illegible]	0.35	E.A.	20
[illegible]	0.12	E.A.	20
[illegible]	0.16	S.A.	20
[illegible]	0.54	E.A.	20
[illegible]	3.19	B.F.	30
[illegible]	[illegible]	P.T.	140
[illegible]	4.50	A.S.	20
[illegible]	4.80	P.T.	140
[illegible]	8.00	S.A.	20
[illegible]	N.A.	P.T.	140
[illegible]	0.05	P.T.	140
[illegible]	[illegible]	P.T.	140
[illegible]	N.A.	P.T.	140
[illegible]	1.12	O.P.	25
[illegible]	0.10	O.P.	25
[illegible]	0.25	O.P.	25
[illegible]	0.55	C.S.	25
[illegible]	1.50	C.S.	25
[illegible]	0.38	C.S.	25
[illegible]	0.30	B.F.	30
[illegible]	1.35	B.F.	30
[illegible]	0.15	O.P.	25
[illegible]	0.18	B.F.	30
[illegible]	0.02	E.A.	20
[illegible]	1.15	B.F.	30
[illegible]	0.20	P.T.	140
[illegible]	0.35	P.T.	140
[illegible]	0.35	B.F.	30
[illegible]	7.70	A.S.	30
[illegible]	0.35	B.F.	30
[illegible]	0.56	B.F.	30
[illegible]	0.30	A.S.	30
[illegible]	0.25	B.F.	30
[illegible]	0.60	O.P.	25
[illegible]	1.20	B.F.	30

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[1] Source for data on quantity, quality, and degree of treatment of waste was obtained from the Louisiana Department of Health, 1969.

[2] Legend for degree of treatment: B.F.-Biological Filtration; A.D.-Aerobic Digestion; O.P.-Oxidation Pond; A.S.-Activated Sludge; E.A.-Extended Aeration; P.T.-Primary Treatment; S.A.-Step Aeration; C.S.-Collecting System.

[3] Based on an estimate that the average B.O.D. of untreated domestic sewage is 200 ppm; primary treatment is 140 ppm; and secondary treatment is 30 ppm unless known to be higher.

Industrial Wastes

Petroleum Products Wastes. With the growth of petroleum and chemical industries in Louisiana, there has also been growth of industrial waste products. Treatment of these wastes is an absolute necessity, but in practice such has not always been the case. For example, carcinogenic derivatives from petroleum and petroleum products processing have been detected in drinking water, in resource nursery areas, and in coastal sediments. Furthermore, in a 1972 study of the Calcasieu River Basin, the State's second largest industrialized area, 14 major industries were found to be discharging carbonaceous materials, suspended solids, and oil and grease into the Calcasieu River or one of its tributaries. Their total daily discharge averaged 37,200 kg (82,000 lbs) of chemical oxygen demand; 271,000 kg (597,000 lbs) of total organic carbon; 273,000 kg (601,000 lbs) of suspended solids; and 22.4 x 10^{12} calories of heat (Environmental Protection Agency, 1972). The degree of treatment of selected industrial discharges flowing into estuarine areas within Terrebonne Parish during 1974 (Table 9) reflects the threat posed by these wastes to the renewable resources of the coastal zone. Although crude petroleum and some of its refined products have been shown to be effectively biodegraded by hydrocarbonoclastic microorganisms, many of the other waste products such as phenols and heavy metals are known to be toxic to marine organisms. Therefore, land treatment of petroleum and petrochemical wastes is not recommended.

Fishery Products Wastes. The fishery resources harvested from Louisiana's estuarine and nearshore environments are bountiful. In 1969, 4 Louisiana ports ranked among the top 10 ports in the nation in terms of volume and value of fishery landings (Table 10). A large portion of these landings was Gulf menhaden (*Brevoortia patronus*), which is processed into protein fish meal, fish solubles, and oils. Of 12 plants in the Gulf area in 1972, 8 were located in coastal Louisiana where landings amounted to 413 million kg (910 million lbs) or 82% of the total Gulf catch. Another industrial fish, abundant in Louisiana waters and easily caught, is the demersal croaker (*Micropogon undulatus*). If this species gains widespread acceptance as a food fish, the total weight landed in Louisiana ports should increase noticeably. The processing of shrimp, oyster, crab, and miscellaneous fishery landings adds to the volume of organic waste in need of treatment.

Fish and shellfish processing plants in coastal Louisiana usually lack adequate facilities for purifying their organic waste effluents (Table 9). The Water Quality Management Plan for Terrebonne Basin (Pollution Control Engineering, Inc., 1975) noted that some industrial fish processing plants in this area lack any kind of waste treatment system, yet it is in this wetland environment that the population is expected to increase

ndustrial discharges and type of treatment in
errebonne Parish, 1974[1].

Company	Type of Treatment[2]
Southdown Sugards, Incorporated	16
Bouquet Canning Co., Incorporated	18
Bouquet, Inc., Co.	3
Union Oil of California	3
Superior Oil Co.- Bayou Penchant	6
Superior Oil Co.- Sun Rise Field	6
Freeport Sulfur Co.	9
Superior Oil Co.- Bayou Rambio	6
Superior Oil Co.- Clovelly Valley Field	6
Superior Oil Co.- Four Ice Dome Field	6
Authement Packing Co.	16
Grand Caillou Packing Co.	16
Voisin Canning Co., Inc.	16
Gulf Coast Packing Company, Inc.	16
Autherment Packing Co.	15
Ivy Authement, Ice, Company, Inc.	6
Chauvin Fish & Packing Co.	16
Indian Ridge Shrimp Company	16
Sea Tang Fisheries	16
Dow Chemical Co.	15
Southeast Corporation	9
Zapata Protein, Inc.	7

lity Management Plan--Terrebonne Basin
by Pollution Control Engineering, Inc., 1975.

reatment is as follows:
o treatment of treatable discharge; 16-18
rimary treatment of effluent amenable to further treatment; 13-15
econdary treatment-inadequate due to various factors; 10-12
rimary and/or secondary treatment, less than best practicable; 7-9
est practicable control technology; 4-6
ertiary or non-contact discharge; 1-3
o discharge; 0

Table 10. Volume and value of landings at certain U.S. Ports, 1969.

	Thousand Pounds	Thousand Dollars
San Pedro, Cal.	406,900	40,500
Cameron, La.	323,900	8,200
Pascagoula-Moss Point, Miss.	256,000	6,600
Dulac-Chauvin, La.	185,300	11,200
Kodiak, Alaska	140,300	18,000
Reedville, Va.	124,200	1,900
Morgan City, La.	122,000	6,400
Beaufort-Morehead City, N.C.	118,100	2,400
Empire, La.	111,200	5,800
New Bedford, Mass.	107,800	17,400

Source: U.S. Department of Interior, Bureau of Commercial Fisheries of the United States, 1969, p. 9.

by almost 70 percent between 1970 and 1995. In south Louisiana, most fishery processing plants are situated near navigation canals and major waterways where boats and vessels can gain access to unload their catch and where an ample supply of water is available for processing operations. Figure 6 shows the location and number of south Louisiana processing plants along with the size and value of fishery landings at various ports. These processing plants are similar to each other in that: 1) fishery wastes have a high organic content and are difficult to handle by conventional methods, 2) plant operations are often seasonal with all or a large part of the waste water created within a period of a few months, and 3) plants are often located in small towns or rural areas where municipal treatment facilities are not adequate to handle extreme seasonal loads. Land treatment offers a sound solution to the pressing problem of finding an inexpensive method for purifying large volumes of organic fishery waste effluents. Utilizing proper public health measures, disease problems could be minimized. One important constraint to land treatment is adequate land for proper waste reclamation.

Spoil Disposal Sites

Confined spoil disposal sites are not presently utilized for productive purposes. If there were a sufficient acreage of diked spoil areas, and if easement of restrictions against property use for disposal were attainable, they could be easily

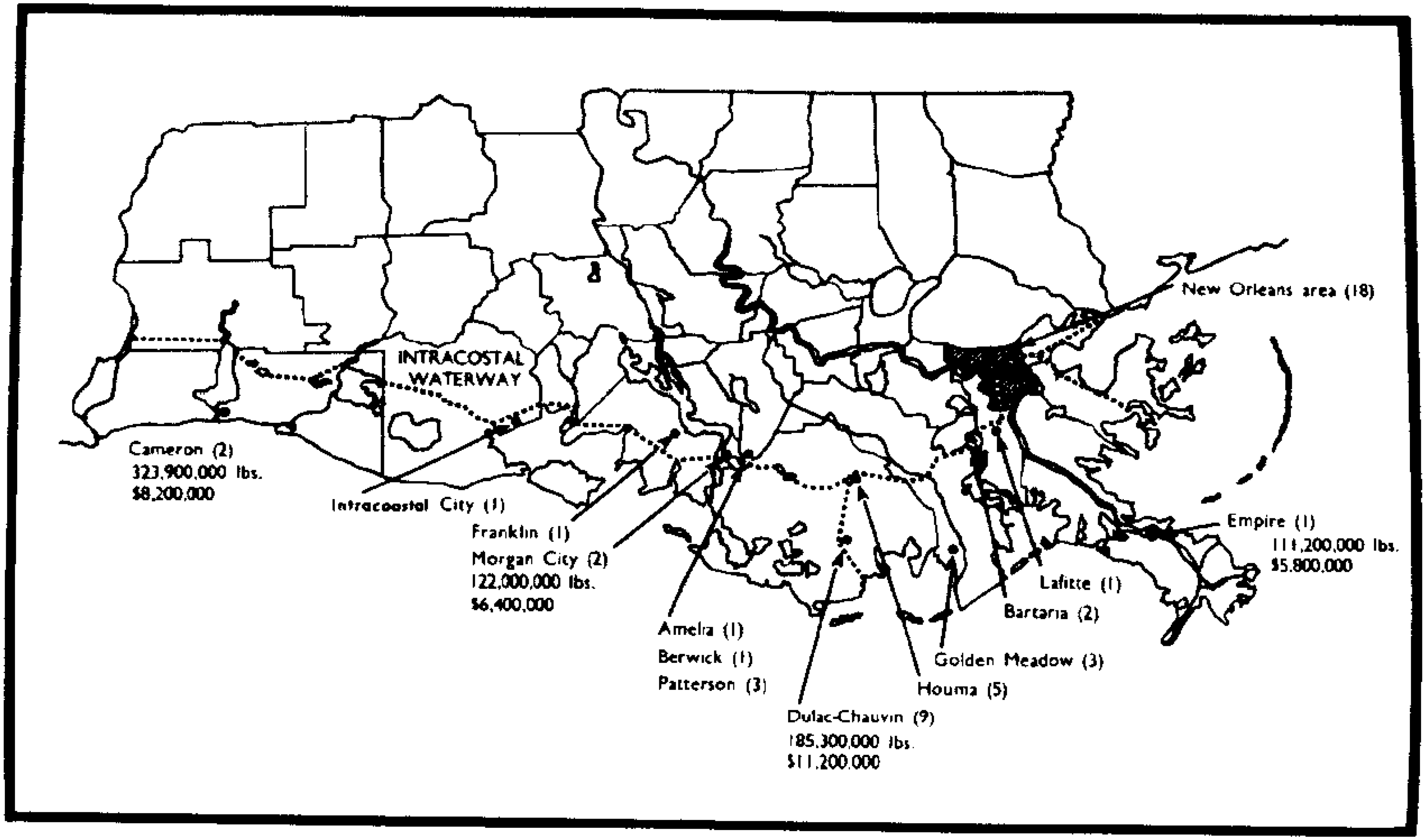

Figure 6. Locations of coastal Louisiana fish processing firms, 1972 (city and number of firms), landings at selected Louisiana ports, 1969 (pounds/value), and the Gulf Intracoastal waterway.

converted into overland flow treatment sites at comparatively small expense. Through the courtesy of the New Orleans District Office of the Army Corps of Engineers, maintenance dredging charts of several commercially important waterways were obtained, and the acreages of their confined spoil disposal sites were measured (Table 11). These areas were selected both on the basis of their proximity to developed or urban areas and their having adequate elevation above normal flood tidal levels. The spoil acreage reflects the wide availability of confined land that could be beneficially employed in multiple use designs. As newer uses are evolved, dredging frequency charts for all commercial waterways, such as the one maintained for the GIWW (Figure 4), will be necessary for optimal resource management.

Cameron is an excellent example of an area where it would be feasible to employ confined spoil disposal sites as treatment centers for both municipal and fishery products waste effluents. In the vicinity of Cameron along the Calcasieu Ship Channel, there are more than 730 ha (1800 acres) of diked dredge spoil about 600 m (2,000 ft) from two principal menhaden processing plants and also within practical pumping distance from the city (Figure 7). A land treatment system using overland flow could be designed to accomodate the organic waste load of the two fish plants and possibly the city of Cameron without threatening the environment or the public health of the surrounding area. The waste load from the fishery plants is seasonal and coincident with the vegetative growing season. In addition, the near subtropical climate in south Louisiana encourages year round growth of roseau cane (Phragmites communis), which served as an excellent cover plant in the pilot project at Dulac. As interest in new paper resources grows, attention may be given to the concept of using diked spoil sites for roseau cane farms in conjunction with overland flow. This technique, which would provide both a fertilizer source and a means of advanced treatment of wastes, will be explored further in the next chapter.

Recommendations

We believe that land treatment by overland flow is well suited for selected waste effluents within the specialized environment of the Louisiana coastal wetlands. As pressure for clean water increases on municipal and industrial sectors, demands for estuarine sanctuaries and protection of productive marshland will be made. This proposal for multiple use management of spoil disposal sites accomodates every demand with substantially more positive impacts than negative. This design for natural waste recycling as well as water purification is flexible enough to be considered worthy of further research into long-term use with organic wastes as well as possible exploratory research into petrochemical waste purification and heavy metals removal. Finally, it provides an inexpensive means by which many fishery industries can achieve satisfactory treatment of their organic waste load without a large capital outlay.

Table 11. Spoil disposal sites in selected areas.

Calcasieu Ship Channel (to Cameron)

Spoil number	Acres
1	187.00
2	202.12
3	135.03
4	161.56
5	202.93
6	115.66
7	746.07
8	186.24
9	490.55
10	228.24
11	108.46
12	120.59
13	127.13
14	300.91
15	338.85
16	654.07
17	79.20
18	810.38
19	296.37
Total	5,491.36

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Houma Navigation Canal (Houma to Dulac)

1	411.69
2	56.57
3	232.49
4	164.56
5	58.06
6	99.63
7	119.19
8	135.15
9	159.28
10	27.70
11	33.18
12	22.02
13	195.79
14	130.93
Total	1,846.24

Mermentau River

Spoil number	Acres
1	37.89
2	24.96
3	13.99
4	27.47
5	40.34
6	81.28
7	27.92
8	24.51
9	37.29
10	23.61
11	11.20
12	9.00
13	17.42
14	24.02
15	19.14
16	12.30
17	66.85
18	30.23
19	20.63
20	1,518.66
21	137.75
22	23.09
23	105.50
24	66.82
25	194.56
26	280.24
Total	2,876.67

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Bayou Carlin

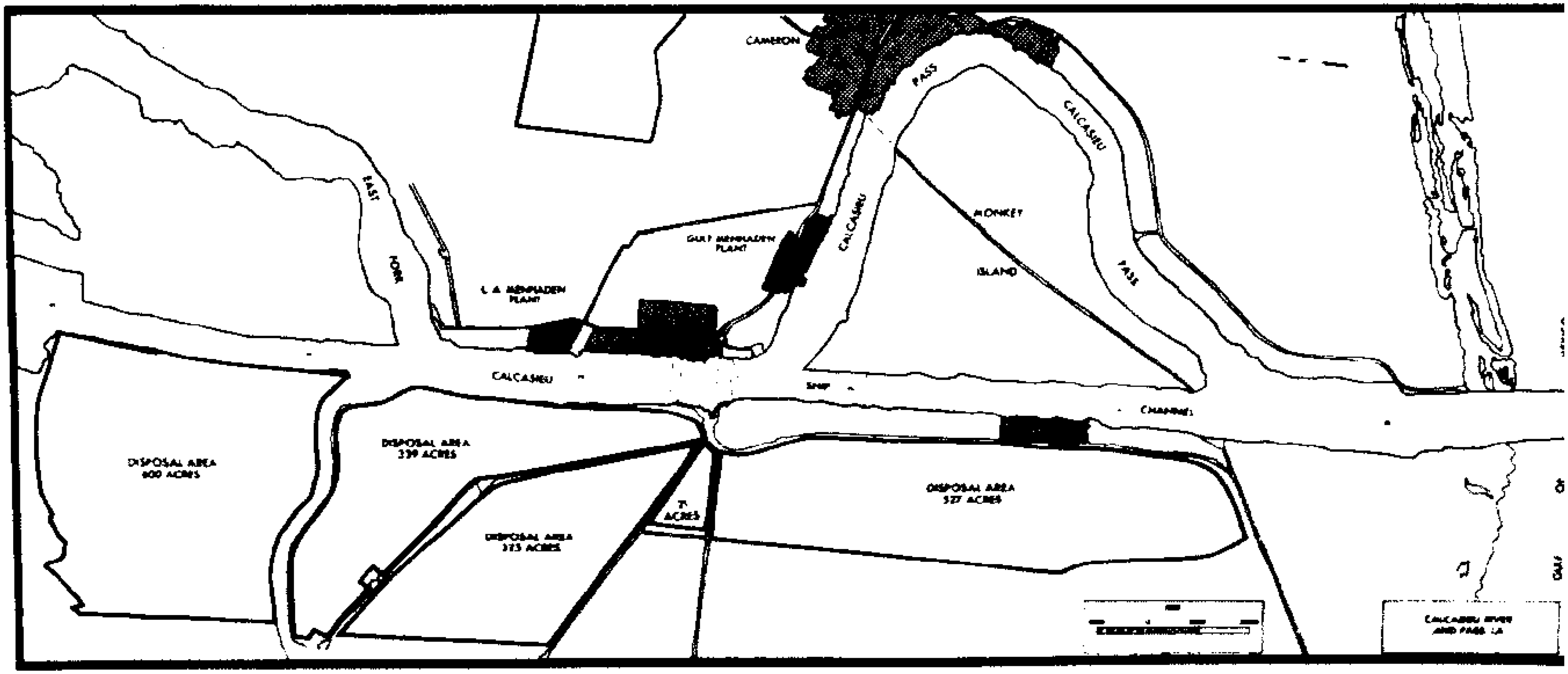
1	76.28
2	29.86
3	51.22
4	35.52
Total	192.88

****

Bayou Petit Anse

1	105.72
2	33.81
3	129.34
4	31.86
5	54.76
6	279.62
7	92.48
8	17.66
Total	745.25

Figure 7. Calcasieu Ship Channel, spoil disposal areas, menhaden plants, and the city of Cameron illustrating the area of land available for overland flow treatment.



POSSIBLE BENEFICIAL APPLICATIONS OF OVERLAND FLOW SYSTEMS

Organic waste effluents are an excellent source of many essential elements required by green plants. As such they can be used in lieu of costly synthetic fertilizers as a nutrient supply for plant culture both in aquatic and terrestrial environments. Sewage wastes have enhanced the growth and production of a wide variety of agronomic crops, algal feedstocks, and silviculture species. Where culture products are destined for human consumption, public health considerations and discharge water quality standards may become decisive factors for large scale implementation of recycling systems. In this chapter we will discuss the variable applications of overland flow treatment to commercial aquaculture and agriculture operations that are well suited to the Louisiana coastal zone.

Aquaculture

Culture techniques for growing finfish or shellfish in confined areas have gained the interest of many scientists and entrepreneurs. Such techniques have the potential of providing commercial food resources while reducing the overhead required for routine harvest. Using treated waste effluents in aquaculture as a source of fertilizer is an attractive method under consideration for reducing feeding costs as well as purifying the effluent. Kildow and Huguenin (1974) reviewed the problems and potentials of recycling wastes for aquaculture and found several operations underway (Table 12).

There are two different approaches currently being pursued in the United States for using secondarily treated sewage in marine aquaculture. At California State University the emphasis is on raising salmon acquired from a hatchery to migrant size, at which time they are released to grow to maturity in the wild. Due to their unique homing instincts, the salmon return to the point of release for harvesting. In these experiments, sewage effluent from an oxidation pond fertilizes algal growth which nourishes zooplankton which are in turn fed to the young fish. The second approach, which is being tested at the Woods Hole Oceanographic Institution, involves the use of a complete aquaculture system for the dual purpose of food production and tertiary sewage treatment (Rhyther et al., 1972). The advantages of the former approach are that potential health problems are avoided since the fish spend a long period in the sea. In the latter, severe sanitary standards must be maintained or public health may be endangered by consumption of contaminated culture products. However, in the former, controlling the harvest of the cultured stock is problematic, while in the latter all the harvestable stock are confined.

Table 12. Aquaculture experiments using sewage products (from Kildow and Huguenin, 1974).

Organization	Location	Species	Remarks
Calif. State Univ., Humbolt	Arcata, Calif.	Chinook salmon	Secondary effluent
Woods Hole Oceanographic Institution	Woods Hole, Mass.	Wide variety	Secondary effluent and seawater
6-State and Federal Agencies	Santee, Calif.	6 species	Secondary effluent
Bavarian Biological Institute	Munich, Germany	Carp, trout	Primary effluent
Salmon, Unlimited	Illinois	Chinook salmon, rainbow	Primary effluent
Michigan State University	East Lansing, Mich.	Catfish, bluegill	Secondary effluent
Trout Hatchery	Cottage Grove, Ore.	Goldfish, trout	Food pellets from sewage sludge

Both of the above systems employ waste effluent that has received prior secondary treatment by conventional methods. Aquaculture serves as an alternative to tertiary treatment. Overland flow treatment, depending upon the climate, vegetative cover, soil composition, and waste characteristics, may provide adequate secondary as well as tertiary treatment. One or more aquaculture systems could be sequentially coupled with an overland flow operation so that the land treatment step provides a steady flow of oxidized nutrients into the receiving aquaculture waters. Combining both designs in the wetland environment would not be disruptive since a vast acreage of coastal marsh has already been severely stressed by canalization and development.

Overland flow-aquaculture combinations for food and fiber production in coastal Louisiana can be achieved with existing technology. Plant protein synthesized from treated waste effluen nutrients could ultimately be used either as a feedstock for animal production or as feedstock for methane generation via anaerobic fermentation. In either process, the cultured plant would be a rapidly growing and easily harvestable aquatic macrophyte, such as water hyacinth (Eichhornia crassipes) or duckweed (Lemna spp.), that has a favorable C:N ratio for use as a feedstock and few natural predators. Culley and Epps (1973) reported that duckweed is an excellent feedstock for swine production and that it is well suited for culture using sewage wastes.

Water hyacinth grows so abundantly in Louisiana fresh water canals and bayous that boat access is sometimes limited. This prolific plant could be used as a source of economical methane gas production for rural industries whose organic waste would be returned to the plant as an energy supply. These two-stage treatment processes could be constructed in association with dredge spoil disposal sites with several distinct advantages over some previously described systems: 1) land treatment operations can usually accomodate a larger volume than container operations, 2) there is less of a threat to public health due to the nonconsumptive nature of the product, 3) disrupted or unproductive environments are returned to production with multiple use benefits, and 4) rural industries could acquire a cheap source of energy as well as a solution to their waste treatment problems.

Finally, a growing industry that could beneficially use treated sewage wastes as a nutrient source is the crawfish pond culture industry. Crawfish (Procambarus clarkii) is a large volume consumer product and is cultured in numerous man-made ponds in fresh water areas, with a high concentration of activit occurring in and around the Atchafalaya Basin. Table 13 shows the increase in the area of such ponds since 1949. Culture nutrient requirements could possibly be satisfied by routing packing house wastes back to the ponds via land treatment system

Table 13. Estimated total crawfish pond area in production for various years (from a number of sources in Gary, 1974).

Year	Area (acres)
1949	40
1960	2,000
1966	6,000
1968	10,000
1969	12,000
1970	18,000
1971	24,000
1973	44,000

Agriculture

Experimental irrigation of agronomic crops with industrial effluent in Louisiana began in 1948 when International Paper Company and Louisiana State University entered into an agreement to study the overall impact of paper mill effluent discharged into Bodcau Bayou at the company's Springhill plant (McCormick, 1959). The experiments established in 1948 and continued through 1956 showed that flooding or some excessive irrigation of the soil with paper mill waste water did little or no damage to soil, cattle, or crops in most cases. In 1957 new experiments were conducted with effluent irrigation of several crops including corn, oats, cowpeas, vetch, rice, coastal Bermudagrass, and dallisgrass. The results revealed no deleterious effects and numerous beneficial effects, especially with regard to increased crop production (Vercher et al., 1965).

Domestic sewage effluent from two treatment plants in Ruston, Louisiana (Lincoln Parish) was analyzed to determine the feasibility of applying treated effluent to neighboring farmland (Wilson and Beckett, 1968). Concentration levels of nitrogen, phosphorus, potassium, calcium, and BOD present in the waste were measured, and the effluent was analyzed to determine total coliform counts and the presence of Salmonella and Shigella. The study concluded that 2.59 m^3 of effluent per min (684 gallons per min) from each treatment plant could be applied to the adjacent farmland as a fertilization and irrigation resource. Lack of proper chlorination was responsible for coliform counts above the Federal Water Pollution Control Administration standards for irrigation water.

Rice

Overland flow techniques are especially applicable for wetland soils and wetland plants. Although initial research in Louisiana involved waste recycling mostly in upland soils and crops, the potential for widespread use of overland flow remains for lowland environments. Hunt (1973) discussed the suitability of applying treated sewage effluent to rice culture. He noted the following as potential benefits available through use of treated waste: 1) the high cost of water, about 20% of the cost of producing a rice crop, would be lowered, 2) ecological problems arising from lowered groundwater levels could be ameliorated, and 3) fertilizer costs could be reduced. This last point may become increasingly important as demand for fertilizer increases while reserves of fossil fuel necessary for synthetic fertilizer production become depleted. Schreiber (1957) reported that the fertilizer content of 1 acre-foot (1230 m^3) of treated domestic sewage effluent was 27-45 kg (60-100 lbs) of nitrogen; 9-18 kg (20-40 lbs) of potassium; and 27-45 kg (60-100 lbs) of phosphate. Rice production from fields irrigated with pulp mill effluent was 5.48 m^3/ha (63 bushels per acre) compared to 5.38 m^3/ha (62 bushels per acre) with water (Vercher et al., 1965). A final advantage is that in rice growing areas, capital expenditure for pipe, pumps, etc. would be much less than in areas where irrigation has not been extensively used (Hunt, 1973).

Sugarcane

Together with rice, sugarcane represented about 45% of the total cash receipts for farm marketing in Louisiana in 1973 (Table 14). If the trend since 1970 of increased sugarcane production continues, sewage effluent may become more significant as a fertilizer source. The advantage of using waste waters for irrigation of this coastal crop is that the potential health hazards may be avoided. However, the similarity between the cultural practices used for this crop and classical overland flow systems is not so apparent, and some significant cultural adjustments will probably be required (Hunt, 1973). Overland flow may also represent a method of treatment of sugarcane wastes. In the past, these wastes have been responsible for considerable water quality problems.

Roseau Cane

Roseau cane (Phragmites communis) has a worldwide distribution. It invades fresh water transition environments and is found in lagoons and in fresh to brackish water marshes. It is a hardy species that can readily survive and proliferate on freshly deposited spoil disposal sites. However, it is usually succeeded by herbaceous and woody stemmed vegetation on dry ground above mean water level. Roseau cane is used for a number of purposes in foreign countries, particularly Rumania where it

Table 14. Cash receipts for farm marketing by commodity groups, Louisiana, 1970-1973 (millions of dollars).

Year	Total Crops	Soybeans	Rice	All Cotton	Sugarcane	Sweet Potatoes	Corn
1970	372	96	102	68	62	8.0	1.9
1971	429	123	102	88	66	10.1	1.8
1972	473	120	126	100	78	12.6	1.9
1973	769	240	252	123	91	13.7	2.1

Source: U.S. Department of Agriculture, Louisiana Farm Income, September 1974 is effectively managed in the Danube Delta for harvest as a paper resource among other things (Kuzenski, 1975). Its ability to withstand submergence makes it ideal for the intermittent flooding of overland flow operations as shown by the Dulac study. Although with overland flow a sizable amount of the nitrogen load is believed to be lost by denitrification processes, roseau cane takes up nitrogen in excess as most plants do. At Dulac concentrations of nitrogen and phosphorus in the plant tissue and plant biomass increased in the waste treated area as compared to controls (Table 15).

The best water reclamation in overland flow systems is achieved when areas are terraced or mechanically graded to produce uniform slopes of between 2 and 6 percent. The resultant sheet flow of the discharged waste maximizes the contact area of the effluent with the soil-plant system. Freshly filled diked spoil disposal sites could be terraced along these guidelines. The rapidly growing roseau cane could be raised in monoculture within these areas and harvested in sequential lots. Because of the year round growing season, the waste effluent could be applied continuously, if necessary. The benefits from such an operation are multiple. If long-term dredge spoil disposal sites are sought within the Corp of Engineers New Orleans district, large acreage sites similar to Craney Island could be constructed in coastal areas already lost due to negative impacts of poorly planned development. Organic industrial and domestic effluents could be pumped to a collection pond. From there they could be allocated to distribution pipelines discharging onto separate terraces supporting dense growths of roseau cane. The harvested cane could be used as a feedstock for methanol production or as a paper resource. In essence, the profits accrued from the sale of the crop could pay for the capital and maintenance costs within a brief period. Among the immediate benefits would be clean water, "zero discharge," and productive land.

Table 15. Total N and Total P Percentages of *Phragmites communis* (dry weight) in the Treated and Control Areas at Dulac.

	Distance Down Slope							
	Top Slope (7.5 m)		Middle Slope (15.0 m)		Bottom Slope (22.5 m)		Control	
Month	%N	%P	%N	%P	%N	%P	%N	%P
June	2.30	0.20	1.80	0.15	1.60	0.14	1.30	0.15
July	2.03	0.22	1.62	0.19	1.78	0.16	1.40	0.19
August	1.95	0.19	1.68	0.17	1.83	0.15	1.04	0.13

Comparison of Live Standing Crop of *Phragmites communis* (dry weight) in the Treated and Control Areas (October only) at Dulac.

	Distance Down Slope			
	Top Slope (7.5 m)	Middle Slope (15.0 m)	Bottom Slope (22.5 m)	Control
# Stems/m^2	25	21	26	17
Live Wt/m^2	1,172 g	1,032 g	1,102 g	726 g
Live Wt/Stem	46.52 g	50.73 g	44.06 g	43.0 g

U.S. AND LOUISIANA LAWS AFFECTING LAND TREATMENT

The Federal Water Pollution Control Act Amendments of 1972 specifically mention land treatment systems as being eligible for consideration as forms of advanced treatment of waste waters. Congressman Vander Jagt of Michigan was instrumental in the inclusion of recycling and waste reclamation activities into the final Act. Sections 201 and 212 contain pertinent details.

Sections 201 (d), (e), and (f) read as follows:

> (d) The Administrator shall encourage waste treatment management which results in the construction of revenue producing facilities providing for--
>
> (1) the recycling of potential sewage pollutants through the production of agriculture, silviculture, or aquaculture products, or any combination thereof;
>
> (2) the confined and contained disposal of pollutants not recycled;
>
> (3) the reclamation of wastewater; and
>
> (4) the ultimate disposal of sludge in a manner that will not result in environmental hazards.
>
> (e) The Administrator shall encourage waste treatment management which results in integrating facilities for sewage treatment and recycling with facilities to treat, dispose of, or utilize other industrial and municipal wastes, including but not limited to solid waste and waste heat and thermal discharges. Such integrated facilities shall be designed and operated to produce revenues in excess of capital and operation and maintenance costs and such revenues shall be used by the designated regional management agency to aid in financing other environmental improvement programs.
>
> (f) The Administrator shall encourage waste treatment management which combines "open space" and recreational considerations with such management.

Section 201 contains in Subsection (g) (2) provisions that require consideration of appropriate alternate waste management techniques. Further, Sullivan (1973) noted that land treatment, even though proven superior initially on a cost/benefit basis, must continue to show its superiority during the life of the recycling project. This may prove advantageous for overland flow designs.

Section 212 of the Act specifically authorizes site acquisitions of land that will be an integral part of the treatment process. Thus land that is used in the actual treatment, such as diked dredge spoil disposal sites, is an eligible cost in a grant. However, land that is not so used, such as real estate upon which a conventional secondary treatment plant is located, will continue to be a non-allowable cost (Sullivan, 1973).

The major requirements for Environmental Protection Agency grants for sewage treatment projects are:

1) All projects must have a priority certification from the state and conform to planning requirements.

2) All projects must be analyzed for cost effectiveness.

3) Pretreatment of industrial wastes is necessary.

4) Environment assessment is necessary.

5) Secondary treatment is required, with best practicable control technology applicable for grants financed with FY 1976 funds or later.

6) All projects must also meet planning requirements to be processed through the State Agency.

Table 16, taken from Stevens (1972) lists the disposition of individual states toward implementation of land treatment facilities. Louisiana's position is difficult to determine. Coerver (1968) noted that the Lousiana Sanitary Code specifically requires a permit for any proposed method of handling or disposing of domestic sewage. The Health Department's approval is also necessary to use sewage effluent for irrigation purposes. Presently, sewage irrigation is not being practiced in Louisiana, and the Health Department would oppose irrigation of dairy pasture or land used to grow vegetables to be eaten raw.

The contemporary laws affecting land treatment systems in Louisiana are presented below as they were collected in the Temple University study, Green Land: Clean Streams (Stevens, 1972):

> Louisiana: The Louisiana Stream Control Commission Acts (Title 56) created the Stream Control Commission of Louisiana. The Commission is empowered to adopt water quality standards and approve permits for waste water treatment facilities. The Act clearly prohibits the discharge into state waters of any waste or pollution of any kind which will destroy fish or aquatic life, wild or domestic animals or fowls, or injure the public health. No specific treatment method or level is prohibited or

Table 16. Disposition of the states toward implementation of land treatment facilities (from Stevens, 1972).

Favorable Orientation	Neutral	Negative Orientation	Judgement Not Possible on Data Available
Arizona[*]	Alabama	Arkansas	Connecticut
California	Alaska	Florida	Delaware
Colorado	Massachusetts	Illinois	Georgia
Idaho		Iowa[+]	Indiana
Maryland		Kansas[+]	Hawaii
Montana		Maine[+]	Kentucky
New Jersey		Michigan[+]	Louisiana
New Mexico		Nebraska	Minnesota
New York		Utah	Mississippi
North Dakota		Virginia	Missouri
Oklahoma		Washington	Nevada
Texas			New Hampshire
Vermont			North Carolina
Wisconsin			Ohio
			Oregon
			Pennsylvania
			Rhode Island
			South Carolina
			South Dakota
			Tennessee
			West Virginia
			Wyoming

[*] Listed alphabetically, not ranked

[+] Permits land treatment but with restrictions recommended by the Act. Land treatment is not dealt with.

Louisiana Law on Polluting the Mississippi River (Acts 1970, No. 449, House Bill No. 335) specifically prohibits the discharge of untreated wastes into the Mississippi River. This law provides that all wastes discharged must have secondary treatment or its equivalent. Also a procedure is set up for civil action and a daily $10,000 fine in the event of continued untreated waste discharge.

The Louisiana Regulation on Reports of Industrial Waste Discharges (A regulation Requiring the Submission of Reports for the Discharge of Industrial Waste and for the Construction or Alteration of Treatment Works, Adopted by the Stream Control Commission, State of Louisiana, Under Authority of Section 1435, Chapter 3, Part 1, of Title 56, Louisiana Revised Statutes of 1950, August 1, 1951) provides for the submission of reports to the Commission by all plants which discharge an industrial waste. This is merely a procedural law and does not set standards or guidelines for the treating of industrial wastes. It very specifically sets out the information to be reported. It calls for the reporting to be done in terms of the existing quality of waste water and the projected quality of waste water, if new or additional treatment is being proposed.

Louisiana Rules Relating to Oil and Gas (Rules Governing Disposal of Waste Oil, Oil Field Brine, and All Other Materials Resulting from the Drilling for, Production of, or Transportation of Oil, Gas, or Sulphur, Adopted by the Stream Control Commission, State of Louisiana, As Amended January 27, 1953, Under Authority of Section 1435, Chapter 3, Part 1, of Title 56, Louisiana Revised Statutes of 1950) deals with the subsurface and ground disposal of oil and oil-related wastes. Deep well injection (below the fresh water level) is permitted for brine wastes. These methods are of questionable utility and environmental soundness and should not be in any way construed to be land treatment methods.

As stated in the Sanitary Code, State of Louisiana (Chapter X, Sewerage and Waste Disposal, Revised through January 23, 1958, State Board of Health) all sewerage or sewerage plant effluents used for irrigation have to conform to the Board's requirements.

Only two existing facilities were documented. No history of land treatment facilities has been noted. It is not clear whether there exists any policy for land treatment in the state. It is certain, however, that the laws reviewed do not in any way prohibit the implementation of land treatment.

FINAL WORDS

We believe we have presented a sound argument for continued research on the practical implementation of land treatment by overland flow on suitable microenvironments within Louisiana's coastal zone. The overland flow process is not only ecologically sound, but within the best interests of the biology, sociology, hydrology, and economy of the wetlands. It is uniquely suited to both the letter and the spirit of State and Federal law, as well as amenable to proper multiple use planning and management in a region that will have to cope with a continuously growing number of conflicts.

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